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METROLOGY
&
QUALITY CONTROL

In Technical Collaboration With
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PART-I : METROLOGY

PART-II : QUALITY CONTROL

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1. **Metrology** **(Marks : 04, Periods : 04)**
Introduction, Scope, Need of Inspection, Concept of mass production , Interchangeability & selective assembly, Concept of precision , accuracy , sensitivity, amplification, magnification Error- Sources of Errors

2. **Measurement** **(Marks : 06, Periods : 06)**
Principles of measurement, Standards of measurements in dial standard, international standard line std, end std wave length std, Linear measurement concept principles, Construction & working of simple instrument like steel rule & vernier calipers surface, plate , angle plate radius / feeler / pitch screw gauge, Micrometers slip gauges end bars , length bars, V block Concept of calibration- Construction & working of calibration Tester

3. **Limits, Fits & Gauges** **(Marks : 08, Periods : 06)**
Definition terminology, Taylor's principle, Design of plug, ring & snap gauges Simple gauges IS 919-1963 (limits, fits & Tolerances) Relation gauges, ISO system of limit and fits, plai plug gauge IS 3484-1966, plain ring gauge IS 3485 -1972. Snap Gauge IS 3477- 1973

4. **Angular Measurements** **(Marks : 05, Periods : 04)**
Construction & working of universal bevel protractor. Spirit level, Sine bar, sine centre, Angle Gauges, Angle Dekkor, Autocollimaters.

5. **Screw Thread measurement** **(Marks : 06, Periods : 06)**
Terminology of screw thread, Measurement of Different elements : Major Diameter; Mino Diameter; Effective Diameter; Pitch; Thread Angle, Construction & working of following instruments to measure above parameters: Floating carriage micrometer; Tool maker's microscope; Optical profile projector; Pitch measuring machine; Screw thread micromete Tangent micrometer.

6. **Comparators** **(Marks : 10, Periods : 08)**
Principles of operation of various types of comparator like mechanical , electrical, optica pneumatic solex gauge low-pressure & high pressure (Trial type working mechanism) typ Characteristic of good comparator. Relative advantages & disadvantages of various types of comparator, Study of dial indicator - types , construction & working details.

7. **Surface Finish** **(Marks : 05, Periods : 06)**

Importance of surface finish for various types of applications, Concept of primary texture & secondary texture (Roughness & waviness), Terminology as per IS, Direction of Lay, C.L.A., RA,R.M.S Actual specimen o f different machine components. E. g. Grinding, lapping, milling ,shaping ,broaching. Principles of operation of stylus probe type of instruments Tomlinson's surface meter. Taylor hobson , Talysurf. Various Techniques of qualitative analysis.

8. **Machine tool Testing Techniques** **(Marks : 10, Periods : 08)**

Testing techniques : Parallelism –parallelism Testing between two planes one plane ,One stationary other moving axis of rotation and trajectory, Flatness testing by straightness testing techniques & by optical flats, Squareness Testing –by dial indicator ,optical square, Indicating method, Straightness testing by straight edge ,spirit level & autocollimators, Machine tool testing – alignment test to be carried out with lathe, drilling, milling machine.

9. **Gear Measurement** **(Marks : 06, Periods : 06)**

Terminology, Measurement of individual elements by different suitable instrument,,gear tooth vernier , tooth profile projector, Parkinson gear tester, Errors :backlash, runout

10. **Quality Function** **(Marks : 06, Periods : 04)**

Meaning of Quality control, Quality objective, Quality policies, quality specifications, Inspection - concept , need , planning, Difference between Quality control and inspection. Difference between Quality of Design , Quality of confirmation & Quality of performance, Concept of Reliability & maintainability.

11. **Quality Assurance** **(Marks : 04, Periods : 04)**

Concept, Quality mindedness, Quality audit , vendor quality rating capability, Quality circles- concept purpose and function.

12. **Quality Economics** **(Marks : 04, Periods : 04)**

Cost of quality, Value of quality balance between the two, Economics of quality of design and quality confirmation, Cost of quality control appraisal, prevention, external and internal failure cost.

13. **Quality Organisation** **(Marks : 10, Periods : 12)**

Organisation for quality, Quality policies, Quality systems ,concept of total quality management ISO 9000.Concept & its evaluation & implication, Machine capability & studies, National & international codes.

14. Statistical Quality Control (SQC) **(Marks : 10, Periods : 12)**

Meaning & importance of SQC,Definition and interpretation of frequency distribution ,mean, mode, median, standard deviation, range ,variance ;variable measurement & attribute measurement, Construction of frequency distribution curve, frequency histogram frequency polygon, frequency curve, Normal distribution curve ,area under the curve & its interpretation. Control charts for variables -X & R chart, Control charts for attributes-P chart & C chart. Process capability of machine concept ,determination of statistical limits & comparison with tolerance limits to determine capable or incapable process, Acceptance sampling. Concept, comparison with 100% inspection different types of sampling plans with merits & demerits O.C. curve -significance & importance , producer's risk , AQL, AOQL, IQL,LTD, Product reliability , MTBF, MTBR

PART - I

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24 Nov 05.

METROLOGY

Chapter 1

METROLOGY

Q.1. What is metrology ?

Ans : Metrology is a science of measurements. It is concerned with numerous problems theoretical as well as practical, related with the measurements, such as units of measurements and their standards, methods of measurement, measuring instruments, accuracy of measurement and measuring instruments, etc. In broad sense, metrology is not limited to measurements only, but is also related with industrial inspection and its various techniques. Inspection is concerned with checking of product at various stages during manufacture and is carried out with gauges. Metrology includes the design, manufacturing and testing gauges of all kinds.

Q.2. Enumerate the scope of metrology ?

Ans : Metrology is a science of measurement. In a broader sense metrology is not limited to length and angle measurements but also concerned with numerous problems theoretical as well as practical related with measurement, such as :

i. Units of measurement and their standards, which is concerned with the establishment, reproduction,conservation and transfer of units of measurement and their standards.
ii. Methods of measurement based on agreed units and standards.
iii. Errors of measurement.
iv. Mesuring instruments and devices.
v. Accuracy of measuring instruments and their care.
vi. Industrial inspection and its various techniques.
vii. Design, manufacturing and testing of gauges of all kinds.

Q.3. What is the need of inspection in industries ?

Ans : Inspection is a recent development. Inspection means checking of all materials, products or component parts at various stages during manufacture. It is the act of comparing materials, products or commponents with the established standards.

In old days, different component parts were made by a craftsman and assembled by the same craftsman. If the parts did not fit properly he used to make the necessary changes in the dimensions of the parts. Therefore, the two matinparts were not required to be of dimensions of close tolerances and there was no need of inspection. But our modern industrial system is based on intrchangeable manufacture (mass production), to reduce cost of production. Different parts are made in large quantities in different plants and asembled in another plant. So it is essential that any part, chosen randomly should fit properly with any other mating part, that too chosen randomly. This can be possible only when the parts are made to close dimensional tolerances. For this the inspection of parts at the various stages of manufacturing is needed. Inspection provides means to find out short comings and defects in manufacture and ensures that the product conforms to the desired standard. It should be done not only at the final stage but must start from the begining i.e. from the time of receiving the raw materials.

Q.4. Describe in short the concept of mass production in modern industrial systems.

Ans : Mass production is the specialised manufacture of identical articles on a large scale. Since identical articles are produced the operations are repeatitive, production auxiliary aids such as special tools, jigs and fixtures, material handing system, inspection devices can be used advantageously.

In mass production the machines are arranged in line layout (according to sequence of operations) Different parts are made in large quantities in different plants/production lines or shops, and assembled in another plant/shop. So it is essential that any part, chosen randomly should fit properly with any other mating parts, that too chosen randomly. to achieve this it is necessary to use precise specialised machines, standard material, built in type material handing equipments, conveyors etc. There is a standardisation of parts, materials, processes, equiments etc. The parts are produced with close tolerances. In mass production line balancing plays important role in mainting the flow of materials as it is being converted from raw material stage to the finished product state. In mass production prior planning and production control is comparatively easier. The cycle time is quite short and the unit cost is less as compared to batch production.

Q.5. What is Interchangeability ? State its advantages ?

Ans : In old days production was confined to small number of parts. The same worker used to produce the parts and assemble them to obtain necessary fits. But modern trend is towards mass production in which parts are made by different workers in different plants and assembled in one shop. Under such conditions, the dimensions of the various mating parts must strictly lie within certain variations so that any one part selected randomly will assemble correctly with any other mating part that too chosen randomly. Such system is called interchangeable system or system of limits and fits.

Interchangeability is possible only when certain standards should be followed. When all the parts to be assembled are manufactured in a single unit, local standards may be followed.

Advantages :

i. Production is increased considerably.

ii. Results in reduced production cost.

iii. Simplifies replacement and repairs of worn out or defective parts, so maintened cost is very much reduced.

iv. A worker is concerned with limited work, so he can easily specialise himself in that work. This results in superior quality of work.

v. Assembly time is reduced considerably, so production rate is increased.

vi. Different components can be manufactured in different parts of the country, depending upon the availability of raw material, skilled labour and other facilities. This reduces cost of production considerably.

Q.6. Write short noe on- selective assembly.

Ans : In selective assembly, the parts of any one type are classified into several groups according to size. The mating parts are also classified into same number of groups, so that the corresponding groups,when assembled will give the desired fit at assembly with little or no further machining. In this method the parts are manufactured to rather wider tolerences and then seperated into number of groups according to their actual sizes. Assembly is then made from the selected groups. Selective assembly results in reduced cost of production without affecting the quality of the product. It is often followed in air craft, automobile industries and in ball and roller bearing industries.

Q.7. What do you understand by measurement ?
What are the different methods of measurement ?

Ans : The set of experimental operations carried out to determine the value of a quantity is called mesurement and the sequence of the operations performed is called process of measurement. The various methods of measurement are as follows :

1. Method of direct mesurement : This is simple method of measurement, in which the value of quantity to be measured is obtained directly by the use of instruments. e.g. measurements by using scales, vernier calipers, micrometers, bevel protractor, etc.

2. Method of indirect measurement : In this method the value of quantity to be measured is obtained by measuring the other quantities which are functionally related to the required value e.g. angle measurement by sine bar, measurement of screw pitch by 3 -wire method.

3. Absolute or fundamental method : In this method the zero division of the measuring instruments e.g. steel rule, vernier calliper, etc.

4. Contact method of measurement : The sensor or the measuring tip of measuring instrument is placed in direct contact with the quantity to be measured e.g. micrometers, vernier calipers, dial indicators, etc.

5. Contactless method of measurement : The sensor or measuring tip of instrument is not placed in contact with the quantity to be measured e.g. measured by optical instruments. Such as tool maker's microscope, projection comparator etc.

6. **Comparative method of measurement :** In this method the value of the quantitiy to be measured is compared with known value of the same quantitiy or another quantity functionally related with it i.e. the deviation of the measured dimension from master gauge are determined e.g. dial gauges or other comparators.

Q.8. Define and explain the term accuracy of measurements.

Ans : The purpose of measurement is to determine the true dimensions of a part. But no measurement can be absolutely accurate; there is always some error and the amount of error depends upon the various factors such as accuracy and design of measuring instruments, skill of the operator using it, method used for measurement, temperature variations, elastic deformation of the part or insturment, etc. Because of these numerous reasons, the true dimension of a part can not be determined but can only be approximated. The agreement of the measured value with the true value of the measured quantity is called accuracy. If the measurement of a dimension of a part approximates very closely to the true value of that dimension, it is said to be accurate. Thus the term accuracy denotes the closeness of the measured value with the true value. The difference between these two value is the error of measurement. The lesser the error, the more is the accuracy.

Q.9. Discuss the possible effects upon accuracy of measurement due to :
(1) Temperature variation, (2) Elastic deformation (3) Contact pressure.

Ans :

1. **Temperature variations :** The standard temperature for measurement is 20 °C. and gauges are made to be of correct size when they are at this temperature. If the measurements are carried out at temperature other than the standard temperature an error will be introduced. Due to expansion or contraction of instrument and part are of similar metals, accuracy of measurement will not be affected even if measurement is carried out at other temperature, because both will contract or expand by the same amount.

The difference between the temperatures of instrument and part will also introduce an error in the measurement, especially when the material of the part or instrument has higher coefficient of expansion. To avoid such errors, instrument and the part to be measured should be allowed to attain the same temperature before use and should be handled as little as possible. To obtain accurate results, high grade reference gauges should be used only in rooms where the temperature is maintained very close to the standard temperature.

2. **Elastic deformation :** Straight edges are used to check the straightness and flatness of parts. They are generally supported at two points. This results in deformation or deflection, the amount of which depends upon the positions of the supports. The deflection causes an error in the straightness of the working faces. To have minimum deflection the distance should be 0.554 times the length of the bar (Airy points : (S/L = 0.554)

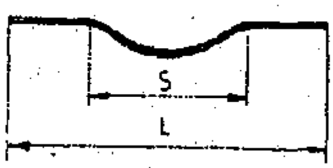


Fig.1.1

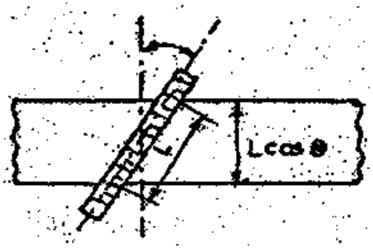
It is also important that the measuring faces of the instrument be parallel to each other i.e. there should not be any slope at the ends. For this the distance between the two supports should be 0.577 times length of the bar (S/L = 0.577)

3. Contact pressure : The variations in the contact pressure between the anvils of instrument and the work being measured produces considerable differences in the readings obtained and introduce errors in the readings. The development of correct feel is one of the skills to be acquired. Errors are caused by deformation of the instrument frame and the workpiece. The deformation of work piece and anvils of the instrument depends upon the contact pressure and shapes of contact surfaces. Too much contact pressure results in deformation of both the instrument and work piece. When there is surface contant between instrument anvils and work surface,there is very little distortion (deformation), But when there is point contact between the surfaces the distortion is appreciable.

Q. 10. State Abbe's alignment principle. Explain sine and cosine errors.

Ans : Abbe's alignment principle :- It states that "the axis or line of measurement should coincide with the axis of measuring instrument or line of the measuring scale".

If while measuring length of a work piece the measuring scale is inclined to the true line of the of dimension being measured there will be an error in the measurement.



L = measured length.
Lcos = true length.
L (1 - cosθ) = error.

Fig,1,2

The length recorded will be more than the true length. This error is called cosine error. In most cases, the angle "θ" is very small and the error is negligible.

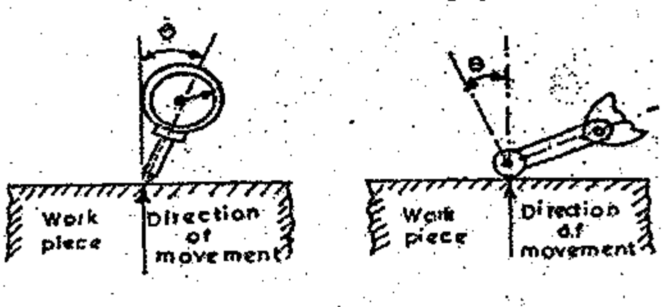


Fig.1.3

The cosine error may occur while using dial gauge, if the axis of the pointer is not along the direction of movement of work. Also, when an indicator is fitted with a ball-end stylus form, the arm should be so set that the direction of movement of work is tangential to the arc along which the ball moves, other wise cosine error will be introduced.

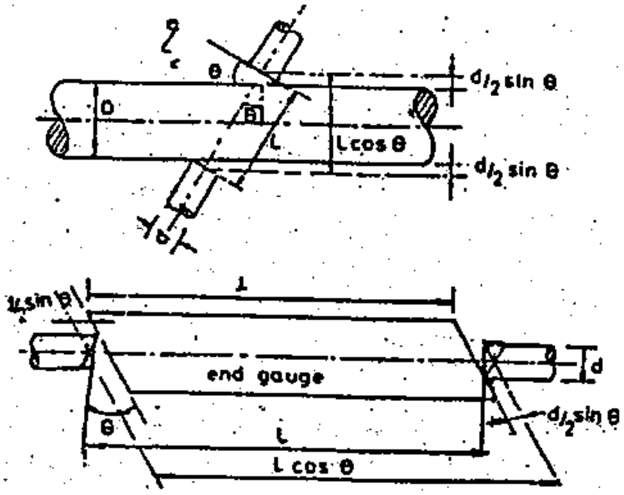


Fig.1.4

The combined cosine and sine error occurs if the micrometer axis is not truely perpendicular to the axis of the work piece (Refer Fig.1.4). The same error occurs while measuring the length of an end gauge in a horizontal comparator if the gauge is not supported so that its axis is parallel to the axis of the measuring anvils or if its ends, though parallel to each other are not square with the ends. The erros of the above nature are avoided using gauges with spherical ends. such gauges need not be aligned accurately when used in combination.

Q.11. Explain the term "precision' as used in measurements. How it is applied in manufacturing a product ?

Ans : It is a repeatability of a measuring process. when number of measurements are carried out for a single quantity in identical conditions (i.e.by the same observer,With the same instrument and in short intervals of time) the precision determines how well these performed measurements agree with each other.

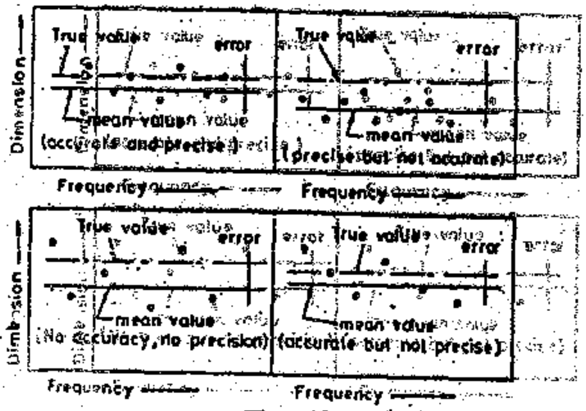
Precision has no meaning for only one measurement, but exists only when a set of measurements is carried out for the same quantity under identical conditions. For any set of measurements, the individual results will vary slightly from the mean or average value. The lesser the variations in the measurement more is the precision e.g.consider a component having true length of 50 mm. A person takes number of readings for the length measurement of this componts, with the same instrument and in short intervals of time. The readings obtained are 49.001, 49.002, 49.00, 48.999, 48, 998 mm. Though the readings are not accurate, they are precise because the variations in the readings above or below the mean value 49.00 mm are very small.

In most of the measurements, very often precision is required. In fact, precision is the main criterion by which the quality of the work is judged.

Modern industrial system is based on interchangeable manufacture, to reduce production cost. Different parts of a product are made in large quantities in different palnts and assembled in another plant. So it is essential that any part, chosen randomly should fit properly with any other mating part that too chosen randomly. This can be possible only when the parts are made to close dimensional tolerances. For this accuracy is not important but precision in measurement is essential.

Q.12. Distinguish clearly between "precision and Accuracy".

Ans : Both the terms are associated with measuring process. Accuracy is the agreement of the result of measurement with the true value of the measured quantity, while precision is the repeatability of the measuring process. It shows how well identically performed measurements agree with each other. Thus accuracy is concerned with the ture value, but precision has no concern with it. Presision has no meaning for only one measurement, but exists only when a set of measurments is carried out for the same quantity under identical conditions.



Extra Point (Same page follows)

Fig. 1.5

If the variations in the measurement of a dimension are very less i.e. if they agree closely with each other, they are said to be precise even though their mean or average value may not agree with the true value of that dimension. Since there is difference between the true and the measured value of the dimension it can not be said to be accurate. In other words, there is no accuracy in the measuring process, but prescision is more.

Similarly if the variations in the measurements of a dimension are more, but their mean value agrees very closely with the true value of that dimension they are said to be accurate, though they are not precise.

Accuracy is usually sought for in a measuring process, but very often, in most of the measurements, only precision is required. It is much easier and cheaper to achieve precision than to achieve great accuracy.

Q.13. What are the sources of errors in measurement? OR Explain systematic erro and random errors .

Ans :- Error in measurement is the difference between the measured value and the true val of the measured dimension. Errors can broadly classified into two catagories viz. Systema or controllable errors and random errors.

Systematic or Controllable errors :- As the name suggests these errors are repeat consistently with the repeatition of the measurement operation and can be controlled magnitude as well as in sense. If properly analysed they can be determined a reduced,Systematic errors include :

i. Calibration errors :- These are caused due to the variation in the calibrated scale fr its nominal value. The actual length of standards such as slip gauges and engraved scale v vary from the nominal value by small amount. This will cause an error in measurement constant magnitude. Some times the instrument inertia and hysterisis effects do not allow instruments to translet the measurement accurately. Drop in voltage along the wires of electric meter may induce an error (called signal transmission error) in measurement.

ii. Ambient or atmospheric conditions (Environmental errors) :- Variation in atmosphe condition (i.e. temperature,pressure and moisture content) at the place of measurement fr internationally agreed standard values (temperature =20 degree C and pressure = 760 mm Hg) can give rise to error in the measured size of a compenent. Temperature is the m significant factor which causes error in the measurement due to expansion or contractio component being measured or of instrument used for measurement.

iii. Stylus pressure (contact pressure) :- Changes in the stylus pressure produces variati in both the deformation of work piece surface and deflection of work piece. This will ca an error in the measurement. Variations in the force applied by the anvils of micrometer the work to be measured result in the difference in its readings. The error is caused by distortion of both,micrometer frame and work piece. To avoid this effect of contact pressu micrometer is fitted with a ratchet mechanism with an operating thimble. The ratchet sl when the applied pressure exceeds the minimum required operating pressure.

iv. Avoidable errors :- These errors may occur due to parallax,non-alignment of work pi centres,improper location of measuring instruments,etc. The error due to misalignmen caused when the centre line of work piece is not normal to the centre line of the measu instruments.

Random errors :- Random errors occur randomly and are accidental in nature. Their spec causes, magnitudes and sense can not be determined from the knowledge of measuring sys or conditions of measurement. The possible sources of such errors are :

i. Small variations in the position of setting standard and work piece.
ii. Slight displacement of lever joints of measuring instruments.

iii. Operator error in scale reading

iv. Fluctuations in the friction in measuring instrument.

Q.14. Differentiate between systematic errors random errors.

Ans :-

Systematic errors	Random errors
1. These errors are repeatitive in nature and are of constant and similar form.	1. These are non-consistent. The sources giving rise to such errors are random.
2. These errors result from improper conditions or procedure that are consistent in action.	2. Such errors are inherent in the measuring system or measuring instruments.
3. Except personal error, all other systematic errors can be controlled in magnitude and sense.	3. Specific causes, magnitudes and sense of these errors can not be determined from the knowledge of meausring system or conditions of measurement.
4. If properly analysed, these errors can be determined and reduced or even eliminated.	4. These errors can not be eliminated, but the results obtained can be corrected.
5. These errors include calibration errors, errors due to variation in atmospheric conditions, variation in contact pressure, parallax errors, misalignment errors, etc	5. These errors include errors caused due to variation in position of setting standard and work piece, errors, due displacement of lever joints of instru-ments, errors resulting from back-lash, friction etc.

Q.15. Explain the following terms used in measurements. Repeatability, Reproducibility, sensitivity and readability, calibration.

Ans :

1. **Repeatability :-** It is the ability of measuring system to reproduce the same results for the measurement of same quantity when the measurements are carried out by the same observer, with the same instrument, under the same conditions and in short intervals of time.

2. **Reproducibility :-** It refers to the consistency of pattern of variation in measurement i.e. closeness of agreement between the results of measurements of the same quantity when individual measurements are carried out by different observers, by different methods, using different instruments under different conditions.

3. **Sensitivity and Readability :-** Sensitivity and readability, both the terms are associated with the measuring instruments and not with the measuring process. Sensitivity measures the ability of a measuring instrument to detect small variations in a quantity being measured. Higher the ability of such detection of an instrument, more sensitive it is, but if the instruments

are made more sensitive they are easily affected by external effects such as temperature variations, vibrations. etc. This affects the accuracy and precision of measurement. If an instrument is more sensitive than requirement,it becomes difficult for operator to obtain a reliable reading.

Readability refers to the ease with which the readings of a measuring instrument can be read. It is the susceptibility of measuring instrument to have its indications converted into meaningful number. To make micrometers more readable they are provided with vernier scale. Redability and hence accuracy of measurement can also be improved by use of proper magnifying devices.

4. Calibration :- It refers to measurements of the measuring instruments, i.e. framing of scale of the instrument by applying some standardised signals. Calibration is a pre-measurement process,generally carried out by manufacturers. Consistent use of instruments affect their accuracy If the accuracy is to be maintained, the instruments must be checked and recalibrated. The schedules of such calibration depend upon the severity of use, environmental conditions,accuracy of measurement required,etc. As far as possible calibration should be performed under environmental conditions which are very close to the conditions under which actual measurements are carried out and as per manufacturers instructions or public standard practies. If the output of a measuring system is linear and repeatable, it can be easily calibrated.

Q.16. What is meant by magnification? Explain briefly.

Ans : To improve the accuracy of measurement, small variations in the quantity being measured should be easily detected by measuring instrument and its readings should also be easily readable. For this the output signal from a measuring instrument is to be amplified or magnified.

Thus magnification means increasing the magnitude of output signal of measuring instrument many times to make it more readable.

Magnification obtained in a measuring instrument may be mechanical, electrical, electronic, optical or pneumatic.

Mechanical magnification is obtained by means of levers or gear trains. In electrical magnification, the change in the inductance or capacitance of electrical circuit,made by change in the quantity being measured is used to amplify the output of the measuring instrument. Electronic magnifications is obtained by the use of valves,transistors or ICs. Optical magnification uses principle of reflection and pneumatic magnification makes use of compressed air for amplifying the output of measuring instruments.

Q.17. Give a brief classification of errors which may arise duing measurement.

Ans : Types of error :- During measurement several types of error may arise, These are

1. Static errors which includes.
   a. Reading errors.
   b. Characteristic errors.
   c. Environmental errors.

In most of the measurements, very often precision is required. In fact, precision is the main criterion by which the quality of the work is judged.

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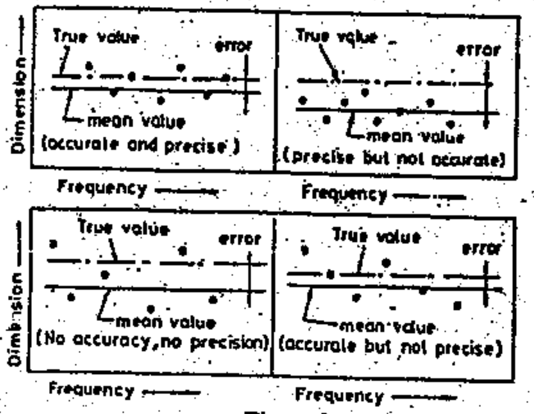

Fig.1.5

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iii. Stylus pressure (contact pressure) :- Changes in the stylus pressure produces variati in both the deformation of work piece surface and deflection of work piece. This will ca an error in the measurement. Variations in the force applied by the anvils of micrometer the work to be measured result in the difference in its readings. The error is caused by distortion of both,micrometer frame and work piece. To avoid this effect of contact pressu micrometer is fitted with a ratchet mechanism with an operating thimble. The ratchet sl when the applied pressure exceeds the minimum required operating pressure.

iv. Avoidable errors :- These errors may occur due to parallax,non-alignment of work pi centres,improper location of measuring instruments,etc. The error due to misalignmen caused when the centre line of work piece is not normal to the centre line of the measur instruments.

Random errors :- Random errors occur randomly and are accidental in nature. Their spec causes, magnitudes and sense can not be determined from the knowledge of measuring syst or conditions of measurement. The possible sources of such errors are :

i. Small variations in the position of setting standard and work piece.
ii. Slight displacement of lever joints of measuring instruments.

iii. Operator error in scale reading

iv. Fluctuations in the friction in measuring instrument.

Q.14. Differentiate between systematic errors random errors.

Ans :-

Systematic errors	Random errors
1. These errors are repeatitive in nature and are of constant and similar form.	1. These are non-consistent. The sources giving rise to such errors are random.
2. These errors result from improper conditions or procedure that are consistent in action.	2. Such errors are inherent in the measuring system or measuring instruments.
3. Except personal error, all other systematic errors can be controlled in magnitude and sense.	3. Specific causes, magnitudes and sense of these errors can not be determined from the knowledge of meausring system or conditions of measurement.
4. If properly analysed, these errors can be determined and reduced or even eliminated.	4. These errors can not be eliminated, but the results obtained can be corrected.
5. These errors include calibration errors, errors due to variation in atmospheric conditions, variation in contact pressure, parallax errors, misalignment errors, etc	5. These errors include errors caused due to variation in position of setting standard and work piece, errors, due displacement of lever joints of instru-ments, errors resulting from back-lash, friction etc.

Q.15. Explain the following terms used in measurements. Repeatability, Reproducibility, sensitivity and readability, calibration.

Ans :

1. Repeatability :- It is the ability of measuring system to reproduce the same results for the measurement of same quantity when the measurements are carried out by the same observer, with the same instrument, under the same conditions and in short intervals of time.

2. Reproducibility :- It refers to the consistency of pattern of variation in measurement i.e. closeness of agreement between the results of measurements of the same quantity when individual measurements are carried out by different observers, by different methods, using different instruments under different conditions.

3. Sensitivity and Readability :- Sensitivity and readability, both the terms are associated with the measuring instruments and not with the measuring process. Sensitivity measures the ability of a measuring instrument to detect small variations in a quantity being measured. Higher the ability of such detection of an instrument, more sensitive it is, but if the instruments are made more sensitive they are easily affected by external effects such as temperature variations, vibrations. etc. This affects the accuracy and precision of measurement. If an instrument is more sensitive than requirement,it becomes difficult for operator to obtain a reliable reading.

Readability refers to the ease with which the readings of a measuring instrument can be read. It is the susceptibility of measuring instrument to have its indications converted into meaningful number. To make micrometers more readable they are provided with vernier scale. Redability and hence accuracy of measurement can also be improved by use of proper magnifying devices.

4. Calibration :- It refers to measurements of the measuring instruments, i.e. framing of scale of the instrument by applying some standardised signals. Calibration is a pre-measurement process,generally carried out by manufacturers. Consistent use of instruments affect their accuracy If the accuracy is to be maintained, the instruments must be checked and re-calibrated. The schedules of such calibration depend upon the severity of use,environmental conditions,accuracy of measurement required,etc. As far as possible calibration should be performed under environmental conditions which are very close to the conditions under which actual measurements are carried out and as per manufacturers instructions or public standard practies. If the output of a measuring system is linear and repeatable, it can be easily calibrated.

Q.16. What is meant by magnification? Explain briefly.

Ans : To improve the accuracy of measurement, small variations in the quantity being measured should be easily detected by measuring instrument and its readings should also be easily readable. For this the output signal from a measuring instrument is to be amplified or magnified.

Thus magnification means increasing the magnitude of output signal of measuring instrument many times to make it more readable.

Magnification obtained in a measuring instrument may be mechanical, electrical, electronic, optical or pneumatic.

Mechanical magnification is obtained by means of levers or gear trains. In electrical magnification, the change in the inductance or capacitance of electrical circuit,made by change in the quantity being measured is used to amplify the output of the measuring instrument. Electronic magnifications is obtained by the use of valves,transistors or ICs. Optical magnification uses principle of reflection and pneumatic magnification makes use of compressed air for amplifying the output of measuring instruments.

Q.17. Give a brief classification of errors which may arise duing measurement.

Ans : Types of error :- During measurement several types of error may arise, These are

1. Static errors which includes.
   a. Reading errors.
   b. Characteristic errors.
   c. Environmental errors.

2. Insturment loading errors.
3. Dynamic errors.

Q.18. Describe the following error's which may arise during measurement

i. Static errors.
ii. Loading errors.

Ans : Static errors :- These errors result from the physical nature of the variable components of measuring system.

There are three basic sources of static errors. The static error divided by the measurement range (difference between the upper and lower limits of measurement) gives the measurement precision.

a. **Reading errors :-** Reading errors apply exclusively to the readout device. These do not have any direct relationship with other types of errors within the measuring system.
Reading errors include.

- Parallax error
- interpolation error.

Attempts have been made to reduce or eliminate reading erors by relatively simple techniques. For example, the case of mirror behind the readout pointer or indicator virtualy elminates occurance of parallax error.

Interpolation error :- It is the reading error resulting from the inexact evaluation of the position of index with regarding to two adjacent graduation marks between which the index is located Interpolation error can be tackled by increasing, using magnifier over the scale in the visinity of pointer or by using a digital read out system.

Characteristic errors :- It is defined as the deviation of the output of the measuring system from the theoretical predicted perfermance or from nominal performance specifications.

Linearity errors, repeatability, hysteresis md resolution errors are part of characteristic errors if the theoretical output is a straight line. Calibration error is also included in characteristic error.

ii. Loading Errors :-Loading errors results from the change in measurand itself when it is being measured,(i.e. after the mesuring system or instrument is connected for measurement. Instrument loading error is the difference between the value of the measurand before and after the mesuring system is connected/contacted for measurement.

For example, a soft or delicate component is subjected to defromation during measurement due to contact pressure of the instrument and cause a loading error. The effects of instrument loading errors are unavoidable. Therefore, measuring system or instrument should be selected such that its sensing element will minimize instrument loading error in a particular measurement involved.

Q.19. Match the following two parts :-

Part I	Part II
i. Error resulting from the change in measurand itself when it is being measured.	a. Random error
ii. Error casued due to effect of surrounding	b. Loading error.
iii. Error casused due to time variation in the measurand.	c. Relative error.
iv. Absolute error divided by true value.	d. dynamic error.
v. Error inherent in the mesuring system	e. systematic error
vi. Repeatative type error.	f. environmental error

Ans :- (i)-(b), (ii)-(f), (iii)-(d), (iv)-(c), (v)-(a), (vi)-(e)

or
error

Chapter 2

MEASUREMENT

Q.1. Enumerate the importance of measurement, define the term physical measurement. Describe in brief the elements of process of measurement.

OR

Q.1. Explain briefly the principles of measurement.

Ans : Mechanical and production engineers are concerned with special aspects of mesurement in designing and manufacturing engineering products. The engineering products vary widely in size, scope etc but have one thing in common,namely,they have to be performed to a specification involving dimensional accuracy.

Measurement is an essential part of the development of technology and as technology becomes more complex the techinques of measurement becomes more sophisticated.

For every kind of quantity measured there must be unit to measure it. This will enable the quantity to be measured in number of that unit. If we say that "A' is longer than "B',untill and unless we answer how much, our statement is incomplete. We must be able to express this difference in quantitative terms i.e. in terms of numbers.

Physical measurement :- A physical measurement can be defined as the act of obtaining quantitative information about a physical object. It can also be defined as the set of experimental operations carried out to determine value of quantity.

Process of measurement :- The squence of operations necessary for the execution of measurement is called process of measurement.

There are three important elements of measurement.

i) Measurand ii) Reference iii) Comparator.

i. Measurand :- Measurand is the physical quantity or property like length, angle, diameter, thickness etc. to be measured.

ii. Reference :- It is the physical quantity or property to which quantitative comparisons are made.

iii. Comparator :- It is the means of comparing measurand with some reference.

Suppose a fitter has to measure the length of M.S.flat, he first lays his rule along the flat. He then carefully aligns the zero end of his rule with one end of the M.S. flat and finally compares the length of flat with the graduations on his rule by his eyes. In this example, the length of M.S. flat is a measurand, steel rule is the reference and eye can be considered as a comparator.

Q.2. What do you understand by "standards of measurement' ? Explain briefly the different systems of measurement.

Ans : A standard is defined as something that is set up and established by authority as a rule for the measurements of quantity,weight,extent,value or quality. Industry, commerce, international trade and in fact, modern civilization itself would be impossible without a good system of standards. The role of standards is to support the systems which make measurements possible throughout the world.

Systems of measurement :- A measureing system is based on few fundamental units,e.g.length,mass, time,temperature,etc. All the physical quantities can be expressed in terms of these fundamental units. The following systems of measurement are in use in different countries.

1. F.P.S. System :- This system is used in English speaking countries.In this system unit of length is yard, unit of mass, weight or force is pound,unit of time is seconds and unit of temperature is 0^{0} Farenheit. This system,being inconvenient is steadily loosing popularity.

2. Metric System :- Metric system is the predominant system in the world. It is the decimal system of weight and measure. It is based on metre as unit of length,kilogram as the unit of mass and kilogram-force (kg-f) as the unit of weight or force. Unit of temperature is 0^{0} centigrade. This system is simple for calculation purposes than F.P.S. system.

3. S.I.System :- This system is extension and refinement of the metric system. It is more convenient and superior to other systems. The unit of length is metre, unit of mass is kilogram, and unit of weight or force is Newton. Unit of temperature is 0 centigrade. This system is followed today in most of the countries.

Q.3. What are line standards and end standards? Explain in brief.

Ans : Line Standards:- When length is expressed as the distance between two lines, it is called line standard. Both material standards-yard and metre-are line standards. Line standards are quick and easy to use, but they are not so accurate. The accuracy of measurement by these standards depends upon the skill of the user.

End Standards :- When length is expressed as the distance between two flat parallel faces, it is known as end standard, e.g. slip gauges, ends of micrometer anvils,etc. These standards are highly accurate and used for measurements of close tolerances in precision engineering as well as in standard laboratories. A modern end standard consists fundamentally of a hardended block or bar of steel. Its end faces are lapped flat and parallel to within few tenths of a micrometre by the process of lapping. Its size too can be controlled very accurately by the process of lapping. Since primary standards are line standards, end standards must be calibrated from line standard.

Q.4. Distinguish clearly between line standard and end standard.

Line standard	End standard
1. Length is expressed as the distance between two lines.	1. Length is expressed as the distance between two flat parallel faces.
2. With line standard, measurement is quick and easy.	2. Use of end standards is time consuming.
3. Line standards, though can be accurately engraved, can not be conveniently used for close-tolerance length measurement.	3. End standards have **very high accuracy** and are suitable for **close tolerance** length measurement.
4. These are subjected to parallax errors.	4. These are subjected to wear on measuring surfaces.
5. These are not subjected to wear except on leading end leads.	5. No parallax error in the measurement
6. Can not be easily aligned with the axis of measurement.	6. Can be easily aligned with the axis of measurement.
7. Examples: yard, metre, etc.	7. Examples: slip gauges, micrometers, etc.

Q.5. What is wavelength standard? State the necessity and advantages of wave length standard.

Ans : Material standards are subjected to destruction and their dimensions change slightly with time. Also a considerable difficutly is experienced while comparing and varifying the sizes of gauges by using material standareds. It, therefore become necessary to have a standard of length, which will be accurate and invariable. In 1829, Jacques Babinet, a French philosopher suggested that wave lengths of monochromatic light can be used as natural and invariable units of length. In 1960, orange radiation of isotope Krypton-86 was chosen for new definition of length;standard metre and yard were defined in terms of wave lengths of Kr-86.

1 metre = 16,50,763,73 wave lengths and

1 yard = 0.9144 metre.

Advantages of wave length standard :-

1. As wave length is not a physical one, it need not be preserved.
2. It is not subjected to destruction by wear and tear.
3. Dimenstons do not change with time.
4. It is a reproduceable standard of length. It is possible to repeat measurement to a very high accuracy. The error of reproduction is only of the order of 1 part in 100 million.
5. Comparing and varifying of material standards (size of gauges) is simplified.

Q.6. Write short note on "End bars'.

Ans : End bars or length bars are primary end standards used for the measurement of larger sizes of work. These are high quality,carbon steel bars of about 20mm to 22mm diameter, made in sizes varying from 10mm to 1200 mm. The bars are hardened at the ends only. The end faces are lapped. They have two bands of slightly larger diameter at the "Airy' points (0.554 times the length.) The bars are supported at these points so that the end faces are parallel to each other. End bars are available in four grades. They are used by stndardising laboratories as reference standards for the calibration of combination end bars,which are in everyday use. Combination end bars have their ends drilled and threaded to receive studs, which are used to join two or more bars together.

Q.7. What do you understand by linear measurement? Name the various instruments used for linear measurements.

Ans : Linear measurement applies to the measurement of lengths, diameters, height and thickness, covering both external and internal measurements. Its principle is to compare the diamensions to be measured with standard dimension which is calibrated on measuring instrument.

The instruments used for linear measurements can be classified into two groups :

i. Non-precision instruments such as steel rule, caliper, etc.
ii. Precision instruments such as vernier calipers, micrometers, slip gauges etc.

Q.8. State the charateristics which a precision instrument should have to function properly.

Ans : To function properly,precision instrument should process the following characteristics.

i. It should be sensitive. If measuring instrument is sensitive, a small change in the measured dimension can be easily determined. But instrument design should be such that its sensitivity remains constant throughout the range of the dimension to be measured.
ii. It should possess high degree of accuracy so that it will be able to give the indications close to the true values of the dimensions to be measured.
iii. Instrument should give nearly the same reading for repeated measurements of same quantity.
iv. Calibration of instrument should be proper and clear.
v. Wear of the measuring surfaces and other parts of the instrument should be minimum possible.
vi. Inertia and friction in moving parts of instrument should be minimum, so that it will not be sluggish.
vii. Instrument should respond to small changes of the quantity measured.
viii. Instrument should have metrological qualities constant at all times.
ix. It should be able to amplify the very small changes in the quantity to be measured.

Q.9. What precautions are to be observed while using metalic scale ?

Ans : The following precautions should be taken while using metallic scale:-

i. Generally the ends of scale are worn out due to continuous use. Therefore, to avoid error in measurement,end of scale should never be set with the edge of the part to be measured.

ii. To have correct reading of the dimension to be measured scale should never be laid flat on the part to be measured.

iii. Scale should never be used for cleaning between parts or as substitute for screw driver, otherwise its edges and ends will be damaged.

iv. To maintain sharpness or the graduations for easy and accurate reading,scale should be cleaned with grease or dissolving fluids.

v. To avoid parallax error,while making measurements, eye should be directly opposite and 90 degree to the mark on the part to be measured.

Q.10. State the principle of vernier. Explain briefly the construction of vernier caliper.

Ans :.Principle : The accuracy of measurement can be increased by utilising the difference between two scales or divisions which are slightly different in size.

Construction : Vernier caliper consists of two scales; one is fixed and other is movable. The fixed scale,called main scale is calibrated on L-shaped frame and carries a fixed jaw. The movable scale,called vernier scale slides over the main scale and carries a movable jaw.Both the scales have two mesuring tips. The accuracy of measurement depends on the condition of the measuring tips,squareness and uniformity of alignment of the sliding frame

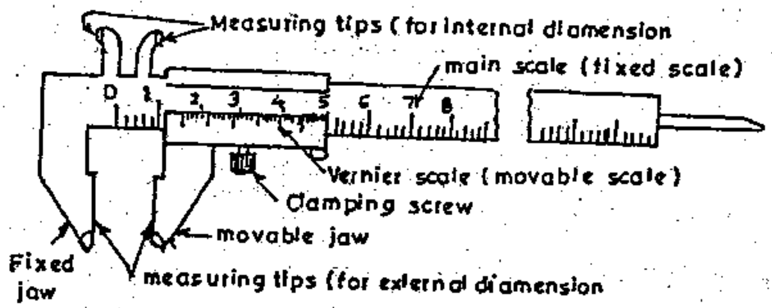


Fig.2.1

w.r.t. the main scale. When two measuring tip surfaces are in contact with each other, scale shows reading. An adjustment screw is provided for finer adjustment of movable jaw. Also an arrangement is provided to lock the sliding scale on the main scale.

Q.11. Define least count of vernier instruments. How is it determined ?

Ans : To increase the accuracy of measurements, vernier instruments make use of the difference between two scales which are slightly different in size. These instruments have two scales. Main scale is fixed and vernier scale slides over the main scale. When zero on the main scale coincides with the zero on the vernier scale, the number of divisions on the vernier scale is one more than the number of divisions on the main scale with which it coincides. S the value of a division on vernier scale is slightly smaller than the value of division on ma scale

Least Count (L.C.) : is the difference between the values of main scale division and verni scale division. It can also be calculated by the ratio of the value of minimum division on ma scale to the number of divisions on vernier scale.

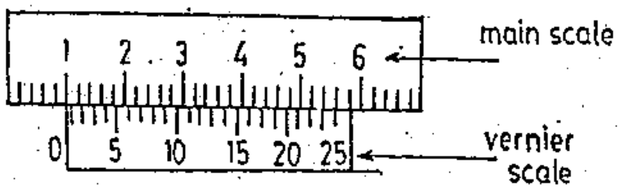


Fig.2.2

Fig.2 .2 shows a vernier having main scale graduations of 1mm and 25 divisions on verni scale coinciding with 24 divisions on the main scale. As 25 divisions on vernier scale measu 24mm, the value of each division is 24/25 = 0.96 mm. The value of smallest division on th main scale is 1mm. So, least count of the instrument = value of smallest division on ma scale

$$= 1 - 0.96 = 0.04 \text{ mm}$$

OR

$$\text{Least Count} = \frac{\text{Value of smallest division on main scale}}{\text{Number of divisions on vernier scale}}$$

$$= \frac{1}{25}$$

$$= 0.04$$

Q.12. Give list of possible errors in vernier instruments. What precautions should be taken to minimise them ?

Ans : The errors in the measurements carried out by a vernier instrument are usually due t mainpulation or mishandling of the instrument and its jaws on the workpiece. The variou causes of errors are given below.

i. Error due to sliding between jaws on the scale.

ii. If the sliding jaw frame becomes worn or warped, it will not slide squarely and accuratal on the main scale. This will introduce error in the measurement.

iii. Wear and warping of the jaws will also cause 0-0 points on the main and vernier scale not to coincide with each other and will introduce error.

iv. Errors are also caused by misreading of the vernier scale or by incorrect adding of the vernier scale coincident reading to the relevant main scale reading. But such errors are not usual.
v. Error is introduced if the line of measurement does not coincide with the line of the scale.
vi. Error is also caused due to incorrect feel and touch.

Precautions :- To minimise the errors, the following precautions should generally be followed.

i. The line of measurement must coincide with the line of the scale.
ii. While measuring outside diameters, the plane of the measuring tips of the caliper must be perpendicular to the centre line of the workpiece. The caliper should not be tilted.
iii. Grip the instrument near or opposite to the jaws and not by the overhanging projected main bar of caliper.
iv. Move the caliper jaws on the work with light touch. Do not apply undue pressure.
v. Before reading, try the caliper again for feel and location.

Q.13. Explain the principle of micrometer and hence define its least count

Ans : Micrometer uses the principle of screw and nut. We know that when a screw is turned through nut through one revolution, it advances through one pitch distance i.e. one rotation of screw thread corresponds to pitch length. If the circumference of screw is divided into number of equal parts, say "n' its rotation through one division (on the circumference) will cause the screw to advance through (Pitch/n) length i.e. the minimum length that can be measured by such arrangement will be (pitch/n) By reducing the pitch of the screw thread or by increasing the number of divisions on the circumference of screw, the length value of one circumferential division can be reduced and accuracy of measurement can be increased considerably.

Least count of micrometer is the value of one division on graduated collar connected to screw (thimble). If the pitch of screw thread is 0.5 mm and the thimble has 50 equal divisions on the circumference, one division on the thimble equals to 0.5/50 i.e. 0.01 mm. Therefore least of count of the instrument is 0.01.

Q.14. What precautions should be taken while using a micrometer ?

Ans :

1. First clean the micrometer by wiping off oil, dust and grit.
2. Clean the mesuring surfaces of the anvil and spindle with a clean piece of paper or cloth.
3. Set the zero reading of the instrument before measuring.
4. Hold the part and micrometer properly. Turn the thimble with forefinger and thumb till the measuing tip just touches the part and final adjustment should be made by ratchet so that uniform measuring pressure is applied.
5. While measuring dimensions of circular parts, the micrometer must be moved carefully over representative area so as to note maximum dimension only.

Q.15. "Micrometer anvil surfaces should be truly flat and parallel". Why? With what instrument and how you will check flatness and parallelism of surfaces?

Ans : Micormeter is an end measuring device and (end standard.) It expresses length as the distance between its anvil surfaces. The lack of flatness and parallelism of the anvils will result in incorrect functioning of the instrument and will cause errors in the measurement. So the micrometer anvil surfaces should be of very high finish (flat) and truly parallel to each other.

Best instrument for mesurement of flatness and parallelism of micrometer anvil surfaces is optical flat. When checking flatness, an optical flat is brought in contact with each of the two anvils in turn and moved in such a manner that minimum number of interference fringes are produced. By observing the number of fringes produced, the condition of flatness of anvil surface can be determined. Interference frignes obsered on each of the two anvils should not be more than two for practically all ranges of grade I micrometers.

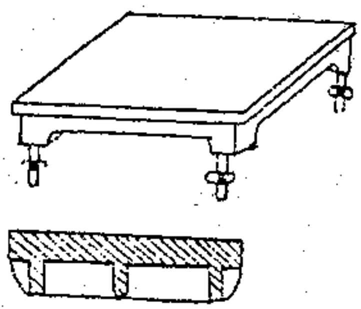
Parallelism of the anvils of micrometer can also be checked by using optical flat and a fla parallel plate. The interference fringes produced between flat parallel plate and anvil surface are observed. The sum of the fringes observed on the two anvil surfaces indicate the degre of parallelism between the surfaces. For 0-25 mm micrometers, the sum of the fringes shoul not be more than 6, for 25 to 75 mm micrometers,-not more than 8 and for 75 to 100 m micrometers-not more than 10.

Q.16. Write short note on :

1. Surface plate,
2. Angle plate,
3. Tool maker's straight edge,
4. Vernier height gauge.

Ans :

1. Surface plate : Surface plates are extensively used in work shops and laboratories reference surface for testing flatness of surface or as reference surface for all other measuri instruments having flat bases, e.g. for mounting V-blocks, angle plates, sine bar, mechani comparator, etc.



sect l.v.

Fig.2.3

Surface plates are massive and highly rigid in desi They have **truly flat level planes**. These plates generally made up of CI, free from blow holes, inclusi and other surface defects and are heat treated to reli internal stresses. All the surface plates are of de section and properly ribbed at the bottom, so that th are rigid enough to carry their own weights as well weights of heavy objects placed on them, with appreciable deflection. The top surface is scrape true flatness, either by hand scraping or by hand lapp The four edges of the plate are finished smooth, strai parallel and reasonably square to each other and to top surface. Big surface plates are provided with four levelling screws to adjust their top surfaces truly horizontal.

Surface plates are also made up of granite and glass. Granite surface plates are non-corrosive and wear resistant. They are not affected by temperature variations or dampness and are heat and electric insulators. All granite plates are stable over reasonably long periods. Glass surface plates are light weight and non-corrosive. They can be manufctured easily to a higher degree of accuracy and maintain their accuracy for a longer period.

Surface plates are designted by their length, breadth, grade and number of Indian standard, According to ISI they are classified into two grades :-

Grade I :

Maximum permissible departure from flatness 5 microns over an area of 300 mm x 300 mm.

Grade II :

Maximum permissilbe departure from flatness 20 microns over an area of 300 mm x 300 mm.

Precautions :

To have minimum wear the whole surface of the plate must be used. The top surface of the plate must be protected from corrosion by applying grease and when not in use, it should be covered by wooden or hard board plate.

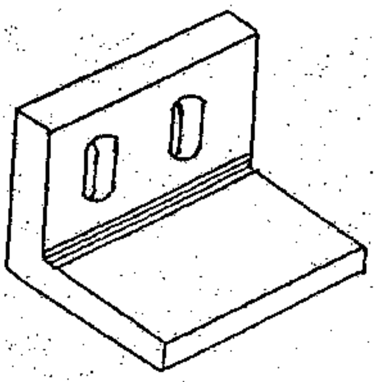


Fig.2.4

1. **Angle plate :** CI angle plates are widely used in workshops or laboratories with surface paltes for measurement purposes. The two working faces are truly perpendicular to each other. Angle plates are generally made form closed grained CI. After being cast and rough machined, they are heat treated to relieve internal stresses and are then finished. The material used for these plates should be sound, free from blow holes and porous patches. Generally no sharp edges are allowed in the plate. Angle plates are available in two grades depending upon the accuracy.

Grade I :

All exterior and interior faces and edges be finished by either grinding or hand-scraping.

Grade II :

All exterior faces are finished by planing or milling operation.

3. **Tool maker's straight edges :-** These straight edges are used for very accurate work,

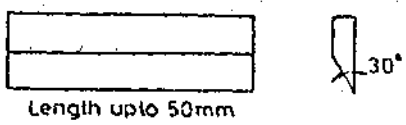


Fig.2.5

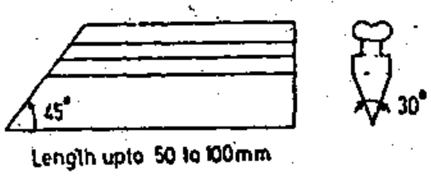


Fig.2.6

such as checking straightness and flatness of surfaces in tool room. They are made of suitable cast or wrought alloy steel, hardened and suitably heat treated to relieve the internal stresses and to give stability. They are available in the range of 15 mm to 30 mm.

The shapes of the sections of straight edges of various lengths are as shown in Fig.2.5 and Fig.2.6. The working edge, commonly known as knife edge is bevelled and very slightly rounded off throughout the length. The faces adjoining the working edge are ground flat. The working edge is finished by grinding and lapping.

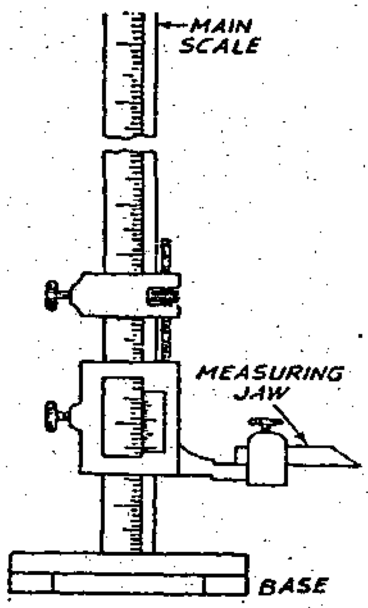


Fig.2.7

4. Vernier height gauge :- Vernier height gauges are used to measure or mark vertical distances. These are mainly used in the inspection of parts and layout work. A vernier height gauge consists of a graduated bar held in the vertical position by a finely ground and lapped base. Other parts are measuring jaw or scriber, a slider with venier scale, fine adjustment screw, clamping screws, etc. All the parts are made of good quality steel or stainless steel. The base is quite robust to ensure rigidity and stability of the insturment. The section of the beam is such that it ensures sufficient rigidity during use. The measuring jaw has a clear projection from the edge of the beam at least equal to the projection of the base form the beam. The upper and lower surfaces of the jaw are parallel to the base. Slide has good sliding fit along the full working length of the beam and is provided with an arrangement for fine adjustment.

Precautions :- When not in use, vernier height gauge is kept in its case. To ensure sufficient accuracy in measurements, it is tested for straightness and squareness or parallelism of the working faces of the beam, measuring jaw and scriber and the accuracy of the scale readings.

Q.17. What are the various instruments used for measuring flatness of a surface plate? Describe the test procedure adopted for measuring flatness of a surface by using one such instrument.

Ans : The various instruments used for measuring flantess of a surface plate are sensitive level, auto-collimator, Beam comparator, liquid surface gauge etc.

Liquid surface gauge method :-This is the most rapid method of testing flatness of large surface plates with accuracy of order of 5 microns. Mercury or weak soda solution is used as the basis of reference to compare the surface to be tested with liquid surface.

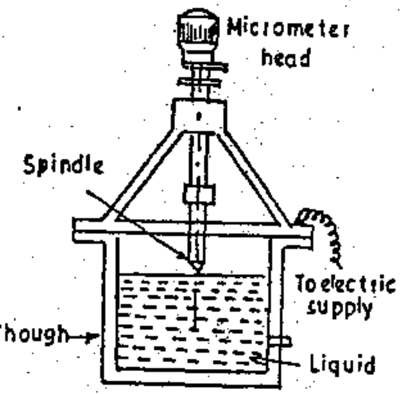


Fig.2.8

The liquid is contained in a trough made of iron channel. The trough carries a form of height gauge with an overhanging micrometer head having a conical point to the spindle.

The spindle points downwards. The gauge is placed over the surface to be tested. The micrometer head is screwed down untill the conical point of the spindle just touches the liquid surface The exact position of contact is determined with the help of on electrical indicator circuit. the gauge is moved from place to place over the surface and for each position a reading is taken. The differences in the readings indicate the errors in flatness. The variations in the flatness of surface are thus compared with the true plane of the liquid surface.

Q.18. Describe the method of testing squareness of angle plate with dial gague.

Ans : The apparatus used for squareness testing consists of a single block and column having a knife edge near its base. A dial gauge is fitted over the column and can be adjusted vertically on it. A square block having two opposite sides accurately parallel is used for setting the instrument.

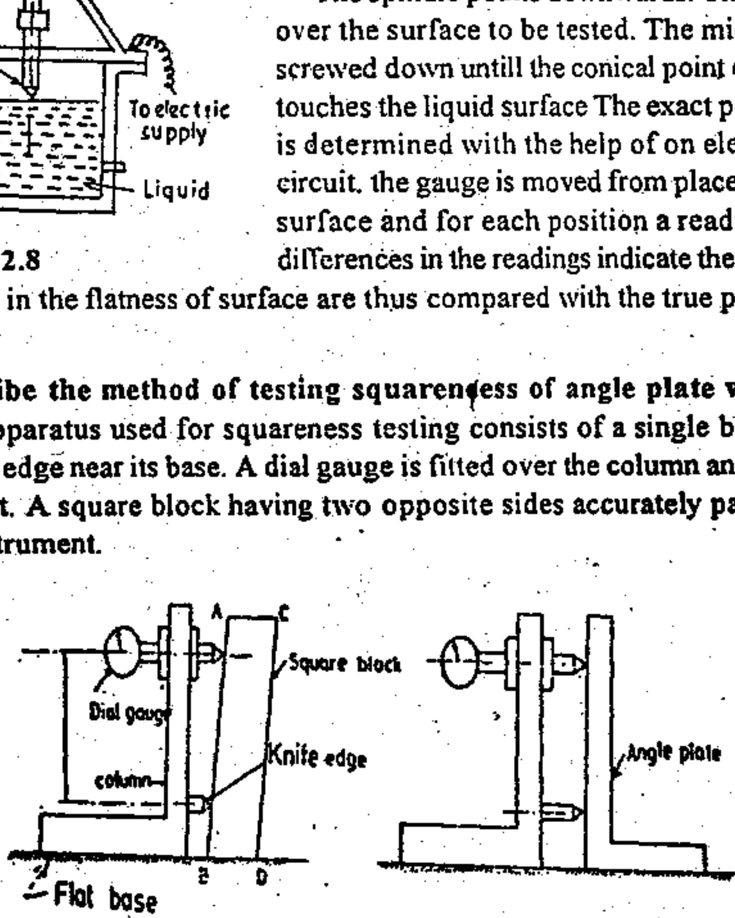


Fig.2.9

The instrument is placed on a flat base (surface palte) and one of the parallel faces (AB) of the square block is brought in contact with the knife edge. The dial gauge reading is taken. The block is then turned around and the opposite face (CD) is brought in contact with the knife edge. The reading of the dial gauge is taken. The mean value of these two readings represents squareness. The instrument is now ready for testing squareness. To test the squareness of angle plate, it is placed on the surface plate and is brought in contact with the knife edge. The reading of the dial gauge is noted the difference between this reading and the mean reading shows on error in squarencess over the distance between the knife edge and the dial gauge(L).

Q.19. Explain the principle and uses of spirit level.

Ans : Spirit level consists of a sealed glass tube mounted on a base. The inside surface of the tube is ground to a convex barrel shape having large radius. The precision of the level depends on the accuracy of this radius of the tube. A scale is engraved on the top of the glass tube. The tube is nearly filled with eather or alcohol, except a small air or vapour bubble.

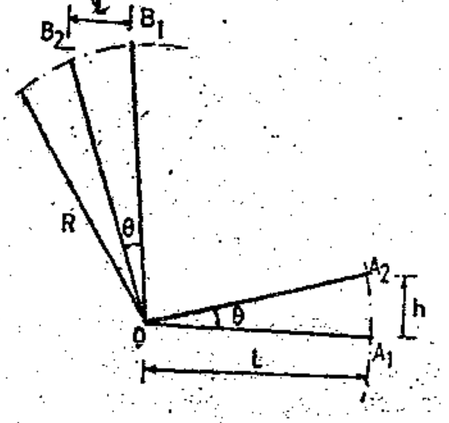


Fig.2.10

Principle : The bubble always tries to remain at the highest point of the tube. If the base of spirit level is horizontal, the centre point is the highest point of the tube; so when the level is placed on a horizontal surface, the bubble rests at the centre of the scale. If the case of the level is tilted through a small angle, the bubble will move relative to the tube a distance along its radius corresponding to the angle.

The Fig.2.10 shows two positions of the base of the level (OA1 and OA2) and corresponding positions of the bubble (B1.B2). When the base (OA1) is horizontal the bubble occupies position B1. Let "θ" be the small angle through which the base is tilted. The bubble now occupy the position B2. Let "l" be the distance travelled by the bubble along the tube and "h' the difference in heights between the ends of the base, then,

$$l = R\theta \text{ and } h = L\theta$$

or $$\theta = \frac{l}{R} = \frac{h}{L} \text{ or } l = h\frac{R}{L}$$

Where R = Radius of curvature of the tube

L = Length of base

Sensitivity of spirit level is the angle of tilt in seconds that will cause the bubble to move through one division. It depends upon the radius of curvature,length of bubble and internal radius of the tube.

Uses : Spirit levels are used to measure small angles or inclinations, to test straightness and flatness of surfaces, etc.

Q.20 How straightness is measured by using spirit level.

Ans : Spirit levels can be used to measure straightness of horizontal surface by measuring the relative angular positions of a number of adjacent sections of that surface.

Two feet are attached at a convenient distance apart to underside of a sensitive spirit level. The level is moved along the surface to be tested in steps equal to the pitch distance between the feet and at each position the reading of one end of the bubble is noted. Variations in the bubble position represent angular variations in surface and these are converted into difference in the heights of the two feet. Thus by moving the level along the whole surface, the heights of the various points above or below the starting point can be determined.

Q.21. Write short note on slip gauges.

Ans : Slip gauges are used as standards of measurement in practically every precision engineering works. These are invented by C.E. Johansen of Swedan and are also called Johansen gauges.

Slip gauges are rectangular blocks made of high grade steel to exceptionally close tolerances. To resist wear, these are hardened throughtout by heating to about 760 degree.C and quenching in water. They are then stabilised by heating and cooling successively in stages so that hardening stresses are removed, after this the measuring faces of the blocks are carefully finished by high grade lapping to have good wringing surfaces. Sectional dimensions of these gauges are 9mm X 30 mm for sizes upto 10mm and 9mm X 35 mm for larger sizes.

Slip gauges are available in the following five grades of accuracy :-

Grade II : Used in workshops for setting up machine tools.

Grade I : Used for more precise work such as setting up sine bars, checking gap gauges etc.

Grade 0 : It is inspection grade and is used for tool room or machine shop inspection.

Grade 00 : Used for highest precision work such as measuring Grade I and II.

Calibration grade : This is special grade and it is also used to measure other grades.

The following two sets of slip gauges are in general use :-

Normal set (M-45)

Range (mm)	steps	pieces
1.001 to 1.009	0.001	9
1.01 to 1.09	0.01	9
1.1 to 1.9	0.1	9
1 to 9	1	9
10 to 90	10	9
		45

Special set (M 87)

Range (mm)	Steps	Pieces
1.001 to 1.009	0.001	9
1.01 to 1.49	0.01	49
0.5 to 9.5	0.5	19
10 to 90	10	9
1.005	-	1
		87

Q.22. State the meaning of wringing. What are the essential conditions of wringing? or Explain wringing of slip gauges.

Ans : When two clean and very accurately flat surfaces are slid together under pressure, they adhere firmly. This phenomenon is called wringing. Generally a minute amount of grease or moisture must be present between the surfaces for them to wring satisfactorily. This effect is caused partly by molecualar attraction between the surfaces and the liquid film and partly by atmospheric pressure. Use of this phenomenon is made when several slip gagues are to be used in combination, because the stack can then be handled as a unit without the need of clamping the pieces together.

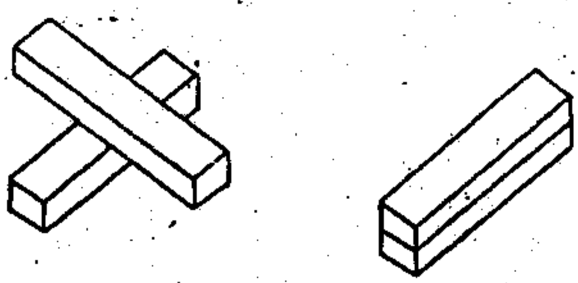


Fig.2.11

To wring two slip gauges together, they are first cleaned because if any dust is present between the surfaces they would not wring together. After cleaning they are placed together at right angles in the form of a cross and then rotated through 90 degree. While being pressed together. This method causes less rubbing of the surfaces.

Q.23. What precautions should be taken while using slip gauges ?

Ans : Slip gauges are high precision measuring devices hence sufficient care should be taken while using them.

When not in use, all the polished surfaces should be protected from atmospheric corrosion by applying petroleum jelly or other suitable anti-corresive agents.

They should be always kept in their cases which should be kept closed.

To prevent corrosion, gauges should not be touched by hand, if it is possible to avoid doing so. They should be handled by using piece of chamois leather or tongs made from a strip of perspex. Handling should be as minimum as possible to avoid transfer of heat from body to the gauges.

After wringing, the surfaces should be wiped with solvent to remove finger marks, if any. To remove grease, a clean rag soaked in petrol is first used, followed by another dry and soft cloth and final cleaning is done by chamois leather.

After use the gauges are wiped and replaced in their proper compartments in the case.

Q.24. Write short note on-Vernier depth gauge.

Ans : It is used to measure the depths of holes, slots and recesses, to locate centre distances, etc. It consists of a sliding head having flat and true base free from curves and waviness. The sliding head slides over a graduated blade called beam.

The beam is perpendicular to the base in both directions and its end is sqaure and flat. The end of sliding head can be set at any point with fine adjustment on it. While using this instrument, hold the base of the sliding head firmly on the reference surface and move gauge beam to measure the depth without applying undue pressure.

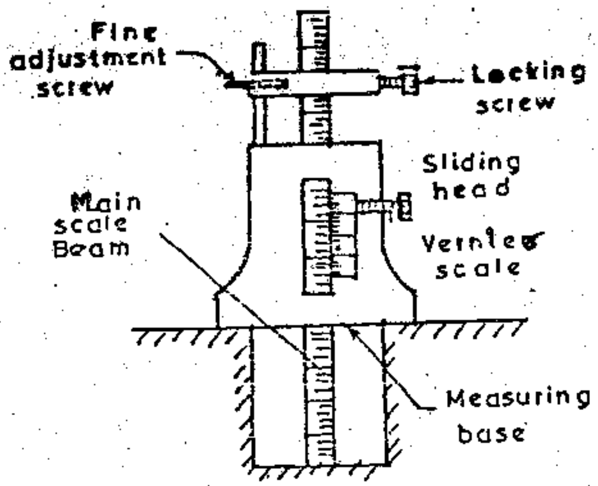


Fig.2.12 Vernier Depth Gauge

While using this instrument, hold the base of the sliding head firmly on the reference surface and move the gauge beam to measure the depth without applying undue pressure.

Q.25. A slip gauge set with 87 pieces, as under, is available :

Range	Step	Pieces	Ranges	Step	pieces
1.001 to 1.009	0.001	9	10 to 90	10	9
1.01 to 1.49	0.01	49	1.005	...	1
0.5 to 9.5	0.5	19			

Build up the following dimensions with minimum number of slip gauges:-

i. 29.758 mm ii. 46.635 mm

Ans :

i. For last decimal place of 0.008, choose 1.008 mm slip gauge.
Now dimension left is 29.758 - 1.008 = 28.75mm
For second decimal place of 0.05 ,choose 1.25mm slip gauge.
Dimension left = 28.75 - 1.25 = 27.5mm
Now choose 20mm and 7.5mm slip gauges to build the required dimensions.
Thus, we have 20 + 7.5+ 1.25 + 1.008 = 29.758mm i.e. the above four slip gauges are required to build 29.758mm.

ii. To build dimension 46.635mm, choose the following slip gauges.
1.005 + 1.13 + 4.5 + 40 = 46.635 mm.
i.e. the above four slip gauges are required to build 46.635 mm.

Q.25 Describe V Block. State its uses.

Ans : TheV-block is made of C.I. with all the faces machined true. V grooves are provided on two oppsite sides and slots on other two faces as shown in fig. 2.13. Generally the angle of V is 90^0 and these are available in wide variety of shapes. U-clamps are provided to secure the work firmly on the V-groove.

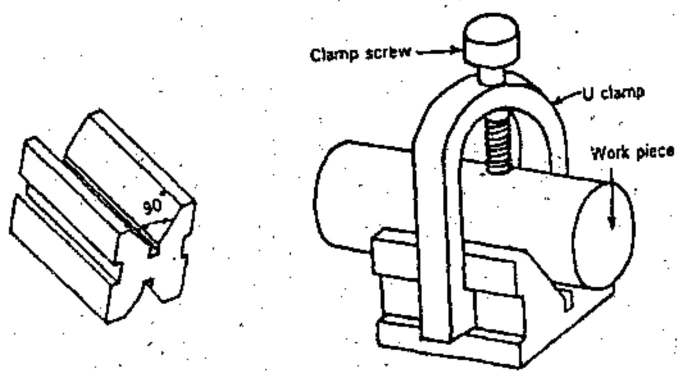


Fig. 2.13 V-block

V-blocks are mainly used for the following purposes.

1. To hold the cylindrical work pieces firmly for marking centres.
2. For checking out of roundness of cylindrical work pieces.
3. To establish precisely the centre line or axis of cylindrical work pieces.
4. They may also be used to support rectangular components at 45^0 to the datum surface.
5. V-blocks are also manufactured in pairs for holding and supporting long circular components parallel to the datum surface.

Depending upon the accuracy IS : 2949-1964 specifies the V-blocks in two grades ; grade A and grade B. These grades vary only in the amount of flatness tolerance on the working faces of the blocks. V-blocks having 120^0 included angles between V-grooves are also available.

In using V-block, it is very essential that the cylindrical piece should rest firmly on the sides of the V and not on edges. These blocks should be checked periodically for basic accuracy and should be prevented from rusting.

Q.26 Write short notes on

1) Feeler Gauge

2) Screw pitch gauges

3) Radius gauges

4) Wire gauges

Ans :Feeler Gauge

Feeler gauge is used to measure/ check the clerance between the two mating parts.For example, it can be used in gauging of the clearance between the piston and cylinder and also for adjusting the spark gap between the distributor points of an automobile. The feeler gauge set consists of narrow strips of sheet steel of different thickness assembled (hinged) together in a holder.

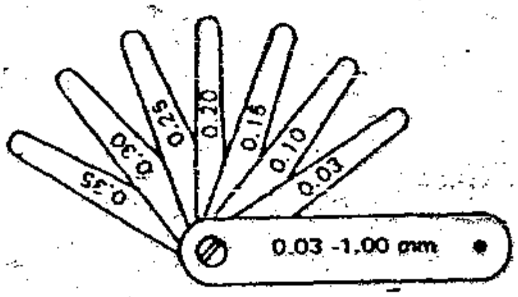


Fig. 2.14 Feeler Gauge

Their working entirely depends upon the sense of feel. In using the strips (blades), it is essential that the strips should neither be forced between the surfaces nor slide freely. The correct strip or a combination of strips will give a characteristic 'gauge fit' type of feel.

A set of feeler gauge generally consists of a series of blades of thickness varying from 0.03 to 1 mm. The blades are made of heat treated bright polished tool steel. The width of the blade in 12 mm at the heal and tapered for outer part of their length so that the width at the tip is approximately 6 mm. The holder protects the blade when not is used. The nominal thickness of the blade is marked on it legibly.

IS : 3179 recommends seven sets of feeler gauges with thickness from 0.03 to 1.00 min. Each set is devised so as to permit maximum utility with minimum number of blades. Table below gives the thickness and number of blades in each set as recommended by Indian Standard IS: 3179.

Set No.	No. of blades in	Thickness of blades in mm in the set
1	8	0.03 to 0.01 in steps of 0.01
2	9	0.03, 0.03, 0.04, 0.04, 0.05, 0.05, 0.06, 0.07, 0.08
3	16	0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.15, 0.20 0.25, 0.30, 0.35, 0.40, 0.45, 0.50
4	11	0.03, 0.04, 0.05, 0.06, 0.07, 0.1, 0.15, 0.20, 0.30, 0.40, 0.50
5	14	0.05, 0.06, 0.07, 0.08, 0.09, 0.1, 0.15, 0.20, 0.25, 0.30, 0.40, 0.50, 0.75, 1.0
6	11	0.05, 0.06, 0.07, 0.08, 0.09, 0.10, 0.15, 0.20, 0.40, 0.75, 1.0
7	11	**0.50, 0.55, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85, 0.90, 0.95, 0.10**

Screw Pitch Gauges -

Screw pitch gauge is used to check the pitch of the screw thread. They quickly determine the pitch of the thread by matching the teeth on the strips with the teeth on the work. They are available with 55° and 60° included thread angles. A typical set is shown in fig. 2.15.

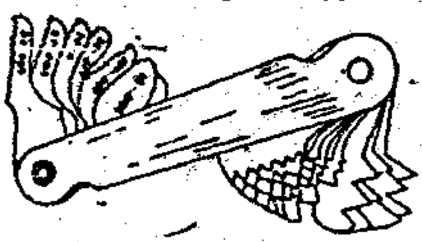


Fig. 2.15 - Screw pitch gauges

Radius Gauges

Radius gauges are employed for checking external and internal radii on a curved surface. Radius gauges consists of sets of blades. The corresponding radius is permanently marked on each blade. The set consists of blade with internal radius on one side and external radius on the other, so that it may be suitable for cheking fillets as well as radius. The passage of light between the gauge and the work allows the radius to be checked properly.

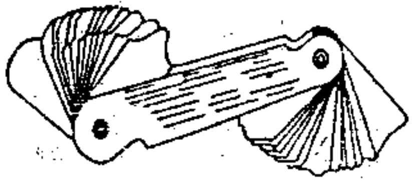


Fig.2.16 Radius Gauge

Wire Gauge

Wire gauge (Fig. 2.17) are used for finding diameters of wires by inserting the wire in the notches provided and finding out which it fits.The diameter and the number marked on the disc are read off from the gauge.The wire gauge has the range from 0.1 **mm to 10mm.**

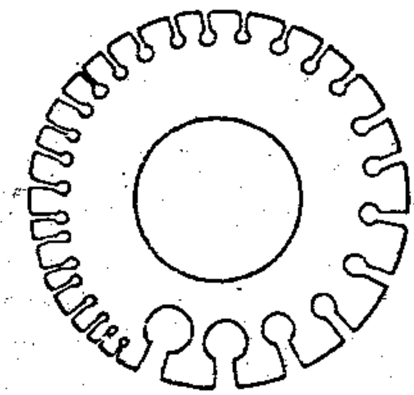


Fig.2.17 Wire Gauge

Chapter 3

LIMITS, FITS AND GAUGES

Q.1. Explain; with the help of a sketch the folloing terms :-
i. Basic size, ii. Limits of size, iii. Deviation, iv. Zero line, v. Tolerance, vi. Fundamental deviation.

Ans :

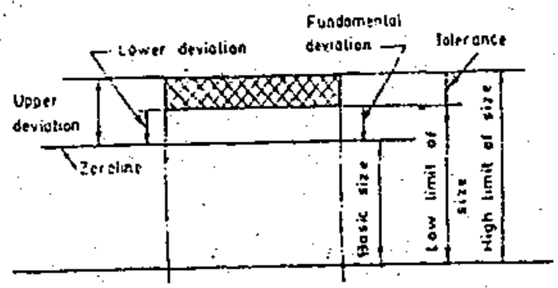


Fig.3.1

i. Basic size : It is the standard size of a part with reference to which all the limits of variations of size are determined. It is same for both hole and its shaft.

ii. Limits of size are the two extreme permissible sizes of a part between which the actual size of that part is contained. The greater of these two sizes is called maxi mum limit or high limit of size, while the smaller size is the minimum limit or low limit of size.

iii. Deviation : It is the amount by which the size of a part deviates from its basic size. Thus it is the algebraic difference between a size and basic size. The algebraic difference between high limit of size and corresponding basic size is called upper deviation, while difference between low limit of size and basic size is lower deviation.

iv. Zero line : It is the line of zero deviation and represents the basic size. In the graphical representation of limits and fits. all the deviations are shown w.r.t. the zero line, positive deviations above the line and negative deviations below the line.

v. Tolerance : It is the algebraic difference between the upper and lower deviation and has an absolute value without sign. It can also be defined as the difference between high and low limits of size

vi. Fundamental deviation : It is either upper deviation or lower deviation which is conventionally chosen to define the position of tolerance zone in relation to the zero line.

Q.2. What do you understand by - Limits, Fits, Tolerance and Allowance.

Ans : Limits : It is not possible to obtain exact dimensions of a part because of the variations in man and machine. Also it is costly affair to obtain perfect size of a part. Therefore, the ranges of permissible differemce in dimensions have been standardised under the name limits. The limits of size of a dimension are two extreme permissible sizes between which the actual size of the dimension is contained. The greater of these two is called maximum or high limit of size, while smaller size is the minimum or low limit of size.

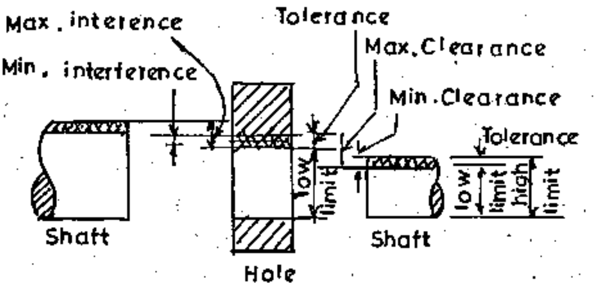


Fig. 3.2

Fits : Fit is the relationship existing between two parts during assembly due to the difference in their sizes. It is the degree of tightness or looseness between two mating parts to perform a definite function. Depending upon the actual limits of the hole or shaft sizes, fits may be classified as : Clearance fit, Interference fit or Transition fit.

Tolerance : It is rather difficult or even impossible to make a part to exact given size. It is, therefore, essential to allow a definite variation in the size of the part. This permissable variation in size or dimension of part is called tolerance. Tolerance is the difference between maximum and minimum limits of size, it is the algebric difference between the upper and lower deviations.

Allowance : Allowance is the prescribed difference between the dimensions of two mating parts (hole and shaft) for any type of fit. It is the intentional difference between the lower limit of the hole and higher limit of the shaft. The allownace may be positive or negative. The positive allowance is called clearance, while negative allowance is called interference.

Q.3. Differentitate between Tolerence and Allowance.

Ans :

Tolerence	Allowance
1. It is the permissible variation in dimension of a part (hole or shaft)	1. It is the prescribed difference between the dimensions of two mating parts (hole and shaft).
2. It is the difference between higher and lower limits of a dimension of a part.	2. It is intential difference between the lower limit of hole and higher limit of shaft.

3. Tolerence is to be provided on a dimension of part as it is not possible to make a part of exact specified dimension.	3. Allowances is to be provided on the dimensions of mating parts to obtain required type of fit.
4. It has an absolute value without sign.	4. Allownace may be positive (clearance) or negative. (interference)

Q.4. Write short notes on : i. Limits. ii. Fits and its types.

Ans :

i. Limits : Every production process is a combination of three elements-man, machines and materials. A change in any of these will result in changes in the sizes of the manufactured parts. The incorrect size relationships between the manufactured parts affect their life and proper functioning. In mass production, where number of parts are to be made, it is not possible to make all parts exactly alike and to exact dimensions. The differences in dimensions do exist because of the variations in tooling, machine variables, raw material and human effort. Also, perfect size is not only a diffcult but a costly affair. Therefore, the ranges of permissible difference in dimensions have been standardised under the name limits. The limits of a size of a dimension of a part are two extreme permissible sizes, between which the actual size of that dimension is contained. They are fixed with reference to the basic size of that dimension. The higher limit for that dimension is the largest size permitted for the dimension and lower limit is the smallest size permitted. e.g. a shaft of 25 mm basic size may be written as $25^{\pm 0.02}$ The higher limit of the dimension is 25.02 mm and lower limit for the dimension is 24.98 mm.

ii. Fits and its types : When two parts are to be assembled, the relation resulting from the difference between their sizes before assembly is called fit. It is the degree of tightness or looseness between two mating parts to perform a definite function. Various kinds of engagement between the hole and shaft result from the difference between their average sizes. Depending upon the actual limits of the hole or shaft sizes, fits may be classified as :-

Clearance fit :- It denotes the condition of assembly of two mating parts in which the size limits of these parts are so chosen that positive allownace i.e. clearance will always occur.

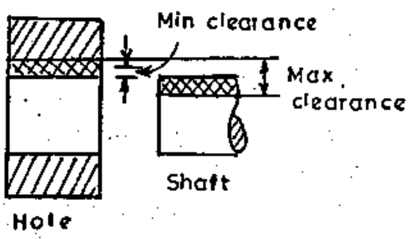


Fig.3.3

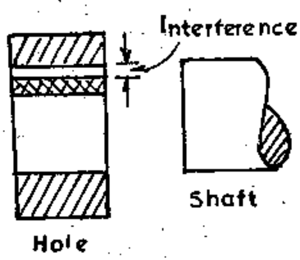


Fig.3.4

The largest permissible shaft size is smaller than the smallest permissible hole size. Sliding fit and running fit are the examples of clearance fit.

Interference fit : In this fit the sizes of the mating parts are so selected that interference or negative allowance will always occur. The minimum permitted shaft size is larger than the maximum permitted hole size. Press fit, driving fit, shrink fit and force fit are the examples of this type of fit.

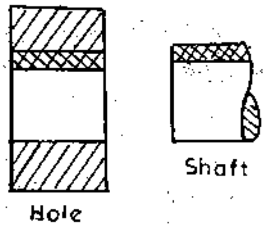


Fig.3.5

Transition fit : In this type of fit, the size limits of mating (shaft and hole) are so selected that either clearance or interference may occur depending upon the actual sizes of the parts. Push fit and light keying fit are examples of this type of fit.

Q.5. What is tolerance ? Explain unilateral and Bilateral systems of tolerance.

Ans : It is never possible to make a part or a component exactly to a given size of dimension and no method is available for absolutely accurate measurement of that dimension. It therefore, is essential to allow a definite permissible variation on every specified dimension. This permissible variation in size or dimension is called tolerance. Thus, the word tolerance indicates that a worker is not expected to produce the part to the exact size, but a small size error is permitted. The difference between higher and lower limits of a dimension represents the margin for variation in workmanship and is called tolerence zone.

Tolerance can also be defined as the amount by which the job is allowed to go away from accuracy and perfectness without causing any functional trouble, when assembled with the mating part and put into actual services. e.g. for a shaft of dimension $25^{\pm 0.02}$, tolerance = 25 .02 - 24.98 = 0.04 mm.

Tolerance for a particular dimension may be allowed to vary either on one side of the basic size or both sides of the basic size. There are two systems of specifying the tolerence of a component.

Unilateral system :- In this system, the dimension of a part is allowed to vary only on one side of the basic dimension or size i.e. tolerence lies wholy on one side of the basic size.

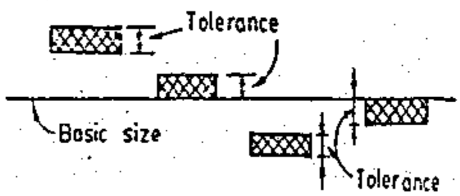


Fig.3.6

either above or below it.

e.g. $25^{+0.02}_{+0.01}$ $25^{+0.02}_{-0.00}$ $25^{-0.01}_{-0.02}$ or $25^{+0.00}_{-0.02}$

This system is preferred in interchangeable manufacture, especially when precision f are required, because it is easy and simpler to determine deviations. Another advantage of t system is that Go gauge ends can be standardised as the holes of different tolerance grad have the same lower limit and all the shafts have same upper limit.

Bilateral system : In this system, the dimension of a part is permitted to vary on both si of the basic size i.e. limits of tolerence lie on either side of the basic size; but may not necessarily equally disposed about it.

e.g. $25^{\pm 0.02}$ or $25^{+0.02}_{-0.01}$

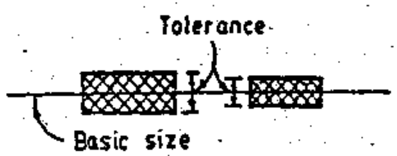


Fig. 3. 7

In this system it is not possible to retain the same when tolerance is varied and basic size of one or both the mating parts to be varied . This system is used large size manufacture. Bilateral tolerances help machine setting.

Q.6. Explain briefly Hole basis system and shaft basis system of Limits and Fit

Ans : A limit and fit system is the system of series of standard allowances and tolerance suit specific ranges of basic size, which, when properly selected and assigned to mating p ensure specific classes of fit. There are two systems of limits and fits.

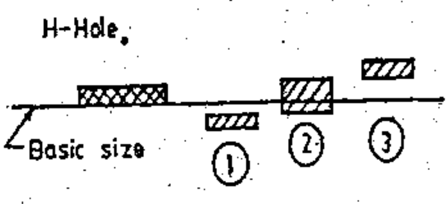


Fig.3.8

1. Hole basis system : In this system, the des size of hole, whose lower deviation (fundame deviation) is zero (H-hole) is assumed as basic and different clearances and interferences (to h different classes of fit) are obtained by varying limits of the shaft. In other words, the limits of hole are kept constant and those of the shaft varied so as to obtain the necessary fit.

Refer fig. 3.8.

1. Clearance fit, 2. Transition fit and 3. Interference fit.

There are considerable advantages in using hole basis system of limits and fits. This sys is recommended by ISI India and preferred in industries, because it is very easy, conven and less costly to make a hole of correct size by using standard drills, reamers, etc. It is much easier to vary shaft sizes according to the fit required,by adjustable methods suc grinding and turning. Also gauging can be conveniently done with adjustable gap gauges direct external measurement is easier than internal measurement.

2. Shaft basis system : In this system, the design size of a shaft whose upper deviation (fundamental deviation) is Zero (h-shaft) is the basic size and different clases of fit are obtained by varying the limits on the hole i.e. the limits on the shaft are kept constant and those on the hole are varied to obtain desired classes of fit.

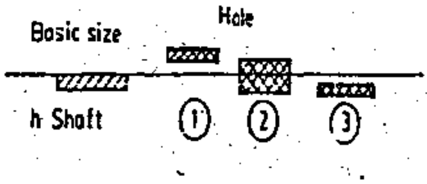


Fig.3.9

In mass production, use of this system will need large amount of capital and storage space for the large number of tools required to produce holes for of different sizes, because drills, reamers, broaches, punches, etc. can not be adjusted to vary the size. So this method is not preferred in mass production. This system is suitable when a long shaft of uniform diameter has to carry variety of accessories having different fits, Such as pulleys,gears bearings, coupling etc.

Q.7 Difference between -Hole basis system and shaft basis system.

Ans :

Hole Basis System	Shaft Basis System
1. Size of hole whose lower deviation (fundamental deviation) is zero (H-hole) is assumed as the basic size.	1. Size of shaft whose upper deviation (fundamental deviation) is zero (h-shaft) is assumed as the basis size.
2. Limits on the hole are kept constant and those of the shaft are varied to obtain desired type of fit.	2. Limits on the shaft are kept constant and those on hole are varied to have necessary fit.
3. System is preferred in mass production because it is easy, convenient and less costly to make a hole correct size.	3. System is not suitable in mass production because it is inconvenient and costly to make a shaft of correct size.
4. It is much easy to vary the shaft sizes according to the fit required.	4. It is rather difficult to vary the hole sizes according to the fit required.
5. It requires less amount of capital and storage space for tools needed to produce shafts of different sizes.	5. It needs large amount of capital and storage space for large number of tools required to produce holes of different sizes.
6. Gauging of shafts can be easily and conveniently done with adjustable gap gauges.	6. Being internal measurement, gauging of holes can not be easily and conveniently done.

Q.8. Study the following figure and answer the following :-

i. Name the type of fit for assembly. ii. State the system of Tolerance.

iii. Name the system of Tolerance for Hole and shaft .

iv. Determine the values of maximum and minimum values of allowances.

Ans :

i. The size limits of hole and shaft are such that either clearance or interference may occur during assembly, so the type of fit assembly is transition fit.

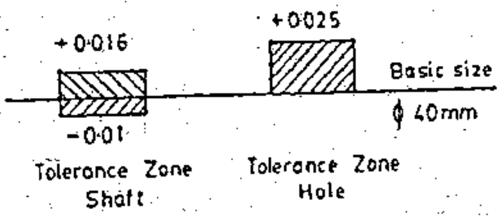


Fig.3.10

ii. The system of tolerance is Newall system because it is hole basis system.

iii. System of tolerance for Hole is unilateral system and for the shaft it is bilateral system.

iv. Maximum clearance or positive allowance = Maximum size of hole-minimum size of shaft = 0.035 mm.

Maximum interference or negative allowance = Minimum size of hole-maximum size of shaft = 0.016 mm.

Maximum and minimum allowance are 0.035 mm and 0.016 mm respectively.

Q.9. Study the given Fig.3.11 and answer the following.

i. Redraw the given fig. proportionately and name the portions indicted by A to K

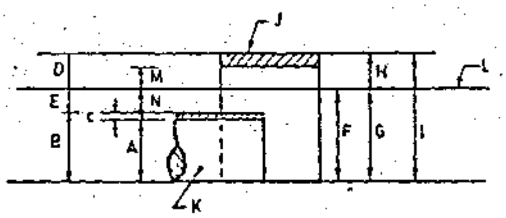


Fig.3.11

ii. Find the magnitudes of Lower and Upper deviation.

iii. Find the magnitude of maximum allowance.

iv. What type of fit it is?

Ans :

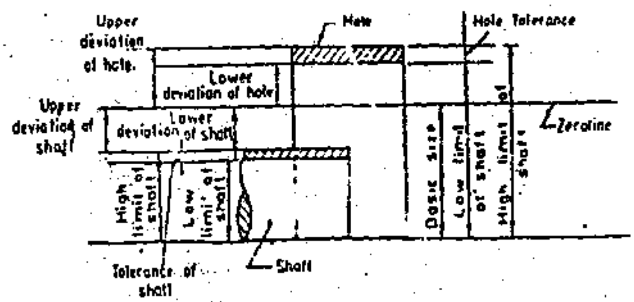


Fig.3.12

Q.10. What is Interchangebility ? State its advantages.

Ans : In old days producion was confined to small number of parts. The same worker used produce the parts and assemble them to obtain necessary fits. But modern trend is towar mass production in which parts are made by different workers in different plants and assembled n one shop. Under such conditions,the dimensions of the various mating parts must strictly lie within certain variations so that any one part selected randomly will assemble correctly with any other mating part that too chosen randomly. Such system is called interchangeable system or system of limits and fits.

Interchangeability is possilbe only when certain standards are strictly followed in various manufacturing units. For universal interchangeability, international standards should be followed. When all the parts to be assembled are manufactured in a single unit, local standards may be ollowed.

Advantages :

i. Production is increased considerably.
ii. Results in reduced production cost.
iii. Simplifies replacement and repairs of worn out or defective parts, so maintenance cost is very much reduced.
iv. A worker is concerned with limited work, so he can easily specialise himself in that work. This results in superior quality of work.
v. Assembly time is reduced considerably, so production rate is increased.
vi. Different components can be manufactured in different parts of the country, depending upon the availability of raw material, skilled labour and other facilities. This reduces cost of production considerably.

Q.11. Write short note on - Selective assembly.

Ans : In selective assembly, the parts of any one type are classfied into several groups ccording to size. The mating parts are also classified into same number of groups, so that the orresponding groups, when assembled will give the desired fit at assembly with little or no urther machining. In this method the parts are manufactured to rather wider tolerances and hen seperated into number of groups according to their actual sizes. Assembly is then made rom the selected groups. Selective assembly results in reduced cost of production without ffecting the quality of the product. It is often followed in air craft, automobile industires and n ball and roller bearing industries.

Q.12. How holes, shafts and fits are designed ?

Ans : To describe completely a hole or a shaft, its basic size followed by appropriate letter nd the number of tolerance grade is given. a hole is designated by capital letter while shaft y small letter. e.g. 20 mm H-hole with tolerance grade IT7 is designgated as 20 H7 and 0mm "g'-shaft with tolerance grade IT7 is designated as 20g7.

A fit is indicated by its basic size followed by appropriate letter and the nuber of tolerance rade is given, a hole is designated by capital letter while shaft by small letter. e.g.20 mm H-ole with tolerance grade IT7 is designated as 20 H7 and 20mm "g" shaft with tolerance rade IT7 is designated as 20g7.

A fit is indicated by its basic size, followed by symbols representing the limits of each o[f] two components, the hole being quoted first.

$$20\,H_7g_7 \quad \text{or} \quad 20\frac{H_7}{g_7}$$

Q.13. Interpret the meanings of the following fits :

H_7f_6, H_7h_7, H_7r_6, H_7v_5.

Ans :

i. H_7f_6 : H_7 is the basic hole with tolerance grade IT7. f_6 is shaft with tolerance gr[ade] IT6. This shaft gives clearance fit with basic hole H_7. It gives normal running fit and is wi[dely] used for grease or oil lubricated bearings such as gear box shaft bearings, small electric m[otor] bearings, pump bearings, etc. This system is hole basis system.

ii. H_7h_7 : This is hole basis system. With hole H_7, shaft h_7 gives a clearance fit whic[h is] suitable for non-running parts. e.g. for spigot and location fits.

iii. $H7r_6$: This is also hole basis system. With basic hole H_7, shaft r_6 gives interferenc[e fit.] It produces medium drive fit on ferrous parts and light drive fit on non-ferrous parts which [can] be easily dismantled.

iv. H_7v_5 : H_7 is the basic hole. v_5 is shaft with tolerance grade IT5. This shaft gives la[rge] interference fit with basic hole H_7 and not recommended for use.

Q.14. What are limit gauges ? sketch any two types of limit gauges.

Ans : Manufactured parts must be checked to determine whether they lie between the gi[ven] limits of size. In mass production it will be very time consuming to measure the dimensio[n of] each part, therefore instead of measuring actual dimensions of each part, the conforman[ce of] part with tolerance specification can be checked by gauges. Gauges are scaleless inspec[tion] tools of rigid design, that are used to check dimensions, form and relative positions o[f] surfaces of parts. They do not determine the actual size of part, but define whether deviations in the actual size or dimensions of part are within the specified limits. They ch[eck] whether a part lies between the two limits of its size, so they consist of two sizes correspon[ding] to their maximum and minimum limits.

Limit gauges are widely used in engineering beacause they are easy to use, requir[e no] adjustment in their use and no claculations are required to be made for determinging variations in size.

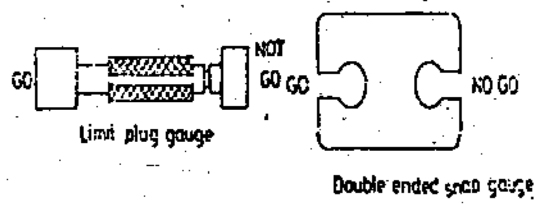


Fig. 3. 13

Q.15. Explain the principles of GO and NO-GO gagues.

Ans : For checking the dimension of work piece, limit gauges usually have two working sizes; one corresponds to the low limit size and other to the high limit size of that dimension. These are known as GO and NO-GO gauges. The difference between the sizes of these two gauges is equal to the tolerance on the work piece. GO gauge checks the minimum metal condition of the work piece. In case of hole, GO gauge corresponds to the low limit size, while NO-GO gague corresponds to the high limit size. For shaft GO gauge corresponds to the low limit size. A part is considered to be good, if the GO gauge enters it and NO-GO gauge fails to enter it under the action of its mass. This indicates that the actual dimensions of the part are within the specified tolerance. If both the gauges fail to enter, it indicates that hole is under size or shaft is over size. If both the gauges enter, it shows that hole is over size or shaft is under size.

Q.16. What is Taylor's principle as applied to design of limit gauges ?

Ans : It states that GO gauges should be of full form i.e. they should check shape as well as size of part, whereas NO-GO gague should check only one dimension of the part. As GO gauge assembles with the mating component it should check number of dimensions, including errors of form such as straightness, roundness, squareness etc.which are outside the maximum metal limit. NO-GO gauge, on the other hand should check only one dimension of part at a time in order to find out any dimension which is outside the minimum metal limit.

To illustrate the principle consider a part having a rectangular hole. If a pin gauge for length and width,made to the lower limits of their respective dimensions is used, it will enter into the hole and thereby indicate that the hole is satisfactory,although the corners may not be square. It is therefore, necessary for Go gauge to be rectangular plate i.e. geometrical equivalent of mating part or full form gauge. However, if NO-GO gauge is of full form, it will not enter the part, even if only one dimension of the part is correct. Thus if gauge is of rectangular shape made to upper limits of their respective dimensions (width and length), it will not enter the hole even if only width is correct and length is excessive or length is correct and width is excessive. NO-GO gaguge must, therefore, consist of two seperate pin gauges, one for length and other for width.

Q.17. What is gauge maker's tolerance ?

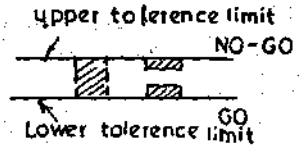
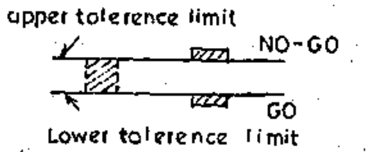
Ans : In pratice gauges can not be manufactured to exact size. The closer the limits are held, the more expensive the gauge is. Also some variations in size can not be eliminated due to imperfections in the process or skill of worker. Some allowance must, therefore,be given to gauge maker for manufacturing gauges. This is known as Gauge maker's tolerence or Gauge allowance. Logically the gauge tolerence should be kept as small as possilbe, but this will increase the cost of manufacturing the gauges. Limit gauges are generally provided with gauge allowance of 1/10th of work tolerance.

Q.18. State why and how wear allowances are considered in gauge design.

Ans : As soon as gauge is put into service, its measuring surfaces rub constantly against the surfaces of the work piece. This results in the wearing of the measuring surfaces of gauge. The gauge loses it's initial dimensions. The size of GO plug gauge is reduced and that of ring or gap gauge is increaed. Hence a wear allowance is provided to the gauges in the directioin opposite to that of the wear. In case of GO plug gauge, wear allowance is added, while in ring or gap gauge it is substrated.

Q.19. Differentiate between i) Workshop gauges and Inspection gauges. ii) GO thread plug gauge and NO-GO thread plug gauge.

Ans :

Workshop gauges	**Inspection gauges**
1. These gauges are used during manufacture of parts in shops.	1. These gauges are used for final inspection of parts.
2.  tolerence on workshop gauges are arranged to fall inside the work tolerence.	2.  The tolerence on inspection gauges are arranged to fall outside the work tolerance.
3. Parts which are in work tolerence limits may be rejected when tested by workshop gauges.	3. Parts that are not in work tolerence may be accepted when tested by inspection gauges.
GO thread plug gauge	**NO-GO thread plug gauge.**
1. It is full form and is made to the minimum effective diameter of screw thread.	1. It is made to maximum effective diameter of screw thread.
2. It checks virtual effective diameter, errors in pitch or flank angles of thread.	2. It checks maximum effective diameter of thread.
3. Tolerences on these gauges are arranged within the work tolerance.	3. Tolerence on these gauges are arranged outside the work tolerence.

Q.20. Draw a neat sketch of double ended snap gauge and indicate on it various identification marks. State in which measurement it is used.

Ans : Snap gauges are suitable for gauging both cylindrical as well as non-cylindrical work. Double -ended snap gauges are used for checking sizes in the range of 3mm to 100mm.

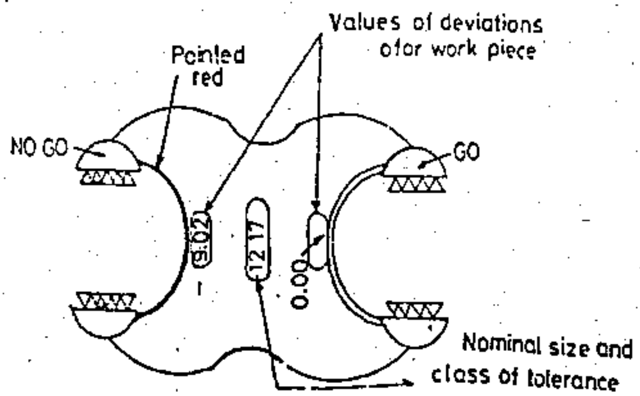


Fig. 3. 14

Q.21. Discuss briefly the use of limit gauges to control the size of parts on shop floor.

Ans : In mass production, where large number of parts are to be manufactured, it is not possible to make all the parts alike and to exact dimensions. Also, no method is available for absolutely accurate masurements of the dimensions of the meanufactured parts. Therefore, without affecting the functional quality of parts, small size errors are allowed in their dimensions. These are called tolerances. Thus two permissible limits of sizes of the part are specified. The actual size of the part must lie within these limits. The limits of sizes of parts are so selected that a satisfactory functioning is assured on assembly. In shops, the manufactured parts must be checked to determine whether they lie between the specified limits of size. In mass production, it is very time consuming to measure the dimensions of each part; therefore, instead of measuring actual dimensions of each part,the conformance of part with tolerence speciations can be checked easily and rapidly by limit gauges. The gauges not only check the dimensions of part,but also check the form of the part and relative position of the surfaces.

Consider a cylindercal male part. In addition to checking the sizes of the part, ring and gap gauges can detect errors such as lobing, raised imperfections, bending, drunkenness (i.e. waved centre line) barreling, indented imperfections, etc. To check the sizes of cylindrical holes and errors in their forms double ended plug gauge or progressive type plug gauge can be effectively used. The various elements of screw thread can be easily and rapidly checked by screw thread gauges.

Thus we see that, though limit gauges do not determine actual size of the manufactured parts, they can conveniently and rapidly determine the errors in the permissible sizes and forms of the manufactured parts; so they are extensively used in workshops and for inspection purposes.

Q.22. Sketch a progressive type of "GO' and "NO-GO' plug gague suitable for 25H, hole. Wear and manufacturing allowances need not be considered. For 25H hole fundamental deviation is zero and IT7 is 21 microns.

b. State one advantage and one disadvantage of this type of gauge when comparted to double-ended plug gauge.

c. How can you identify the GO and NO-GO ends of double-ended plug gauges?

Ans :

a. Fundamental deviation of the hole (i.e. lower deviation) = 0

IT7 = 21 microns.

$\therefore$ Upper deviation $= 21 \times 10^{-3} = 0.021$ mm

$\therefore$ Limits of $25H_7 = 25^{+0.021}_{+0.00}$

Lower limit of hole = 25 mm and upper or high limit of hole = 25.021 mm.

$\therefore$ Since wear and manufacturing allowancs are not to be considered, size of GO gauges = 25 mm and size of NO-GO gauge = 25.021 mm

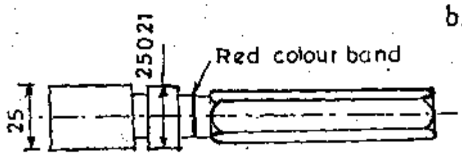


Fig.3.15

b. Advantage of progressive type gauge is that, as the gauge is not to be reversed each time gauging is done more rapidly. Disadvantage is that it can not be used for checking shallow blind holes such as recesses.

c. NO-GO portion of double ended gauge is made shorter than GO portion and also it is painted with red colour band.

Q.23. Design the "Workshop', "Inspection' and "General' types of GO and NO-GO plug gauges for checking the hole of $\phi\ 30^{-0.03}$ Assume each of the wear alowance and gauge allowance as 10% of work tolerance.

Ans : Low limit of hole = 30 - 0.33 = 29.97 mm.

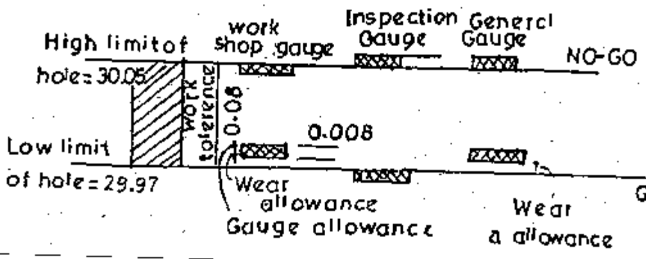
High limit of hole = 30 + 0.05 = 30.05

Work toerance = 0.08

Gauge tolerance = wear allowance = 10% of work tolerence.

= 0.1 x 0.08

= 0.008 mm.



i. Workshop gauge :

Upper limit of GO gauge $= 29.97 + 0.008 + 0.008$
$= 29.986\ mm = 30 - 0.014$

Lower limit of NO-GO gauge $= 29.97 + 0.008 = 29.978\ mm$
$= 30 - 0.022$

$\therefore$ Limits of GO gauges $= 30^{-0.014}_{-0.022}$

Upper limit of NO - GO gauge $= 30.05\ mm$

Lower limit of NO - GO gauge $= 30.05 - 0.008 = 30.042\ mm$

Limits of NO - GO gauge $= 30^{+0.005}_{+0.042}$

ii. Inspection gauge :

Limits of GO gauges $= 30^{-0.03}_{-0.03} - 0.008$
$= 30^{-0.030}_{-0.038}$

Limits of NO - GO gauges $= 30^{+0.058}_{+0.050}$

iii. General type of gauge :

Limits of GO gauge $= 30^{-0.14}_{-0.022}$

Limits of NO - GO gauge $= 30^{+0.058}_{+0.050}$

.24. Design the general type GO and NO-GO gauge for components having 20H,f_8 fit, Given:

1. **i (micron) = 0.45 $\sqrt[3]{D}$ + 0.001D (where D in mm)**
2. **Upper deviation of ' f ' shaft = $-5.5\ D^{0.41}$**
3. **20 mm falls in the dimcter step of 18mm to 30mm.**
4. **IT7 = 16i,** 5) **$IT_8 = 25$ i**
6. **Wear allowance 10% of gauge allowance.**

ns :

$D = \sqrt{18 \times 30} = 23.2379\ mm.$

$i = 0.45\ \sqrt[3]{23.2379} + 0.001 \times 23.2379$
$= 1.3074$ micron

$\therefore IT7 = 16i = 16 \times 1.3074 = 20.918$

$\therefore IT7 \simeq 21$ microns $= 0.021$ mms

$IT8 = 25i = 25 \times 1.3074 \simeq 33$ microns
$= 0.033mm$

ndamental or upper deviation of shaft :

$= -5.5\ (23.2379)^{0.41}$

$\simeq -20$ microns $= -0.02$ mm

Fundamental or lower deviation of H-hole = 0

$$\text{Limits for 20H7} = 20^{+0.021}_{+0.000}$$

$$\text{and Limits for } f_8 = 20^{-0.02}_{-0.02-0.033} = 20^{-0.02}_{-0.053}$$

Gauge tolerence for hole gauging = 10% work tolerence
= 0.1 x 0.021 mm
= 0.0021 mm

∴ Wear allowance on this gauge = 10% of gauge tolerence
= 0.1 x 0.0021
= 0.00021mm.

Gauge tolerence for shaft gauging = 0.1 x 0.033
= 0.0033 mm.

Wear alloance on this gauge = 0.1 x 0.0033
= 0.00033 mm.

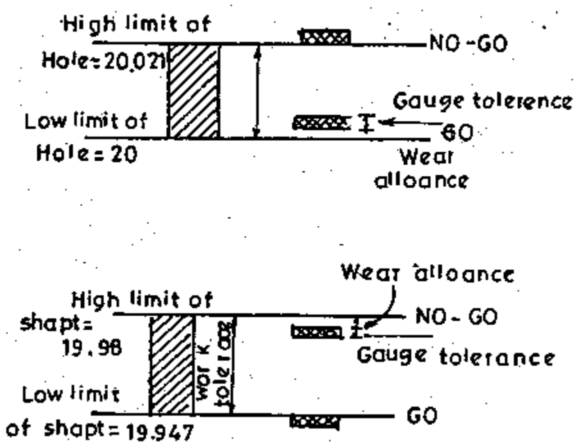


Fig. 3.17

For hole :

Upper limit of GO gauge = 20 + 0.00021 + 0.0021
= 20.00231mm.

Lower limit of GO gauge = 20 + 0.00021 = 20.00021mm.

$$\therefore \text{ Limits of No - GO gauge} = 20^{+0.00231}_{+0.0021}$$

Upper limit of NO-GO gauge = 20.021 + 0.0021
= 20.0231mm.

Lower limits of NO-GO gauge = 20.021 mm

$$\therefore \text{ Limits of No - GO gauge} = 20^{+0.0231}_{+0.0210}$$

For shaft :

$$\text{Limits of GO gauge} = 19.947^{-0.000}_{-0.0033} = 20^{-0.0530}_{-0.0563}$$

$$\text{Limits of No - GO gauge} = 19.98^{-0.00033}_{-0.00033\ -0.0033}$$

$$= 20^{-0.02033}_{-0.02363}$$

Q.25. Distinguish between precision instruments and gauges.

Ans:

Precision instruments	Gauges
1. These are measuring tools carrying calibrated scales.	1. These are inspection tools without scales.
2. These are used to measure the actual dimensions of parts.	2. These are used to determine whether the dimensions of part are within the specified limits.
3. Measurement by precision instruments is time consuming, so they are not suitable for mass production.	3. Measurement by gauges is easy and rapid, so they are suitable in mass production.
4. These instruments are required to be handled by skilled workers.	4. The gauges can be easily handled by unskilled worker.
5. Use of the precision instruments in mass produciton results in increased cost of part.	5. Use of gauges results in reduced production cost.

Q.26 Draw neat sketches of the various types of Limit Plug Gauges.

Ans. Types of Plug Gauges

1. Solid Type : For sizes up to 10 mm.

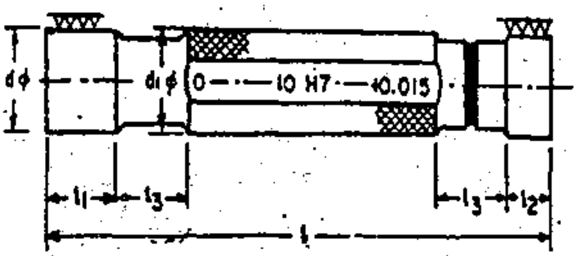


Fig. 3.18 Solid Type double-ended plain plug gauge (Reproduced from IS : 3484)

2. Renewable Type (Taper Inserted Type : For sizes over 10 mm and up to 30 mm.

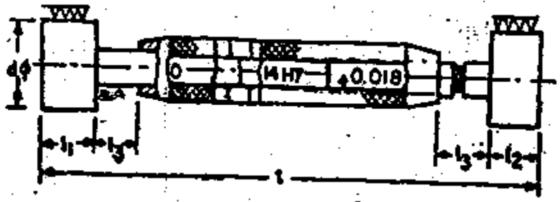


Fig. 3.19 Inserted Type Plain Plug Gauge (Reproduced from IS : 3484)

3. Fastened Type :

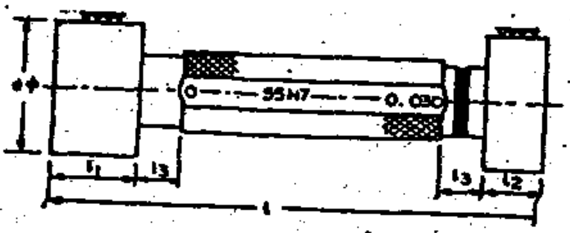


Fig. 3.20 Fastened type plain plug gauge (Reproduced from IS : 3484)

(a) Double-ended : For sizes over 30 mm and up to 63 mm.
(b) Single-ended : For sizes over 63 mm and up to 100 mm. (Fig. 3.21).

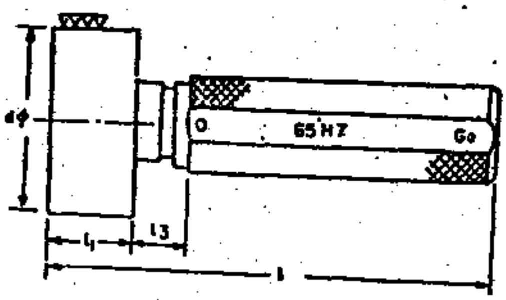


Fig.3.21 Single Ended

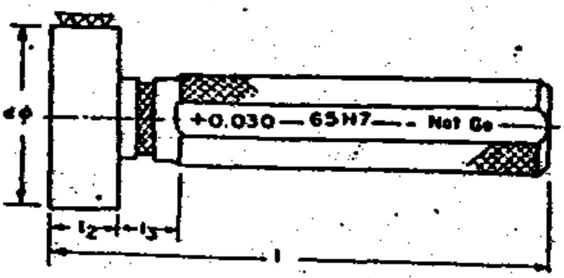


Fig. 3.21 Fastened type Go and Not-Go plug single ended gauges (Reproduced from IS : 3484)

) Progressive form of plug gauge

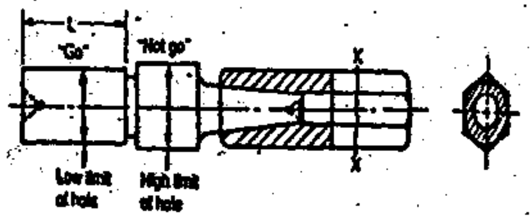


Fig. 3.22 A progressive form of plug gauge in which L = Length of component + 3.2 mm

) Flat Type : For sizes over 100 mm and up to 250 mm.

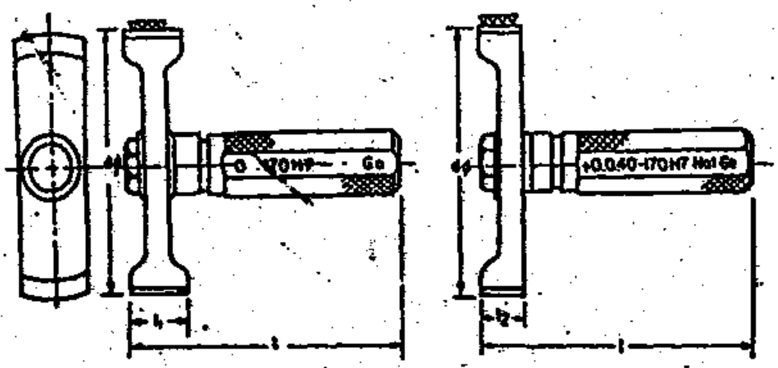


Fig. 3.23 Flat type Go and Not-Go plug single ended gauges (Reproduced from IS:3484)

Renewable end type plug gauges

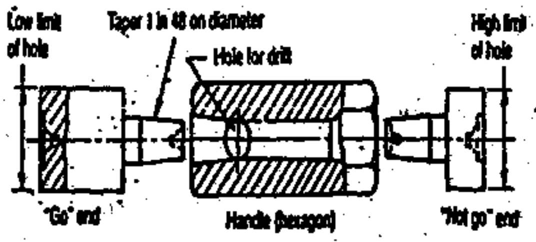


Fig. 3.24 Renewable End Type

Chapter 4

ANGULAR MEASUREMENTS

Q.1. Name the various instruments used for measurement of angles.

Ans : The various instruments used for measurement of angles are as follows :-

Bevel protractor, sine bar, angle gauges, spirit level, clinometer, auto-collimator, angle dekkor, etc.

Q.2. What is sine bar? How is it used for angle measurement ?

Ans : Sine bar is a precision instrument used along with slip gauges for accurate angle measurments or angle setting. It consists of a steel bar and two rollers. The bar is made of high carbon, hgh chromium corrosion resistant steel, suitably hardened stabilised and precision ground. The rollers are of accurate and equal diameters. They are attached to the bar at each end. The axes of the rollers are parallel to each other and also to the upper surface of the bar. The nominal distance between the axes is exactly, 100m, 200mm or 300mm. When the rollers are brought in contact with a flat surface, the top of the bar is parallel to the surface. All the working faces of the bar and cylindrical surfaces of rollers have surface finish of 0.2 μm Ra value or better.

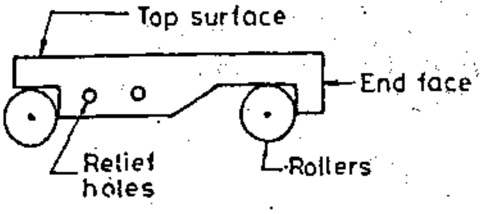


Fig. 4.1

The use of sine bar is based on the laws of geometry and trignometry. To set a given angle, one roller of the bar is placed on the surface plate and combination of slips gauges is inserted under the second roller. If "h" is the height of the combination of slip gauges and "L" the distance between the roller centres. Then,

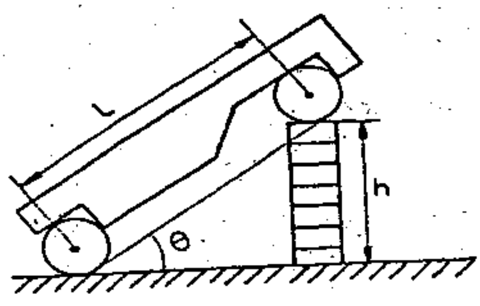


Fig.4.2

$$\sin\theta = \frac{h}{L} \quad \text{or} \quad \theta = \sin^{-1}\left(\frac{h}{L}\right)$$

Thus the angle to the measured or to be set is determined by indirect method as a function of sine : for this reason, the device used is called sine bar.

Q.3. Explain how sine bar is used to measure angle of a component.

Ans : i. When component is of small size :

For checking the angle of a component of small size, a sine bar is set up at nominal (approximate) angle on a surface plate by suitable combination of slip gauges. The component to be checked is placed over the surface of the sine bar as shown in fig. 4.3 A dial gauge is carried in a surface gauge on the surface plate and is moved along the upper surface of the component. If there is variation in parallelism of the upper surface of the component and the surfce plate, it is indicated by the dial gauges. The combination of the slip gauges is so adjusted that the upper surface of the component is truly parallel with the surface plate.

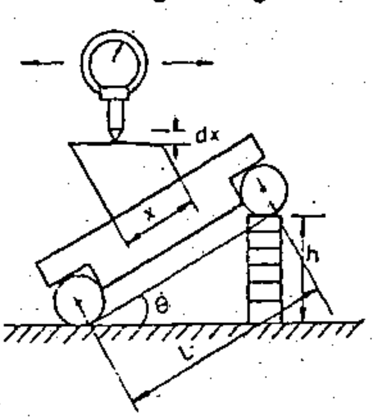


Fig. 4.3

The angle of the component, $\theta = \sin^{-1}\left(\frac{h}{L}\right)$

The perfect adjustement of slip gauge combination requires too much time, so the variation in the parallelism of the upper surface of the component and the surface plate indicated by the dial gauge is converted into corresponding angular variation. If "dx' is the variation in parallelism over a distance "x' the corresponding

variation in angle, " $d\theta = \sin^{-1}\left(\frac{dx}{x}\right)$

and the approximate or nominal angle, $\theta = \sin^{-1}\left(\frac{h}{L}\right)$

$\therefore$ Actual angle of the component = $\theta \pm d\theta$

$$\sin^{-1}\left(\frac{h}{L}\right) \pm = \sin^{-1}\left(\frac{dx}{x}\right)$$

ii. When component size is large :- The component is placed over a surface plate. The sine bar is placed over the component as shown in fig 4.4(a). The heights over the rollers are measured by means of a vernier height gauge. A dial gague is used to check the measuring pressure. If "h' is the difference in the heights and "L' distance between the roller centres of the sine bar, then , $\theta = \sin^{-1}\left(\frac{h}{L}\right)$

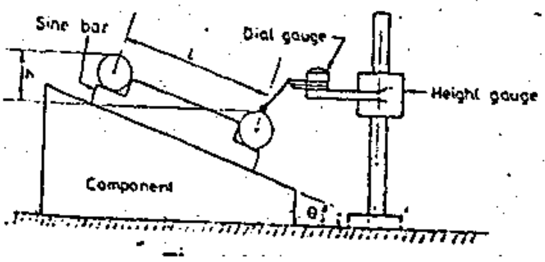


Fig. 4.4 (a)

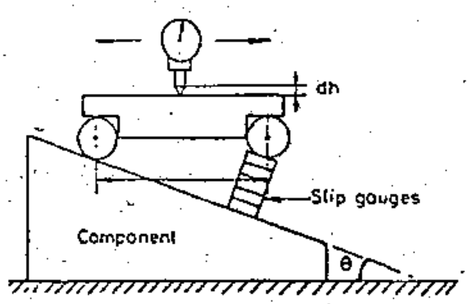


Fig. 4.4 (b)

Another method of determining angle of large sized part is shown in the fig. 4.4(b). The component is placed over a surface plate and sine bar is set up at approximate angle on the component so that its surface is nearly parallel to the surface plate. A dial gauge is moved along the top surface of the sine bar to note the variation in parallelism. If "h' is height of the combination of the slip gauges and "dh'. the variation in parallelism over distance "L' then ,

$$\theta = \sin^{-1}\left(\frac{h \pm dh}{L}\right)$$

Q.4. Explain why it is not preferred to use sine bar for measuring angles greater than 45°.

Ans : The accuracy of the angle set by a sine bar depends upon the errors in its important dimensions such as error in distance between roller centres,error in combination of slip gauges used for setting, error in parallelism between the gauging surface and plane of roller axes, etc.

The slip gauge combination (h) required to set an angle (θ) is given by

$h = L \sin\theta$

The effects of error in spacing of roller centres (dL) or error in combination of slip gauges(dh). on angular setting accuracy can be obtained by partial differentitation of the above equations.

$$h = L \sin\theta$$

$$\therefore \frac{dh}{d\theta} = \sin.\theta \frac{dL}{d\theta} + L\cos\theta$$

$$\therefore dh = \sin\theta\, dL + L\cos\theta \,.\, d\theta$$

$$\therefore d\theta = \frac{dh}{L\cos\theta} - \frac{\sin\theta \,.\, dL}{L\cos\theta}$$

$$= \tan\theta\left(\frac{dh}{L\sin\theta} - \frac{dL}{L}\right)$$

But, $L\sin\theta = h$

$$\therefore d\theta = \tan\theta\left(\frac{dh}{h} - \frac{dL}{L}\right)$$

From the above equation we can see that the effect of error in roller spacing or slip gauge combination is a function of tangent of angle θ . As the angle θ increases, the error (dθ) in the angular measurement increases and above 45° value it is more significant, because above 45° value of tan θ is greater than unity and increases progressively.

Q.5. State the features of sine bar which have toleranes for accuracy.

Ans : Following features of the sine bar have tolerance for accuracy.

1. Upper and lower surfaces : flatness and parallelism with respect to datum surface.
2. Side faces : Flatness, squareness to upper surface, squarencess to the axes of rollers.
3. End faces : Flatness, squarencess to upper surface, parallelism to the axes of rollers.
4. Rollers : Straightness, cylindrical accuracy (freedom from lobing, and taper,) mean diameter.
5. Roller axes : Centre distance, parallelism with each other, parallelism with upper surface.

Q.6. Name the various factors on which the accuracy of a sine bar depends.

Ans : The accuracy of a sine bar depends on the following factors.

1. Equality of size of rollers.
2. Cylindrical accuracy of rollers.
3. Centre distance of rollers.
4. Parallelism of roller axes with each other.
5. Parallelism of roller axes to upper surface of the sine bar.
6. Equality of distance from roller centres to the upper surface.
7. Flatness of upper surface of the bar.

Q.7. List the possible sources of errors in angular measurement by sine bar.

Ans : The different sources of errors in angular measurement by a sine bar are listed below :

1. Error in distance between roller centres.
2. Error in slip gauge combination used for angle setting.
3. Error in parallelism between the gauging surface and plane of roller axes.
4. Errors in equality of size of roller and cylindrical accuracy in the form of the rollers.
5. Error in parallelism of roller axes with each other.
6. Error on flatness of the upper surface of the bar.

Q.8. Draw a neat sketch to illustrate the use of a sine bar for measurement of taper pluge gauge and explain briefly.

OR

How you will measure the angle of a taper plug gauge with the help of a sine bar?

Ans : Fig. 4.5 illustrates the use of sine bar for measurement of angle of a taper plug gauge.

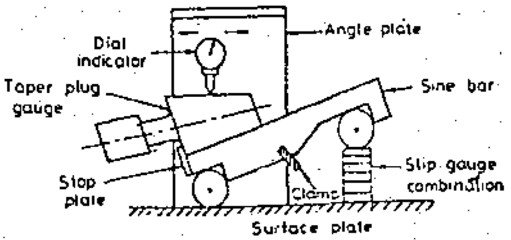


Fig.4.5

The sine bar is set up on a surface plate to the nominal angle of the taper plug gauge and clamped to an angle plate. Taper plug gauge is placed on the sine bar and prevented from sliding down by a stop plate. The axis of the taper plug gauge is aligned with the bar aixs. A dial gauge, supported in a stand is set at one end of the plug gauge and moved to the other end and the difference in the readings is noted.

Let "dx' be the difference in the readings of the dial gauge over a distance "X' Let "h' be the height of the combination of the slip gauges used and "L' .distance between the roller centres.

Then, nominal angle $\theta = \sin^{-1}\left(\frac{h}{L}\right)$ and variation in the angle,

$$d\theta = \sin^{-1}\left(\frac{h}{L}\right)$$

∴ Actual angle of the taper plug gaugue,

$$= \theta \pm d\theta = \sin^{-1}\left(\frac{h}{L}\right) \pm \sin^{-1}\left(\frac{dx}{x}\right)$$

Q.9. A 100 mm sine bar is to be set up to an angle of 33°. Determine the slip gauges needed from 87 piece set ?

Ans : Combination of slip gauges requried to set up an angle is given by,

$h = L \sin\theta$

Where L = distance between roller centres

= 100 mm

and θ = 33°

∴ $h = 100 \sin 33^\circ = 54.464$ mm

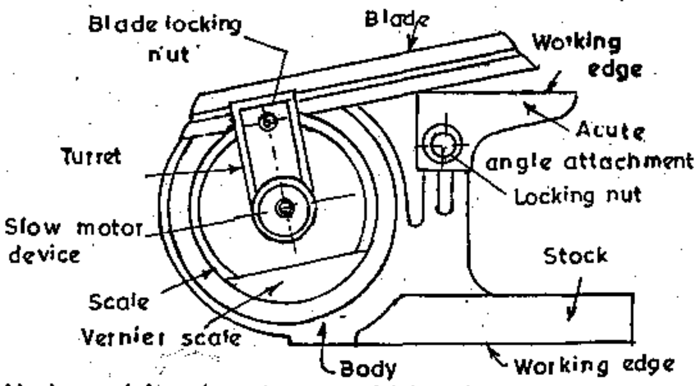
∴ The minimum number of slip gagues needed to build up 54.464 mm is as follows :-

1.004	-	one
1.460	-	one
2.000	-	one
50.000	-	one
54.464		four

Q.10 Write short notes on i) Vernier Bevel protractor ii) Angle gauges.

Ans : i. Vernier Bevel Protrator :- Bevel protractor is a simplest instrument for measuring angle between two faces of parts such as taper shafts bushing, etc. It has two arms, which can be set along the faces and a circular scale to indicate the angle between them. The accuracy of the instrument is increased by the addition of a vernier.

The body of the instrument is extended from one of the arms, known as a stock. The other arm is in the form of an adjustable blade.



Mechancal bovel protractor with Vernier and acute angle attacnment

Fig. 4.6

The working edge of the stock is about 90mm long and 7mm thick and as far as possible perfectly straight. The blade is about 150mm or 300mm long, 13mm wide and 2mm thick. Its ends are bevelled at angles of 45° and 60° within the accuracy of 5 minutes of arc. The blade rotates in a turret, mounted on the body and can be clamped in any position by a locking nut. Either the body or the turret carries a divided circle, (main scale) and other member carries a vernier or index. The least counts of vernier bevel protractor is 5 minutes.

2. Angle gauges :- In 1941, Dr. Tomlinson devised a set of angle gauges, which enables any angle to set to the nearest 3". These are pieces of hardened and stabilized steel The mesuring faces are lapped and polished to a high degree of accuracy and flatness. They are 75mm long and 16mm wide and are available in two sets. One set consists of 12 pieces and a square block, in three series of values of angle viz.

1°, 0°, 3°, 9°, 27°, and 41°
1', 3', 9' and 2' and
6", 18" and 30"

Another set contains 13 pieces and a square block
1°, 3°, 9°, 27° and 41°
1', 3', 9', 27' and
3", 6", 18" and 30"

Each angle gauge is accurate to within one second and is marked with engraved V which indicates the direction of the included angle. These gauges, together with square block can be so wrung that any angle between 0° to 360° can be set. This is possible because the gauges in combination can be added or substrated as required (refer fig.4.7).

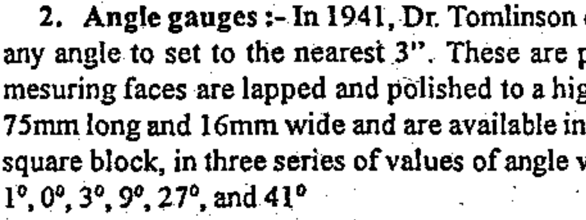
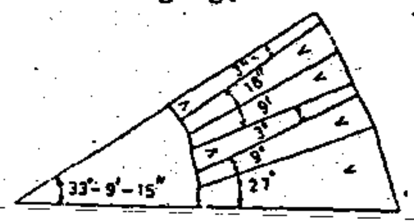


Fig. 4.7

These gauges are widely used in engineering industries for quick measurement of angles between two surfaces, to check angle tolerance of work pieces, etc. But the block formed by the combination of number of these gauges is rather bulky and can not always be conveniently applied to work, so they are used as reference along with other angle measuring devices.

Q.11. An angle of value 33°- 9' -15" is to be measured with the help of the following standard angle gauges (1°, 3°, 9°, 27°, 41°) ,(1', 3', 9', 27) ,(3", 6", 18", 30") Show the arrangements of angle gauges with a neat sketch by selecting minimum number of gauges.



Ans : Minimum number of angle gauges required to obtain the angle 33°, -9' -15" are as follows.

27° + 9 °-3' + 9' +18" - 3"

The combination of the above gauges is shown in fig.4.8

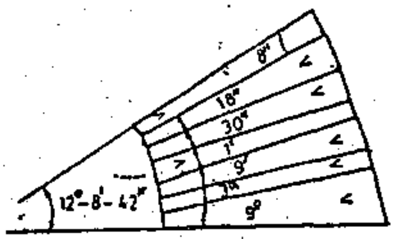


Fig. 4.9

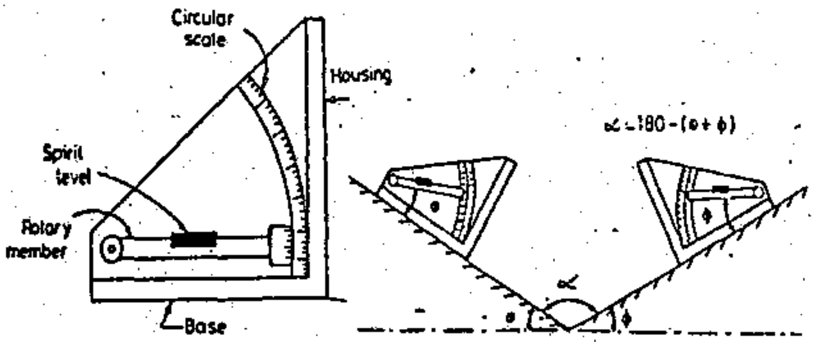
Q.12. An angle of value 102 ° - 8'- 42 " is to be measured with the help of standard 13 pieces set of angle, gauges and a square block, sketch the combination.

Ans : Angle being greater than 90°, it is measured with the help of square block. So angle to be set by angle gauges is equal to (102° - 8' - 42") - 90 = 12° - 8' - 42"

Combination of angle gauges required = 9° + 3° +9 '- 1' + 30" + 18" - 6".

Q.13. What is clinometer ? Describe how it can be used for measurements and setting ? Illustrate your answer with sketches ?

Ans : Clinometer is a spirit level mounted on a rotary member carried in a housing.



(a) Fig. 4.10 (b)

One face of the housing forms the base of the instrument. On the housing, there is a circular scale. The angle of inclination of the rotary member relative to the base can be measured by a circular scale. The scale may cover the whole circle or only part of it.(refer fig.4.10). (a)

Clinometers are generally used to determine the angle included between two adjacent faces of a work piece (refer fig.4.10 (b). The base of the instruments is placed on one of the surfaces and rotary member is adjusted till zero reading of the bubble is obtained. The angle of rotation is noted on the circular scale. The instrument is then palced on other surface and reading is taken in the same manner.

If θ and ϕ are the readings of the instrument, the included angle between the surfaces,

$$\alpha = 180 - (\theta \times \phi)$$

Clinometers are also used for checking angular faces and relief angles on large cutting tools, for setting tables of jig boring machine, grinding machine for angular work etc.

Q.14.Explain with the help of neat sketches principles and construction of an auto-colimator.

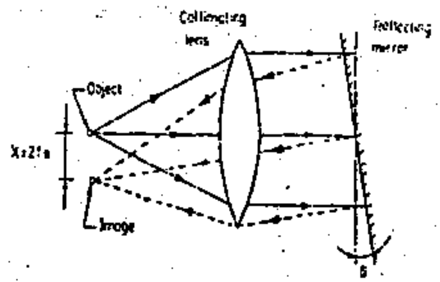


Fig.4.11 Principle of auto-collimator

Ans : Auto-colimator is an optical instrument used for the measurement of small angular differences, changes or deflection, plane surface inspection, etc. The principle of the instrument is explained below.

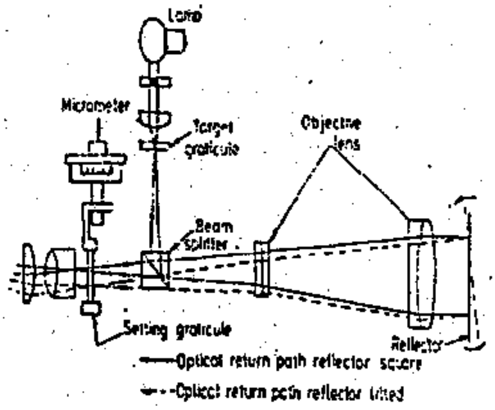


Fig.4.12 Principle of auto-collimator

Principle : If a light source is placed in the focus of a collimating lens, it is projected as a parallel beam of light. If this beam is made to strike a plane reflector, kept normal to the optical axis, it is reflected back along its own path and is brought to the same focus. If the reflector is titled through a small angle "θ", the parallel beam is deflected through twice that angle and is brought to a focus in the same plane as the light source, but to one side at a distance, $x = 2f\theta$

where f = focal length of lens

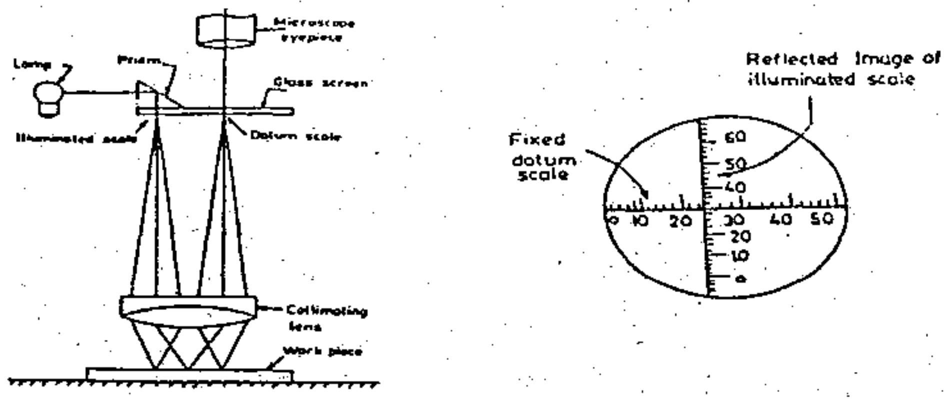
θ = angle of inclination of reflecting mirror.

Construction : In an auto-collimator there are three parts, viz. micrometer microscope, lighting unit and collimating lens. A line diagram of a modern auto-collimator (injected graticule auto-collimator) is shown in the Fig.5.12.

A 45° transparent beam splitter reflects the light from the graticule towards the objective (collimating) lenses. The image seen after reflection in the external reflector, whose angular variations are being measured is formed by the light from the objective lens. This light passes through the beam splitter and the image is picked up by the microscope. For simultaneous measurements in two planes at right angles a micrometer is fitted to the target graticule, optically at right angles to that on the eye piece graticule.

Q.15. Write short notes on :- (1) Angle dekkor. (2) Optical square.

Ans : 1. Angle dekkor : This is a type of auto-collimator. It consists of a microscope, objective (collimating) lens and two scales engraved on a glass screen which is placed in the



(a) Fig. 4.13 (b)

focal plane of the objective lense. One of the scales, called datum scale is horizontal and fixed. It is engraved across the centre of the screen and is always visible in the microscope eyepiece. Another scale is an illuminated vertical scale which in normal position is outside the view of the eye piece and only its reflected image is visible. When an image of the illuminated scale is received at right angles to the fixed scale vertical and horizontal angular displacements can be simultaneously measured.

The sensitivity of this instrument is lower than the other types of auto collimators. But it is widely used for general angular measurements. In combination with angle gauges it is used to measure angle of a component, for angular setting of machines,checking slope angles of V-block, to measure angle of taper gauges etc.

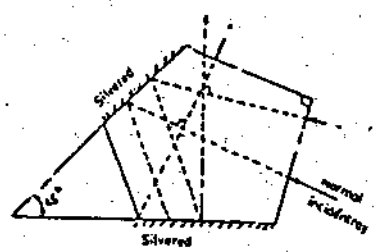


Fig. 4. 14

2. Optical square (penta prism) :- Sometimes it is not possible to align an auto-colimator to obtain a reflection from the surface to be tested. In such case an optical square is often used.

Optical square is a constant deviation five sided prism which reflects rays of light through the same angle irrespective of the angle of incidence. The two reflecting surfaces have a 45° included angle. In the general case of a contant deviation prism, the ray of light is deflected through twice the angle between the relfecting surfaces. So the angle of deflection 2 x 45° = 90°. The rays of light are, therefore, turned through 90° without necessarily setting the square precisely in relation to the light. The acutal angle is not exactly 90°, but the error is only a second or two. The deviation angle of the square is calibrated to the nearest second.

- When used with an auto-colimator, the optical square enables both the projected and reflected beam of rays to be turned through a right angle without precise setting of the square. This is useful in alignment tests involving two surfaces at right angles.

Q.16. Explain how angle of a workpiece or taper plug gauge is measured with the help of angle dekkor and angle gauges.

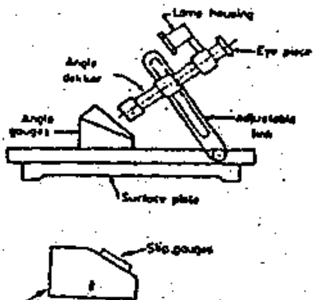


Fig. 4. 15

Ans : i. Measuring angle of a workpiece : To measure an angle of a component, first the angle gauges combination is set up to the nominal angle with 10' or 20'. Using special attachment and link, angle dekkor is set to receive the reflection and adjusted to obtain zero reading on the illuminated scale. The angle gauges are then removed and the workpiece under test is put in place. If the surface of the workpiece is not sufficiently polished, a slip gauge is placed in it to form a reflecting surface. Angle dekkor is again adjusted to receive the reflection. The new reading of the reflected scale w.r.t. the fixed scale gives the difference between the angle of the component is obtained by algebraic addition of the reading of the angle dekkor and the nominal angle set up by the angle gauges.

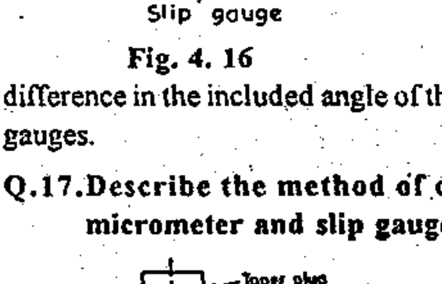


Fig. 4. 16

ii. Mesuring angle of a taper plug gauge : First the angle gauges combination is set up to the nominal angle of the taper gauge. The instrument is adjusted to receive the reflection and set to obtain zero reading on the illuminated scale. The angle gauges are removed and taper gauge is placed in that position. A slip gauge is held against the curved surface of the taper gauge. New reading of the instrument is noted. It indicates the difference in the included angle of the taper plug gauge and nominal angle set up by the angle gauges.

Q.17. Describe the method of checking the angle of a taper plug using rollers, micrometer and slip gauges.

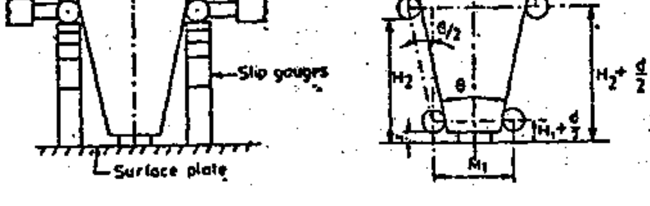


Fig. 4.17

Ans : Fig.4.17 shows the metod of checking the angle of **a taper plug using rollers, micrometer and slip gauges. Taper plug is placed on a** surface plate. First two rollers of equal diameters are placed touching on the opposite sides of the lower surface of the plug on the slip gauge combinations of equal heights (H_1). The distance (m_1) between the ends of the rollers is measured with micrometer. Then the rollers are placed on slip gauge combinations of heights (H_2) touching on the opposite sides of the top portion of the plug. The disatance

(M_2) between the ends of the roller in this new position is again measured by means of micrometer. The half the taper angle of the plug is then calculated as follows :-

If d = diameter of roller, then

$$\therefore \tan \theta/2 = \frac{\left[\frac{M_2 - d}{2} - \frac{M_1 - d}{2}\right]}{\left\{\left(H_2 + \frac{d}{2}\right) - \left(H_1 + \frac{d}{2}\right)\right\}}$$

$$\therefore \tan \theta/2 = \frac{M_2 - M_1}{2(H_2 - H_1)}$$

Q.18. While checking angle of piece tapered on one side with the help of two discs, slip gauges and dial indicator the following observations were obtained. :-
Diameter of larger disce = 25 mm Diameter of smaller disce = 15mm
The dial indicator shows no variation when traversed along the surface of the piece placed over the disc. Draw the sketch of the set up and find angle of taper.

Ans :

From triangle O_1AO_2

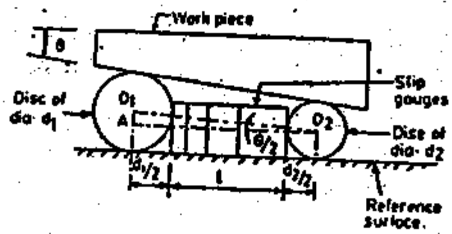


Fig.4.18

$$\therefore \tan \theta/2 = \frac{O_1A}{AO_2} = \frac{\frac{d_1}{2} - \frac{d_2}{2}}{l + \frac{d_1}{2} + \frac{d_2}{2}}$$

$$\therefore \tan \theta/2 = \frac{d_1 - d_2}{2l + d_1 + d_2}$$

But $d_1 = 25$ mm, $d_2 = 15$mm and $l = 40$mm.

$$= \frac{25 - 15}{80 + 25 + 15} \quad \theta/2 = 4.76364^0 \qquad \theta = 9.522728^0$$

Q.19. Calculate the angle of taper and minimum diameter of an internal taper from the following redings :
Diameter of bigger ball .... 10.25 mm.
Diameter of smaller ball .... 6.07mm.
Height of top of bigger ball from datum 30.13
Height of top smaller ball from datum- 10.08.

Ans :

$d_1 = 10.25$ mm, $d_2 = 6.07$mm, $h_1 = 30.13$mm, $h_2 = 10.08$ mm.

$$\sin \theta/2 = \frac{O_1A}{A_1O_2} = \frac{O_1A}{BD - O_1B - O_2D}$$

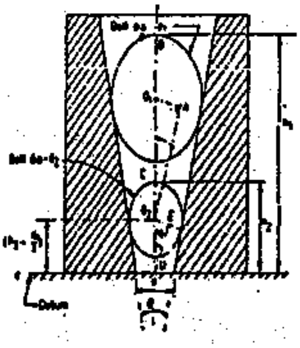


Fig.4.19

$$= \frac{\frac{d_1}{2} - \frac{d_2}{2}}{h_1 - \frac{d_1}{2} - \left(h_1 - \frac{d_2}{2}\right)}$$

$$= \frac{d_1 - d_2}{2\,h_1 - d_1 - 2\,h_2 + d_2}$$

$$\therefore \sin \theta/2 = \frac{d_1 - d_2}{2\,(h_1 - h_2) - (d_1 - d_2)}$$

$$= \frac{10.25 \quad 6.07}{2\,(30.13 - 10.08) - (10.25 - 6.07)}$$

$$= \frac{4.18}{35.92} \quad \therefore \theta/2 = 6.6826^0 \quad \therefore \theta = 13.3652^0$$

From triangle O_2DE

$$\sin \theta/2 = \frac{O_2E}{O_2D} = \frac{\frac{d_2}{2} - \frac{d}{2}}{h_2 - \frac{d_2}{2}} = \frac{d_2 - d}{2\,h_2 - d_2}$$

$$\sin 6.6826 = \frac{6.07 - d}{2 \times 10.08 - 6.07} \quad \therefore d = 4.43 \text{ mm}$$

Angle of taper = 13.3652°
and minimum diameter of taper = 4.43 mm.

Q.20 Describe with the help of neat sketches
1) Sine Centre 2) Sine Table

Ans. :

Sine Centre :

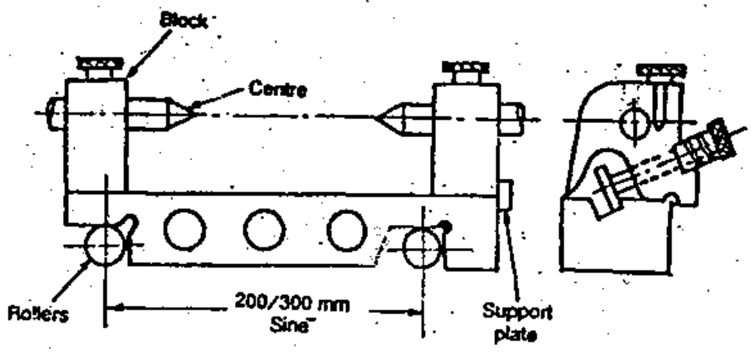


Fig. 4.20 Sine Centre

Due to difficulty of mounting conical work easily on a conventional sine bar, sine centres are used. Two blocks as shown in Fig. 4.20 are mounted on the top of sine bar. These blocks accomodate centres and can be clamped at any position on the sine bar. The centres can be also be adjusted depending on the length of the conical work piece, to be held between centres. Sine centres are extremely useful for the testing of conical work, since the centres ensure correct alignment of the work piece. The procedure for its setting is the same as that for sine bar.

Sine Table : The sine table is the most convenient and accurate design for hevy work piece. The equipment consists of a self-contained sine bar, hinged at one roller and mounted on its datum surface. The table is quite rigid one and the weight of unit and work-piece is given fuller and safer support. The table may be safely swing to any angle from 0 to 90° by pivoting it about its hinged end. Due to the work being held axially between centres, the angle of inclination will be half the included angle of the work. The use of sine centres and sine table provides a convenient method of measuring the angle of a taper plug gauge.

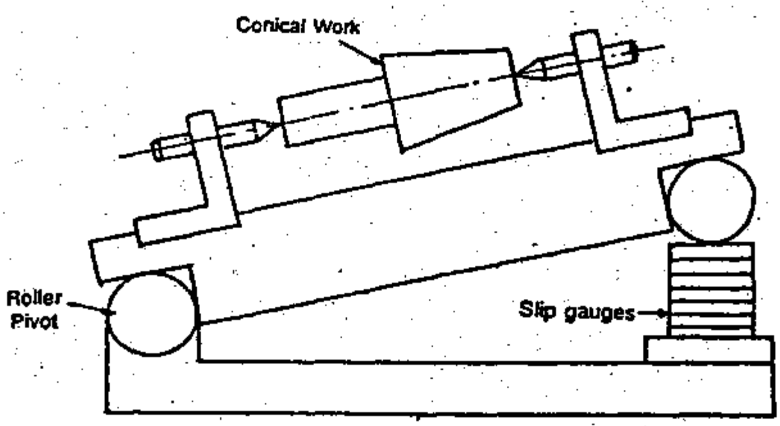
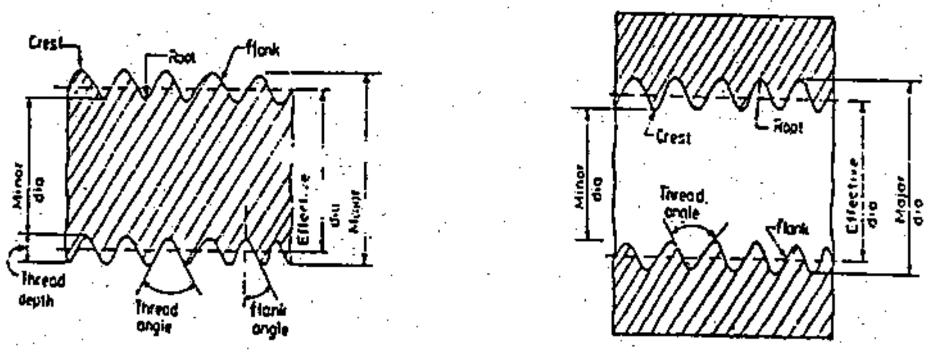


Fig. 4.21 Sine Table

Chapter 5

SCREW THREAD MEASUREMENT

Q.1. Define with neat sketches the basic nomenclature of parallel threads.
Ans :



(a) External thread **Fig.5.1** **(b) Internal thread**

Crest : It is the prominent part of thread i.e. top surface joining the two sides of thread.

Root : It is the bottom of the groove between the sides of two adjacent threads.

Flank : The straight surface between the crest and root of a thread.

Pitch : The distance measured parallel to the axis from a point on a thread to the corresponding point on the next (adjacent) thread.

Lead : The distance through which a screw thread advances axially in one complete revolution.

Depth of thread : The distance between the crest and the root of a thread measured perpendicular to the axis of the thread.

Thread angle : Angle included between the flanks or slopes of a thread, measured in an axial plane.

Flank angle : Angle made by the flank of a thread with the pependicular to the thread axis. It is equal to half the thread angle.

Minor diameter : (Core diameter or root diameter). It is the diameter of an imaginary co-axial cylinder which would touch the roots of an external thread or crests of an internal thread.

Major diameter : (External diameter) It is the diameter of an imaginary co-axial cyclinder. which would touch the crests of an external thread or roots of an internal thread.

Effective Diameter : (Pitch diameter) :- It is the diameter of an imaginary co-axial cylinder which intersects the flanks of the threads such that the widths of the threads (metal) and widths of the spaces between the threads are equal; each being half the pitch.

Q.2. What are the various characteristics that you would measure in a screw thread? Also list the instruments appratus that are required for this.

Ans : The various characteristics or elements that are required to be measured in a screw thread and the instruments or appratus used for the measurement are listed below.

External thread mesurement :

i. **Major diameter :** Ordinary micrometer or Bench micrometer.
ii. **Minor diameter :** Two V-pieces and a floating carriage diameter measuring machine or optical projector or microscope.
iii. **Simple effective diameter :** Thread micrometers, or Ball-point micrometers or wires (rods) with a micrometer.
iv. **Pitch :** Pitch measuring machine or screw pitch or profile gauge or microscope.
v. **Thread angle and form :** Either a microscope or an optical projector.

Internal thread measurement :

i. **Minor diameter :** Using taper parallels, using rollers or by thread mesuring machines.
ii. **Effective diameter :** Using screw thread micrometer, using measuring machines or comparator or using cast of the thread.
iii. **Major diameter :** Using cast of the thread. Once a cast is made, major diameter can be determined by using microscope or optical projector.
iv. **Pitch :** Screw pitch or profile gauge, microscope or pitch measuring machine.
v. **Thread angle and Form :** Using cast of thread. Once a cast is made either a microscope or an optical projector.

Q.3. Descirbe any one method of checking major diameter of an external straight thread.

Ans : A good quality hand micrometer can be used to measure major diameter of external threads, but it has deficiences like variation in measuring pressure, pitch errors in its threads, etc. Therefore for greater accuracy and covenience a bench micrometer is preferred. This instrument was designed by N.P.L.

In place of fixed anvil fiducial indicator is used. This ensures constant pressure for all the measurement. The instrument has a micrometer head with a vernier scale to read to the accuracy of 0.002 mm. It is used as comparator in order to avoid pitch errors of micrometer threads,

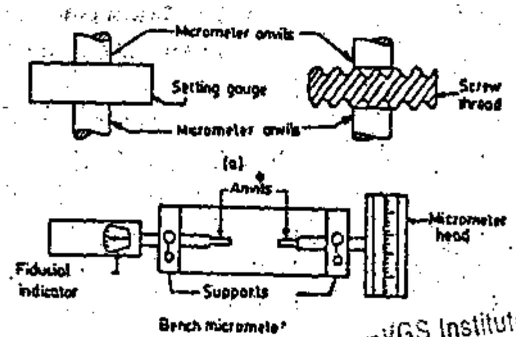


Fig.5.2 (b)

zero error setting,etc. A calibrated setting cylinder having nearly same diameter as the major diameter of the thread to be mesured is used as setting stadard. The setting cylinder is held between the anvils and reading is taken. The cylinder is then replaced by the threaded workpiece and again the micrometer reading is noted for the same reading of the fiducial indicator.

If D = diameter of the setting cylinder.
R1 = reading of micrometer on setting cylinder.
R2 = reading of micrometer on screw thread.

then major diameter of screw threaded = $D \pm (R_2 - R_1)$

Measurement is taken at two or three positions to determine the amount of taper and also at one plane in different angular positions to detect ovality.

Q.4. Briefly give the procedure for measuring accurately the minor diameter of a "V' screw thread. Name the instrument used. Illustrate your answer with suitable sketch.

Ans : Minor diameter of a V- screw thread is measured by comparative method using floating carriage diameter measuring machine and two small V-pieces. Which make contact with the root of the thread.

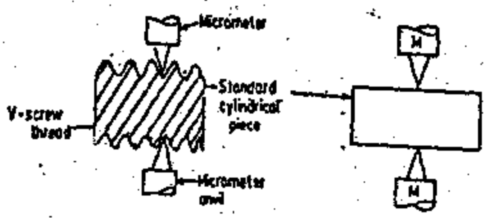


Fig.5.3

V-pieces are made of hardended steel. Their ends have radius less than the root radius and included angle less than the thread angle. Floating carriage diameter measuring machine is a bench micrometer mounted on a carriage which is confined to move at right angles to the axis of the centre by a V-ball slide.

The threaded workpiece is mounted between the centres of the instrument. The V-pieces are placed on each side of the workpiece with their bases against the anvils of the micrometer is noted. The threaded workpiece is replaced by a standard reference disc or a plain cylindrical standard gauge of diameter approximately equal to the minor (core) diameter of the screw to be measured and second reading of the micrometer is taken for the same fiducial reading.

If R1 = micrometer reading on standard cylinder.
R2 = micrometer reading on threaded workpiece.
D = diameter of the setting (standard) cylinder.

then minor diameter of thread = $D \pm (R_2 - R_1)$

To detect the taper and ovality, readings at various positions are taken.

If the threads are very sharp or have no radius at the root, the measurement of minor diameter is done by projecting the thread form on a screen and comparing it with standards or making use of microscope.

Q.5. How the effective diameter of a screw thread is measured ?

Ans : Effective or pitch diameter of a thread can be measured by using (i) thread micrometer or (ii) Wires or rods.

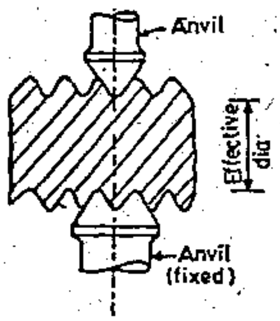


Fig.5.4

i. Thread micrometer method : This method is simple and rapid. For measuring effective diameter, a thread micrometer is used. This micrometer is similar to ordinary micrometer except that it has anvils having special contour to suit the end screw thread form to be checked.

Micrometer anvils are first fitted into each other and reading is taken. The anvils are then made to contact the thread to be checked and second reading is taken. The difference between the two readings is the effective diameter of the thread. In this method, actually the measurement is in between the major diameter on one side and minor diameter on the other side which gives the effective diameter. For more accuray a setting gague is used.

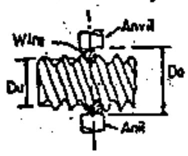


Fig.5.5(a)
Two wire method

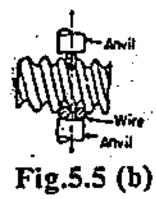


Fig.5.5 (b)
Three wire method

ii. Using wires or rods : This is the most common method of measuring pitch or effective diameter of thread. The method uses two or three small diameter (rods) and a floating carriage diameter measuring machine. The wires are made of hardended steel and have high degree of accuracy and finish.

Wires (rods) of same diameter are placed in the V-grooves on the opposite sides of the thread. Then the distance over or under the wires is measured accurately on floating carriage diameter measuring machine. The wires may be either held in hand or secured in the grooves using grease or may be hung through threads on a stand.

If D_0 = distance over the wires.

D_u = distance under the wires,

p = pitch of thread, d = wire diameter and 2θ = thread angle.

Then,

effective diameter $D_e = D_u + p = D_o - C$

Where P and C are constants. Their values depend on wire diameter, pitch and thread angle.

$$P = \frac{P}{2}\cot\theta - d(\operatorname{cosec}\theta - 1)$$

$= 0.86\,p - d$ ----- for I.S.O. metric thread

$= 0.9605\,p - 1.1657d$ ---- for Whitworth thread

$C = 2d - p$

Q.6. How the major diameter of an internal thread is measured ?

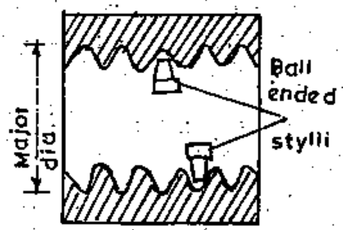


Fig.5.6

Ans : The major diameter of internal thread is usually measured with a thread comparator fitted with ball ended stylii of radius less than the radius of the root of the thread to be mesured. One of the stylii is attached to a floating head which is kept in contact with the spindle of dial indicator the folating head towards the indicator is constrained by a spring.

The insturment is first set on a cylindrical reference standard having diameter approximtely equal to the major diameter of the internal thread to be checked and reading of the dial indicator is noted. Then the floating head is retracted to engage the tips of the stylii at the root of the under spring pressure. Second reading of the dial indicator is noted.

If D = diameter of cylindrical standard

R_1 = reading of dial indicator on the standard

R_2 = reading on thread

Then, major diameter of internal thread = $D \pm (R_2 - R_1)$

Q.7. What are the pitch errors? Explain brief the causes and effects of pitch errors in threaded component.

Ans : The various types of pitch errors and their causes are explined below.

Progressive pitch error : The pitch of the thread may be longer or shorter than its nominal value but uniform such errors are caused due to (i) incorrect ratio of the linear velocity of tool and angular velocity of the work.(ii) pitch error in the lead screw of lathe or other machine used for thread cuting (iii) Use of incorrect gear or gear train between work and lead screw.

Periodic pitch error : Pitch of the thread is not uniform i.e. increases gradually to a maximum value, then reduces gradually below the normal value. This error repeats itself at equal intervals along the thread. In this case successive portions of the thread length are either longer or shorter than the mean value. Such errors are caused (i) when tool work velocity ratio is not uniform or (ii) if the lead screw of machine lacks squarencess in the aboutment so that it moves forward and backward once in each revolution.

Irregular error or drunken error : The pitch of the thread is not uniform. It varies in magnitude over equal fractions of each turn of the thread. These errors have no specific causes. They may arise due to disturbances in the machine set up, variation in the cutting properites of material etc.

Effects of pitch error : This error results in progressive tightening and interferenance on assembly and increase the strain in the parts on engagement. An error in pitch virtually increases the effective diameter of a bolt or screw, even though it has the same actual effective diameter as that of one having perfect pitch, and virtually decreases the effective diameter of nut. So a perfect bolt having some pitch error will not assemble with a nut of perfect form and pitch without interference and strain. Now if the effective diameter of the nut is increased,retaining the same pitch,then the assembly will be possible. But this will lead to thining of the thread flanks and consequent weakening of the assembly. For most of the threads the change in pitch diameter is approximately twice the pitch error.

Q.8. What is effect of pitch error and thread angle error on effective diameter of screw ?

Ans : Error in pitch virtually increases the effective diameter of a bolt or screw. This can be understood by the following example.

Consider a perfet bolt having some error in the pitch. Assume that it has to engage with a nut of perfect form and pitch. This will not be possible without interference and strain in the joint. But if the effective diameter of the nut is increased retaining the same pitch, the two parts can assemble without interference i.e. pitch error has virtually increased the effective diameter of bolt, so for perfect engagement (without strain) the effective diameter of the nut is to be increased. For most of the thread the change in the effective diameter is twice the pitch error.

Similarly the vitual effective diameter of a nut is decreased by the error in pitch. Therefore if a screw of perfect form and pitch is to be enganged without interference with a nut of perfect form having some error in pitch the effective diameter of screw is to be reduced.

The effect of both longer and shorter pitch is same, each reducing the clearance or increasing the interference between the meshing threads. Even if the error in pitch is not uniform the effect would be the same.

The effect of error in the thread angle is same as that of the error in the pitch. Thread angle error also increases or decreases the effective diameter of screw or nut. If $d\theta_1$ and $d\theta_2$ are the errors in degrees in the angles on the two flanks of thread, the change in the effective diameter of the thread is given by,

$$0.0115\, p\, (d\theta_1 - d\theta_2)$$

where p = nominal pitch.

Q.9. What do you understand by "Best size' wire? For M,16X 2 external thread calculate the diameter of best size wire and difference between the size under the wires and effective diameter.

Ans : Best size wire is a wire of such diameter that it makes contact with the flanks of a thread of effective diameter or pitch line. While making measurements of effective diameter by wire method if best size wire is used any error in the measurement due to error in the thread form or thread angle is minimised.

Diameter of best size wire is given by,

$$Db = \frac{P}{2} \sec\theta$$

Where, p = pitch of thread.

θ = half thread angle or flank angle.

For M 16 x 2 external thread, pitch , p = 2mm and and $\theta = 30^0$

$\therefore$ diameter of best size wire.

$$Db = \frac{P}{2} \times \sec\theta = \frac{2}{2} \times \sec 30^0 = 1.1547 \text{ mm}$$

The difference between the size under the wires and effective diameter.

$$p = 0.866 \quad p - d = 0.866 \times 2 - 1.1547$$

$$= 0.5773\text{mm.}$$

Q.10. Write a short note on :

Tool Maker's Microscope :

Ans : This is a versatile instrument based on optical means. It consists of a heavy hollow base accomodating the illuminating unit underneath. Work table is mounted on the base of the instrument on cross slides and is equipped with accurate micrometer screws to move it in two mutually perpendicular directions in the horizontal plane i.e. longitudinal and lateral directions.

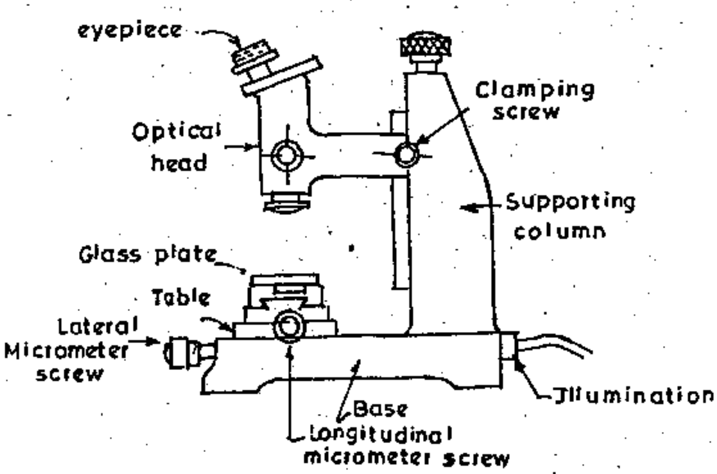


Fig. 5.7

Optical head is mounted on a vertical column and can be moved up or down and focussed over the work. To clamp the optical head at any desired position a clamping screw is provided.

Work piece is mounted on a glass plate placed on the table. A ray of light from a lamp is collimated and then reflected as a parallel beam by the prism at the end of the tube connecting the lamp to the centre of the instrument. It then passes through the glass tube. The shadow image of the outline or contour of the work piece passes through the objective of the optical head and is projected by a system of three prisms to a ground glass screen. Observations are made through an eyepiece. Measurements are made by means of cross lines engraved on the glass screen. The screen can be rotated through 360^0 and the angle of rotation can be read through an auxiliary eye piece provided on the optical head.

Applications : The following are the applications of tool maker's microscope.

i. Measurement of length in rectangualar and polar co-ordinates.
ii. Mesuring tool angles, milling cutter angles, thread angles etc,
iii. Comparing thread forms with standard profiles.
iv. Checking contours.
v. Determining the relative position of various points on work.

Q.11. Explain the principle, of operation, construction, working and and uses of an ontical projector.

Ans : Optical Projector : Optical comparators which make use of the enlarged image principle are commonly knows as optical projectors use:

The optical projector is used for checking the shape or profile of a relatively small engineering components with an accurate standard or drawing. It enables a magnified image of part of a component to be projected on to a screen where it is compared with an enlarged profile drawing. The degree of magnification available may range from 5 to 100.

Principle of working : The essential elements of an optical projector are shown diagrametically in fig. 5.8. Light from the lamp L passes first through a condenser lens C and then thro' a projection lens p. The component supported on the work table between these two lenses, interrupts the light and causes an inverted magnified image to appear on the screen.

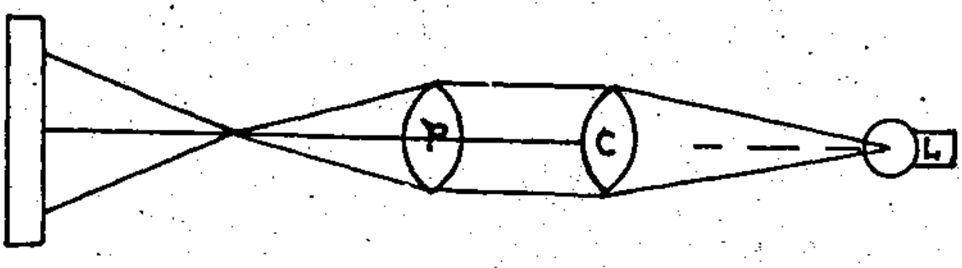


Fig. 5.8

Commercial Projectors : A commercial projector is shown in Fig. 5.9. Its principle is the same as described above, construction :

It consists of :

i. A projector (having a light source, a condenser or collmating lens system to direct the light past the part and into the optical system)

ii. Suitable work holding table which may be fixed or movable,

iii. Projection optics including both mirrors and lenses.

iv. Screen where the image of workpiece is projected and where measurements or comparisons are made.

v. Measruing devices. A good optical projector must have a precise optical system, and means for preceise mechanical measurement.

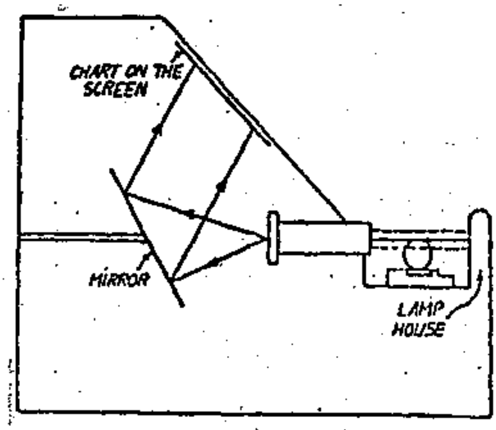


Fig.5.9. Optical projector

When an object is placed before a light source, shadow of the profile is projected at some enlarged scale on a screen where it is compared to a master chart drawing. To reduce the thermal effects an extra arrangement for water lenses is generally provided. The magnification is usually from 5 to 100 The light source may be a tungsten lamp, fillament lamp or High pressure mercurcy or zenon arc lamp. A strong beam of light consisting of parallel light rays is produced by optical means. Beam of light should be of large enough diameter to provide coverage on the test piece and adequate illumination intensity for projecting surface characteristics.

The object to be tested is placed on the work table. The work table may be either stationary or moving type. Some tables are also equipped with an angular adjustment for positioning to the helix of threads and worms. These tables usually have in and out movement parallel to the axis of the beam for focussing purposes; and also provision for movements in other two planes. Micrometers in combination with dial indiacators are fitted as measuring attachments for either two or three directions.

The light beam after passing the object to be projected passes into the projection system having lenses and mirrors which must be held in accurate alignement on rigid supports. The lenses are used to obtain the desired magnification and mirrors to direct the beam of light on screen. The screens are usually made of glass with the surface facing the operator ground to very fine grade.

Q.12. Explain the construction and working of a pitch measuring machine.

Ans : The screw pitch measuring machine is used to measure the pitch error of individual threads accurately. It employs various stylus points to suit the screw threads that are to be checked. The screw under measurement is held stationary between centres on the machine.

The indicator unit, carrying the stylus which bears on the flanks of each thread successively, is carried on a slide which is mounted on balls. The slide is actuated by means of a micrometer.

The act of rotating the micrometer spindle causes the slide to move in relation to the work being measured. The stylus which is mounted on a leaf spring, falls in and out of each thread, the pointer of the indicator reads zero (it is adjusted to read zero in the first groove) when this stylus is in a central position in each successive thread. The micrometer reading is taken each time the indicator reads zero, these readings then show the pitch error of each thread of the screw that is being mesured. Special graduated discs are provided to fit the micrometer to suit all ordinary pitches whilst special pitches can be provided for.

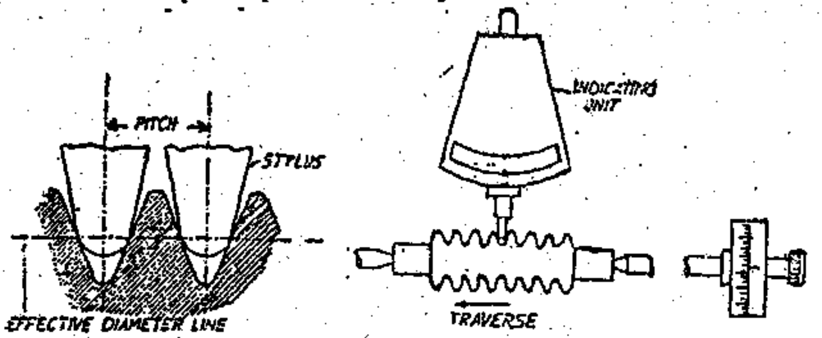
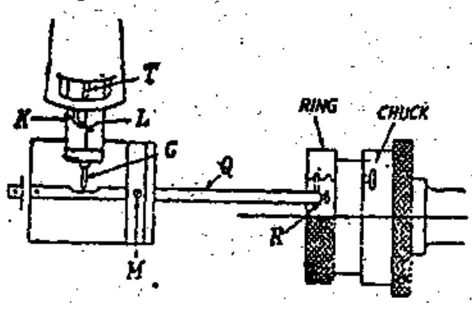


Fig. 5.10 Pitch Measuring Macine

The small hand wheel below the micrometer screw serves the purpose of moving the indicator in relation to the slide so as to bring the stylus opposite to the screw to be tested in any position between centres. The total travel of the micrometer is 25 mm.

The pitch errors extremely small, being of the order of 0.002 mm for a thread. A test screw is also supplied with the machine and a chart of pitch error for this screw.

Q.13. Describe the procedure for measuring the pitch of the internal threads by means of a pitch measuring machine.



G Stylus
Q Rod holding stylus R.
L Line for adjusting stylus G. This is arranged opposite to pointer K.
M Locking screw for Q.
T Indicator pointer which is arranged to read zero while taking micrometer reading.

Fig. 5. 11 Measurement of pitch of internal threads

Ans : The pitch of an internal thread can be measured on any of the standard pitch mesuring machine by using an adaptor. This adapter carries a bar which can be inserted into the ring, the stylus being fitted to the bar end engaging with the thread in the usual manner. The ring gauge is mounted on a face plate or on the head stock of the machine, which will accomodate rings upto several c.m in diameter for very large rings, a special set up on a surface plate is necessary, utilising an indicator and slip gauges.

Q.14. Explain the construction and operation of a screw thread micrometer.

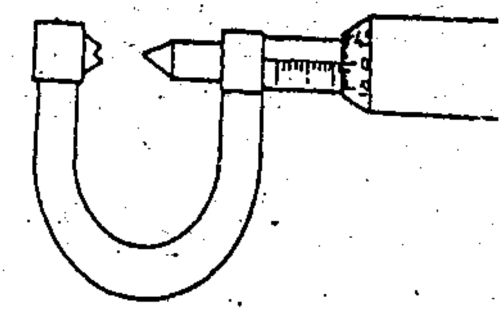


Fig. 5.12.
Screw Threaded Micrometer.

Ans : The screw thread micrometer is just like an ordinary micrometer with the difference that it is equipped with a special anvil and spind'e. The anvil has an internal vee which fits over the thread. the end of the spindle of a thread micrometer is pointed to 60° cone for American standard threads and an accurate 60° V is grooved in the anvil. The anvil is free to rotate.

Thus vee of the anvil can adjust itself to the helix angle of the thread being measured. When the conical spindle is brought into contact with the vee of the anvil micormeter reads zero. A setting gauge is also provided to remove zero error if any. Different sets of anvils are provided for different type of therads and the contact points of micrometers are so designed that some allowance for thread clearance is always made.

Q.15 Explain the construction and operation of a tangent micrometer.

Ans. A tangent micrometer is provided with flanked anvils. It essentially consists of a fixed anvil and a movable anvil. There is a micrometer on the moving anvil side and this has a very limited movement on either side of the setting. The distance is adjusted by setting the fixed anvil at a desired placed with the help of locking ring and setting tubes. It is also called as David Brown Tangent comparator. It is used to compare the thread parameter with the standard dimension. It is also used for checking gear tooth parameters.

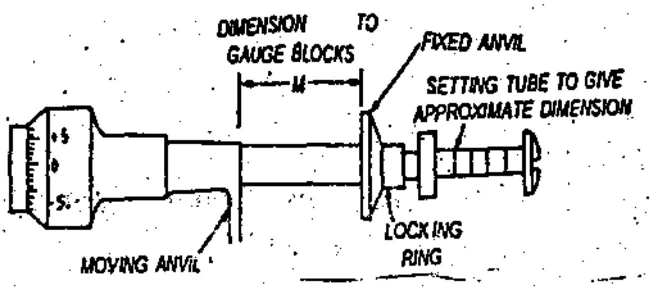


Fig. 5.13 David Brown Tangent Comparator

Chapter 6

COMPARATORS

Q.1. What is a comparator ? How they are classified Enumerate the various uses of comparator ?

Ans : Comparator is an instrument used to compare linear dimension of gauges and work pieces with working standards such as slip gauges. It indicates the difference in sizes between the working stndard and work piece being measured. This difference is magnified by some means and indicated on a calibrated dial by some form of pointer. The magnification varies between 2000 to 40, 000.

Classification : Depending on the method used to magnify and record the variations in the dimensions of standard and work piece being measured,comparators are classified as follows:

1. Mechanical comparators, 2. Electrical comparators, 3. Optical comparators,
4. Electronic comparators, 5. Pneumatic comparators, 6. Fluid comparators,
7. Combinations of the above.

Uses :

1. To check the components and newly purchased gauges.
2. As laboratory standards to set working or inspection gauges.
3. As working gauge in important stages of manufacture.
4. As a final inspection gauge.

Q.2. Describe the esential characteristics of comparator OR What are the fundamental requirements of comparator?

Ans :

1. **Robust design and construction :** The design and construction of the instrument should be robust so that it can withstand the effects of ordinary uses without affecting its measuring accuracy.

2. **Linear characteristics of scale :** Recording or measuring scale should be linear and uniform (straight line characteristic)and its indications should be clear.

3. **High magnification :** The magnification of the instrument should be such that a smallest deviation in size of component can be easily detected.

4. Quick in results : The indicating system should be such that the readings are obtained in least possible time.

5. Versatility : Instrument should be so designed that it can be used for wide range of measurement.

6. Measuring plunger should have the hardened steel, or diamond contact to minimise wear and contact pressure should be low and uniform.

7. The pointer should come rapidly to rest and should be free from oscillations.

8. System should be free from back lash and unnecessary friction and it should have a minimum inertia.

9. Indicator should be provided with maximum compensation for temperature effects.

10. Indicator should return to its initial zero position every time.

Q.3. State the principle of working of mechanical comparator, electrical comparator, optical comparator and pneumatic comparator ?

Ans : 1. Mechanical comparators : The magnification of plunger movement can be obtained by mechanical means such as levers, gear and pinion arrangement or other mechanical means.

2. Electrical comparators : These instruments are based on the theory of Wheatstone A.C. bridge. When the bridge is electrically balanced,no current will flow through the galvanometer connected to the bridge and pointer will not deflect. Any upset in inductances of the arms will produce unbalance and cause deflection of the pointer.

3. Optical comparators : Operating principle of this type, of comparator is based on the laws of light reflection and refraction. Magnification system depends on the tilting of a mirror, which deflects a beam of light, thus providing an optical lever.

4. Pneumatic comparators : These instruments utilise the variations in the air pressure or velocity as an amplifying medium. A jet or jets of air are applied to the surface being measured and the variations in the back pressure or velocity of air caused due to variations in size are used to amplify the output signals.

Q.4. What are the advantages and disadvantages of mechanical comparators?

Ans : Advantages :

i. Compact and robust contruction.
ii. They are portable and cheaper.
iii. They are easy to handle and can be set quickly.
iv. Scale is linear or uniform.
v. They are independent of any external power supply, So the accuracy of the readings is not affected by the variations in the power supply.

Disadvantages :

i. More number of moving parts, so friction and wear is more and accuracy is less.
ii. Slackness in moving parts reduces the accuracy of the instrument.
iii. Inertia of moving parts makes the instrument sensitive to variations.
iv. Range of the instrument is limtied by the range of the fixed scale.
v. Parallax errors are introduced as the pointer moves over a fixed scale.

Q.5. Describe in brief construction and working of a mechanical comparator. ?

Ans : Johansson "Mikrokator' is a mechanical comparators having magnification of about 5000. It works on the principle of a button spinning on a loop of string.

Johansson "Mikrokator' : The instrument consists of a plunger, twised thin metal strip, spring elbow, pointer, etc. A very light glass pointer is attached to the centre of the twiested strip. The two halves of the strip from the centre are twisted in opposite directions,so that any pull in the strip causes the centre and hence the pointer to rotate.

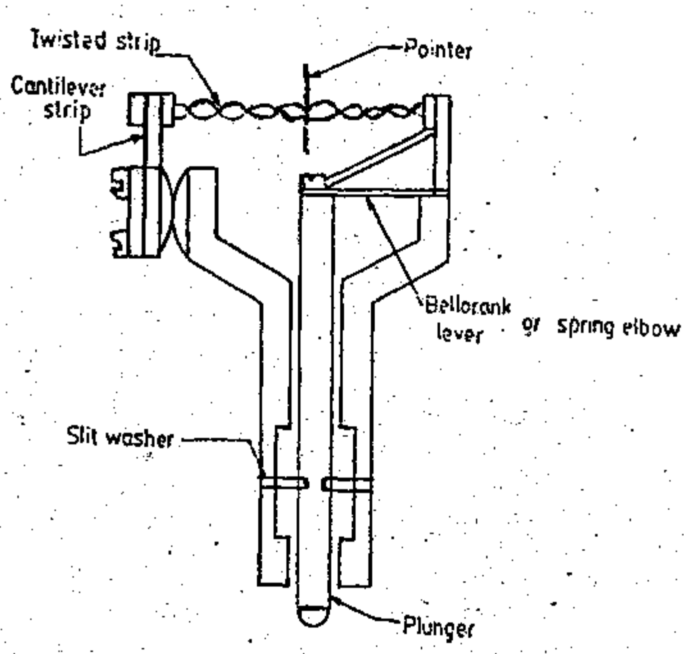


Fig. 6.1

One end of the strip is fixed to an adjustable cantilever strip and other end is attached to an arm of spring elbow. The measuring plunger is mounted on a flexible diaphram. Its inner end is attached to the other arm of spring elbow. Thus the vertical movement of the plunger is transmitted to the metal strip through the elbow.Any vertical movement of the plunger will make it to twist or untwist. This will casuse the pointer to rotate by an amount proportional to the change in the length of the strip.

Magnification of the instrument depends upon the length, width and number of twists of the twisted strip. It can be varied by changing the length of the strip with the screws provided on adjustable cantilever strip.

Q.6. State requirements of good dial indicator ?

Ans : 1. Design and construcion must be robust so that it can give trouble free and dependable readings over a long period without attention.

2. Pointer movement should be properly damped so that it will not oscillate when readings are being taken.

3. To avoid damage to the instrument, movements of plunger larger than the specified amount on the scale should be controlled by some means.
4. The instrument should be useful for the movement of the measuring plunger in either direction without affecting the accuracy.
5. The pointer movement on the dial (scale) should be such as to indicate the direction of movement of the measuring plunger.
6. Accuracy of readings should be laid down to close limits for various sizes and ranges of instruments.
7. Operating pressure required on measuring head to obtain zero reading must remain constant over whole range.

Q.7. Enumerate the various advantages of dial indicator.?

Ans : 1. The instrument can be easily used and read even by unskilled worker.
2. Contact pressure is low and uniform.
3. It is not subjected to problems such as gauge wear, temperature variations, etc.
4. It is best suited in mass production for precision dimensional control.
5. It can detect small dimensional variations that are beyond the range of conventional gauges.
6. The instrument is accurate and economical.
7. It is versatile i.e. can be easily and rapidly used for different types of precision measurements e.g. testing roundess, taper etc.
8. It is portable, easy to handle and can be set very quickly.

Q.8. Wirte short notes on : i. Dial indicator, ii. Sigma comparator.

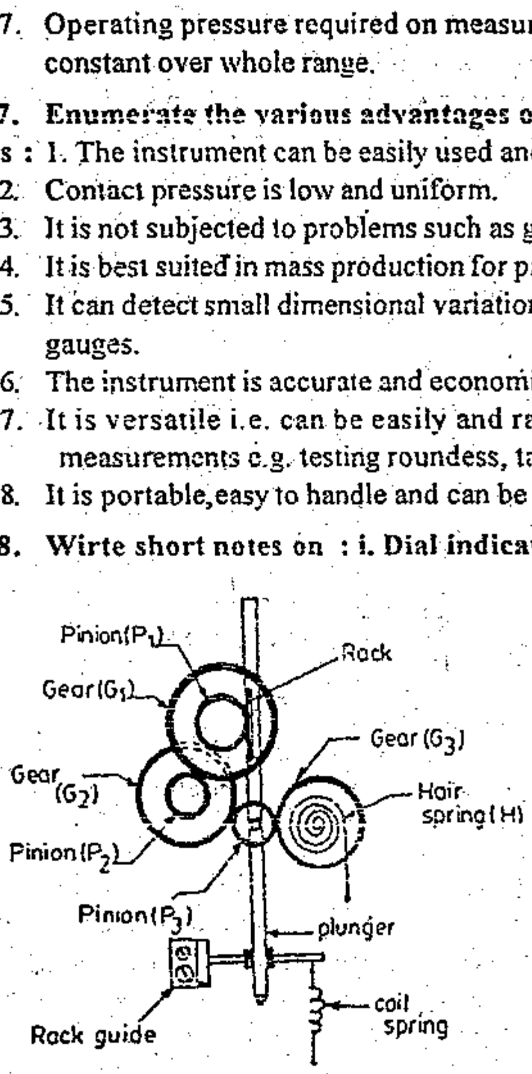


Fig.6.2

Ans : 1. Dial indicator :- Dial indicator is a small indicating device using mechanical means such as gears, pinions for magnification. The usual magnigication is about 250 to 1000.

It consists of a plunger which slides in bearing and carries a rack at its inner end. The rack meshes with a pinion. (p_1) which drives another gears and pinions.

The plunger is kept in its normal extended position by means of a light coil spring. The linear movement of the plunger is magnified by the gear train and transmitted to the pointer on the dial scale. The pointer is mounted on the spindle of pinion (p_3). To take up the back lash, a light hair spring (H) is attached to the gear (G_3)of the gear train.

Dial indicators are compact and robust in construction. They are protable, easy to handle and can be set very quickly. They are used for inspection of small precision machined parts, testing alignment, roundeness, parallelism of work pieces, etc. But these insturments have following drawbacks:-

i. Wear of plunger bearing surfaces, gear bearing points etc. cause an error in the measurement.
ii. Accuracy of the instrument is reduced due to backlash in rack and pinion or gear train.
iii. As the plunger moves inside, the contact pressure of the plunger increases. The variation in the plunger contact also introduces error in the measurement.

Sigma comparator : This is a mechanical comparator providing magnification in the range of 300 to 5000. It consists of a plunger mounted on two steel strings (slit diaphrams). This provides a frictionless linear movement for the plunger. The pluner carries a knife edge, which bears upon the face of the moving block of a cross-strip hinge.The cross-strip hinge is formed by pieces of flat steel springs arranged at right angles and is a very efficient pivot for smaller angular movements. The moving block carries a light metal Y-forked arms. A thin phosphor bronze ribbon is fastened to the ends of the forked arms and wrapped around a small drum, mounted on a spindle carrying the pointer.

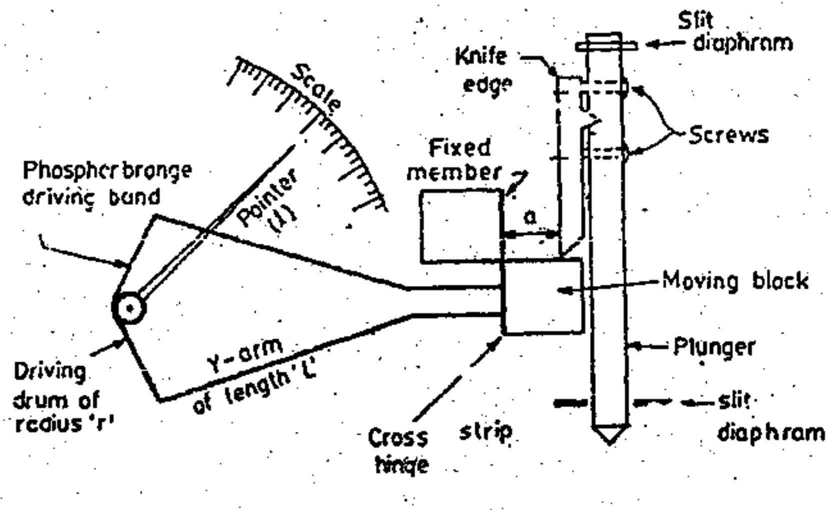


Fig. 6. 3

Any vertical displacement of measuring plunger and hence that of the knife edge makes the moving block of the cross-strip hinge to pivot. This causes the rotation of the Y-arms. The metallic band attached to the arms makes the driving drum and hence the pointer to rotate.

The ratio of the effective length (L) of the arm and the distance (a) of the knife edge from the pivot gives the first stage magnification and the ratio of pointer length(L) and radius(r) of the driving drum gives second stage magnification of the instrument. Total magnification of the instrument is thus ($L/a \times l/r$). The magnification of the instrument can be varied by changing the distance(a) of knife edge by tightening or slackening of the adjusting screws.

Q.9. State the advantages and limitations of an electric comparator. ?

Ans : Advantages :

i. Small and compact size.
ii. Small number of moving parts,hence less friction and wear.
iii. It has wide range of magnification.
iv. The mechanism carrying the pointer,being very light is not sensitive to vibrations.
v. Operation of the instrument on A.C. supply reduces sliding friction errors due to cyclic vibrations.
vi. Instrment can be easily set up in variety of positions and can be easily operated.
vii. Indicating instrument need not be placed close to the measuring unit.

Limitations or disadvantages :

i. Fluctuations in the voltage or frequency of the electric supply may effect the results.
ii. Heating of coils in the measuring unit may cause zero drift and alter the calibations.
iii. When mesuring unit is remote from the indicating unit, reliability is lower.
iv. Cost is generally more than mechanical comparator.

Q.10. Distinguish between:- Mechanical comparator and electrical.comparator. ?

Ans :

Mechanical comparators	Electrical comparators
1. More number of moving parts, so friction and wear is more, and accuracy is less.	1. Small number of moving parts. hence less friction and wear and accuracy is more.
2. They are independant of any external power supply, so accuracy of the readings is not affected by the variations in the power supply.	2. Fluctutions in the voltage or frequency of the electirc power supply may affect the results and accuracy of measurement.
3. These intruments are portable and cheaper.	3. Measruing and indicating units being seperate and as they require supply they are not so easily portble and also cost is more.
4. Inertia of moving parts makes the instrument sensitive to vibrations.	4. The mechanism carrying the pointer being very lingt is not sensitive to vibrations.
5. Range of the instrument is limited by the range of the fixed scale.	5. It has wide range of magnification.

Q.11. What are advantages and disdvanges of pneumatic comparators ?

Ans : Advantages :

i. Very high magnification of about 30,000 is possible.

ii. As there is no physical contact between gauging member and the part to be measured, no wear of gauging member or parts and accuracy is more.
iii. Absence of friction and less inertia,so accuracy is more.
iv. As it is independant of operator skill, stability and reliability is more.
v. It can be used to measure diameters, length, squareness, parallelism concentricity, roundness and other geometric conditions.
vi. Gauging pressures can be adjusted to prevent deflection of parts being measured.
vii. Best suited for checking multiple dimensions and conditions on a part in least possible time.
vii. Jet of air helps in cleaning dirt and dust, so accuracy is more.
ix. Indicating instrument can be placed away from the measuring unit.

Disadvantages :

i. Scale is generally not uniform.
ii. It is not easily portable as it requires elaborate auxiliary equipment such as accurate pressrure regulator, etc.
iii. Low speed of response.
iv. Needs different types of measuring heads for different dimensions.

Q.11. Describe with neat sketch the construction and working of Solex Pneumatic comparator. ?

Ans :

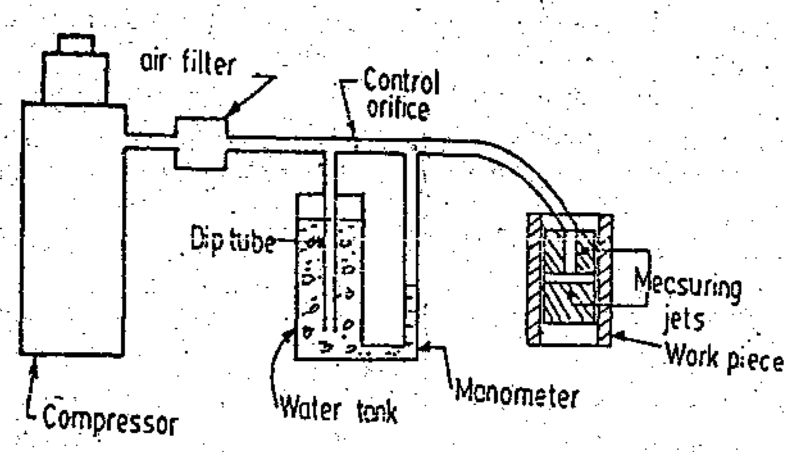


Fig. 6 .4

This instrument was first commercially introduced by Solex Air Gauges Ltd. It uses a water manometer for the indication of back pressure.

It consists of a vertical metal cylinder filled with water upto a certain level and a dip tube immersed into it upto a depth corresponding to the air pressure required. A calibrated manometer tube is connected between the cylinder and control orifice as shown in the fig. 6.4

If the pressure of the air supplied is higher than the desired pressure, some air will bubble out from the bottom of the dip tube and air moving to the control volume will be at the desired constant pressure. The constant pressure air then passes through the control orifice and escapes form the measuring jets. When there is no restriction to the escape of air, the level of water in the manometer tube will coincide with that in the cylinder. But, if there is a restriction to the escape of air through the jets, a back pressure will be induced in the circuit and level of water in the manometer tube will fall. The restriction to the escape of air depends upon the variations in the dimensions to be measured. Thus the variation in the dimensions to be measured are converted into corresponding pressure variations, which can be read from the calibrated scale provided with the manometer.

Q.12. Due to which characteristics air gauaging has rapidly increased used in mass production gauging ?

Ans : Air gauging has rapidly increased use in mass production gauging because of the following advantages possessed by it over other methods.

Refer Q. (10)

Q.13. What is the basic difference between a measuring instrument and a comparator ? Define sensitivity in both the cases. ?

Ans : A measuring instrument indicates the actual value of the quantity being measured while a comparator indicates the difference in the sizes between the working standard and the work piece being measured.

Sensitivity of a measuring instrument for a specified value of quantity measured is expressed as the ratio of the increment of the observed variable and the corresponding increment of the quantity measured. Sensitivity of a comparator can be defined as the rate of displacement of the indicating device w.r.t. the difference in the sizes of working standard and work piece being measured.

Q.14. What is the basic difference between a guage and a comparator ?

Ans : A gauge is an inspection tool used to check dimensions, form, etc. and to define whether the deviations from the actual dimensions or form of part are within the specified limits; Whereas a comparator is used to compare linear dimension of work piece with standards such as slip gauges. Comparator indicates the difference in sizes between the standard and the work piece being measured, while guage determines whether the manufactured part lies between the given limits of size.

Q.15. What are the merits and demerits of optical comparator ?

Ans : Merits :

i. Very few moving parts, hence less friciton, wear and hence higher accuracy.
ii. Scale can be moved past a datum line and so have high range and no parallax errors.
iii. Very high magnification, so, suitable for precision measurements.
iv. Since scale is illuminated, it enables readings to be taken irrespective of room lighting conditions.

Demerits :

i. As the magnification is high,heat from the lamp, transformers, etc. may cause the setting to drift.

ii. Depends on external electrical power supply.

iii. Apparatus is usually bulky and expensive.

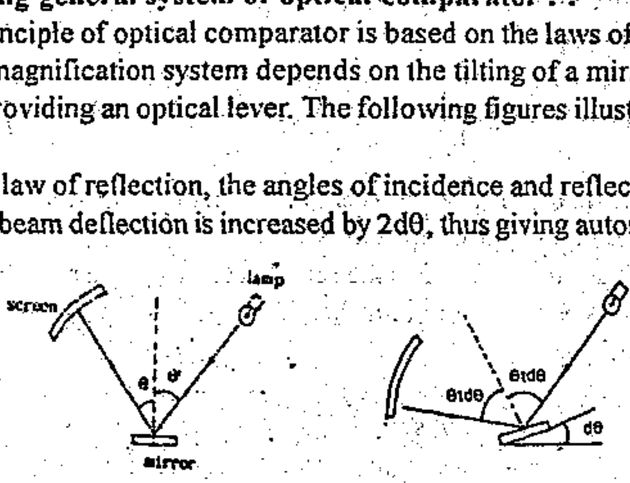
iv. When scale is projected on a screen, the instrument is to be used in dark room.

v. Instrument is inconvenient for continuous use, because the scale is to be viewed through eye piece.

Q.16. Explain the principle of optical lever with the help of a neat sketch. Draw a figure showing general system of optical comparator . ?

Ans : Operating principle of optical comparator is based on the laws of light reflection and refraction. Optical magnification system depends on the tilting of a mirror which deflects a beam of light thus providing an optical lever. The following figures illustrate the principle of optical lever.

According to the law of reflection, the angles of incidence and reflection are equal. "dθ', the total angle of the beam deflection is increased by 2dθ, thus giving automatic magnification.



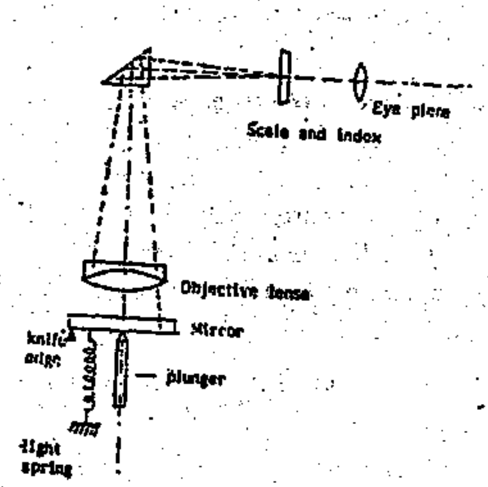


Fig. 6. 5

Q.17) Differentiate between
i. Comparator and measuring instrument, ii. Comparator and gauge. ?

Ans :

Comparator	Measuring Instrument
1. It is used to compare dimensions of parts with working standards and to measure difference between the sizes of parts and working standards.	1. It is used to measure the actual dimensions of the manufactured parts.
2. The reading are magnified by suitable arrangements.	2. No magnification system is provided.
3. Measurements can be done rapidly and accurately, so it is suitable in mass production.	3. Measurements is time consuming so not suitable in mass production.
4. Can be used to check dimensions as well as geometric forms.	4. Can not be used to check geometric forms.
5. No chances of errors due to incorrect contant pressure or deformation of work piece.	5. Errors are caused due to misalignment of instrument or work piece, incorrect contact pressure and deformation of instrument of workpiece.
6. Accracy is independant of correct feel or operator skill.	6. Accuracy depends on the correct feel and operator skill.

Comparator	Gauge
1. Used to compare the dimensions of parts with working standards.	1. Used to determine whether the dimensions of part lie within the given limits of size.
2. Determines the difference between the sizes of part and standard.	2. Determines deviation from the actual dimensions or form of part.
3. Magnification and indicating systems are provided.	3. No magnification and indicating systems are provided.
4. Less wear or even no wear as in case of electrical, optical comparators	4. Surface of GO gauge wears during continuous use.
5. Can be used to compare dimensions of larger and thin walled parts.	5. Can not be used to gauge the dimensions of larger and thin walled parts.

Q.18. Explain the construction and operation of a reed type mechanical comparator ?

Ans : Reed Type mechanical Comparator :- In reed type mechanical comparator, the gauging head is usually a sesitive, high quality, dial indicator. The dial indicator is mounted on base supported by a stardy column. Fig. 6.6 shows a reed type mechanical comparator.

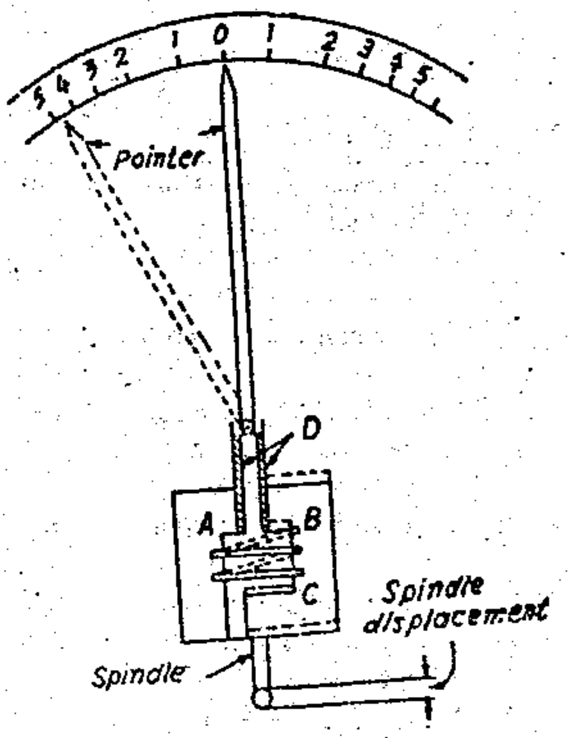


Fig. 6.6

Reed type mechanical Comparator

The reed mechanism is frictionless device for magnifying small motions of the spindle. It consists of a fixed block 'A' which is rigidly fastened to the gauge head case, and floating block B, which carries the gauging spindle and is connected horizontally to the fixed block by reed C.

A vertical reed is attached to each block with upper ends joined together.

These vertical reeds are indicated by D. Beyond this joint extends a pointer.

A linear motion of spindle moves the free block vertically causing the vertical reed on the floating block to slide past the vertical reed on the fixed block. However, as the vertical reads are joined at the upper end, instead of slipping, the movement causes both reads swing through at arc and as the target is merely an extension of the vertical reeds, it swings throgh a much wider arc. The amount of target swing is proportional to the distance the floating block has moved but of course very much magnified.

The scale may be calibrated by means of gauge block (slip gauges) to indicate any deviation from an initial setting.

The mechanical magnification is usually less than 100, but it is multiplied by the optical lens system. It is available in amplifications ranging from **X 500 to x 1000**.

Q.19 (a) Name the two types of dial indicatars.

(b) Draw a simple diagram of a plunger type dial indicator indicating the values of (1) read division on the main scale (2) each division on the revolution counter scale

Ans. The two distinct types of dial indicators are

1. Plunger type (with linear moving plunger)
2. Lever type(with an angular moving stylus)

(b) Fig. 6.7 shows a plunger type dial test indicator (i) The value of each division on the main circular scale is 0.01 mm.

(ii) The value of each division on the revoluion counter is 1mm.

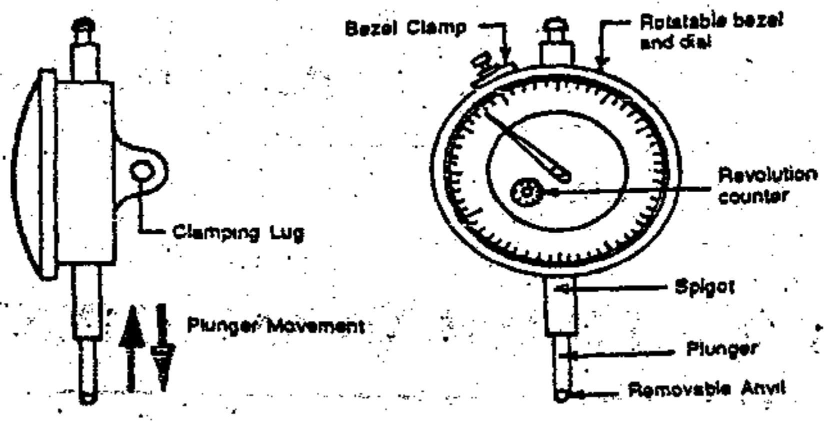


Fig. 6.7 Plunger Type Dial

Q.20 With the help of a neat sketch. Explain the working of a lever type dial indicator. Why a revolution counter is not provided in lever type dial test indicator.

Ans. Fig. 6.8 shows a lever typedial indicator. In this type the plunger is replaced by a ball tipped lever arm which is pivoted on the body of the indicator. The ball-tippped portion is called stylus.

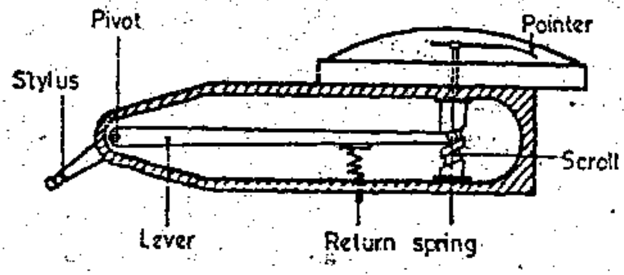


Fig. 6.8 Lever Type Dial Indicator

The movement of the lever is such that it is at right angles to the main scale. Fig. 6.8 shows the mechanism of the lever type dial indicator. It relies upon a lever, which is pivoted at its lower end. A ball at the upper end of the main lever rotates the scroll and this movement is displayed by the pointer on the main scale.

It has only a limited range (limited by the scroll length), which usually allows about 1 1/2 revolutions of the pointer to be made. It is for this reason that a revolution counter is not provided in this type of dial indicator.

Uses : This instrument is more compact than the plunger type and it is most commonly used for both inspection and machine setting. With the ball tip placed inside a small bore, concentricity, roundness or machine setting can be conveniently checked.

Chapter 7

SURFACE FINISH MEASURMENTS

Q.1. What are the different modes of defining surface texture ?

Ans : On any finished surface imperfections or irregularities are bound to be there. They are in the form of succession of hills and valleys which vary both in height and its spacing, depending upon the production process or manufacturing process used.

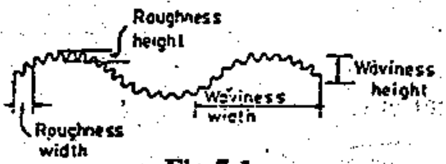


Fig.7.1

Surface irregularities superimposed on a plane, curved or wavy base portion of a surface is called surface texture. There are two modes of defining surface texture, viz primary texture and secondary texture.

i. Primary texture (roughness) : The surface irregularities of small wave length are called primary texture or roughness. These are caused by direct action of the cutting element on the material i.e. cutting tool shape, tool feed rate or by some other disturbances such as friction, wear or corrosion. These irregularities constitute micro-geometrical errors. The evaluation of surface finish is based on the height and character of the microgeometrical irregularities.

ii. Secondary texture (Wavyness) :- The surface irregularities of considerable wave length of a periodic character are called secondary texture or wavyness. These irregularities result due to inaccuracies of slides, wear of guides, misalignment of centres, non-linear feed motion, deformation of work under the action of cutting forces, vibrations of any kind, etc. These errors are macro-geometrical errors. Roughness (primary texture) is superimposed upon the secondary texture (waviness).

Q.2. Describe with a neat sketch construction and working of an instrument used for measurement of surface texture.

Ans : Comparatively cheap and reliable instrument using mechanical cum optical means of magnification was designed by Dr. Tomlinson (Refer Fig.7.2)

The instrument consists of a diamond probe (stylus) held by spring pressure aganist the surface of a lapped cylinder by a leaf spring. The lapped cylinder is supported on one side by the probe and on the other side by fixed rollers. A light spring steel arm is attached to the lapped cylinder. It carries at its tip a diamond scriber which rests against a smoked glass. The motions of the stylus in all the directions except the vertical one are prevented by the forces exerted by the two springs.

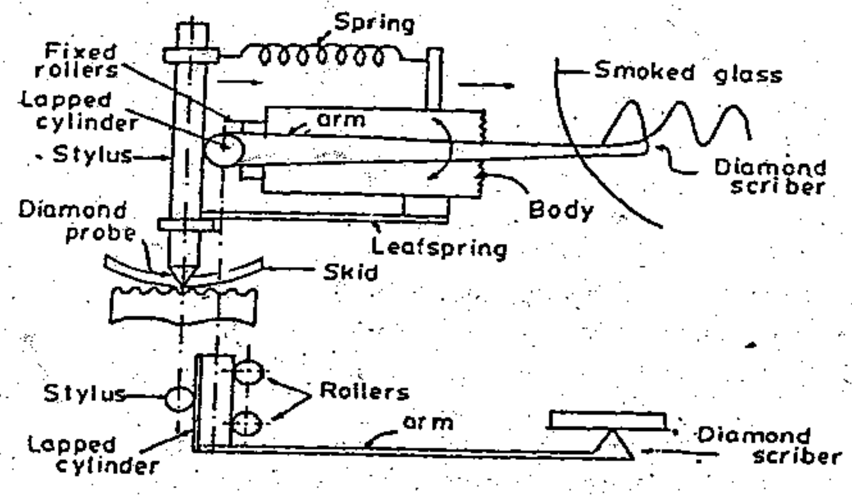


Fig.7.2

For mesuring surface finish the body of the instrument is moved across the surface by screw and motor arrangement. The vertical movement of the probe caused by surface irregularities makes the horizontal lapped cylinder to roll. This causes the movement of the arm attached to the lapped cyliner. A magnified vertical movement of the diamond scriber on smoked glass is obtained by the movement of the arm. This vertical movement of the scriber together with horizontal movement produces a trace on the smoked glass plate. This trace is further magnified at X 50 or x 100 by an optical projector.

Q.3. What are roughness comparison specimens? How they assess surface roughness ? What are the limitations ?

Ans : The roughness comparison specimens are either flat or segmented cylindrical pieces having known roughness value. They are used for qualitative assessment of surface roughness of a finished product by comparison materials such as steel having hardness of about 400, nickel alloy or metalised plastics. They are rigidly supported on a base to prevent warping or distortion during use.

The assessment of surface roughness of a finished product is done by comparison with the specimen of known roughness value and finished by machining process similar to that of the product under test. The comparison may be done by visual inspection,or touch inspection. In visual inspection, the product and the specimen are seen simultaneously and the roughness of the product is compared with that of the specimen by naked eye. In touch inspection, the feel of the surface is experienced by moving finger nail lightly across the lay of the roughness of the product to be tested and afterwards moving across the surface of the specimen of known roughness value. Then the two feels are compared to assess the surface roughness of the product.

Though the methods of assessment of surface roughness by using speicmens of known roughness value are rapid, they are not reliable because visual inspection by naked eye is always likely to be misleading especially when the surfaces to be tested have high degree of finish. Touch inspection can not give reliable results and can not detect minute flaws, unless the person is very well trained. Also the results obtained by comparison vary from person to person. Errors may also be caused due to difference in the material, shape, method of machining, method of finish, etc. of product and the specimen.

Q.4. Explain the principle, general construction and operation of stylus type surface texture measuring instruments. What are the disadvantages of these types of instruments ? why are they widely used ?

Ans : If a finely pointed probe or stylus be moved over the surface of a work piece, the vertical movement of the stylus caused due to the irregularities in the surface texture can be used to assess the surface finish of the work piece.

Stylus which is a fine point made of diamond or any such hard material is drawn over the surface to be tested. The movements of the stylus are used to modulate a high frequency carrier current or to generate a voltage signal. The output is then amplified by suitable means and used to operate a recording or indicating instrument.

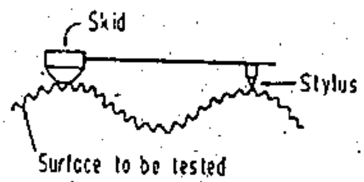


Fig.7.3

Stylus type instruments gnerally consist of the following units :

i. Skid or shoe.
ii. Finely pointed stylus or probe.
iii. An amplifying device for magnifying the stylus movement and indicator.
iv. Recording device to produce a trace and
v. Means for analysing the trace.

Skid or shoe is drawn slowly over the surface either by hand or by motor drive. It follows the general contours of the surface and provides a datum for measurments. The stylus moves over the surface with the skid. It moves vertically up and down due to surface roughness and records the micro-geometrical form of the surface. The stylus movements are magnified by an amplifying device and recorded to produce a trace. The trace is then analysed by some automatic device incorported in the instrument.

Disadvantages :

i. The instruments are bulky and complex.
ii. They are relatively fragile.
iii. Intial cost is high.
iv. Measurement are limited to a section of surface.

v. Need skilled operators for measurements.

vi. Distance between stylus and skid and the shape of the skid introduces errors in measurement for wavy surfaces.

Inspite of all the above disadvantages, the main advantage of such instruments is that the electrical signal available can be processed to obtain any desired roughness parameter or can be recorded for display or subsequent analysis. Therefore the stylus type instruments are widely used for surface texture measurements.

Q.5. Explain the following terms used in surface finish measurement: Roughness, Waviness, Effective profile, Lay, Sampling length, Mean line and centre line of profile.

Ans : i. Roughness : It is also called primary texture It refers to surface irregularities of small wave length i.e. finely spaced irregularities produced due the action of cutting tool, friction, wear or corrosion, tool feed rate or tool chatter. (refer fig.7.1)

ii. Waviness : Or secondary texture. This includes irregularities of considerable wave length of periodic character. i.e. irregularities of greater spacing which are in the form of waves. This type of irregularities are caused due to misalignment of centres,vibrations, machine or work deflections, warping etc. (refer 6.1)

iii. Effective profile : It is real contour of a surface obtained by using instruments.

iv. Lay : It is the direction of predominant surface pattern produced by tool marks or scratches. Symbols used to indicate the direction of lay are given below

|| = Lay parallel to the line representing surface to which the symbol is applied e.g. parallel shaping,O.D.turning.

| = Lay perpendicualr to the line representing the surface to which the symbol is applied e.g. side view of shaping. O.D. grinding.

x = Lay angular in both directions to the line representing the surface to which symbol is applied e.g. transversed end mill, end wheel grinding.

M = Multidirectinal lay e.g. lapping,superfinishing.

C = Lay approximately circular relative to the centre of the surface to which the symbol is applied e.g. facing on lathe.

R = Lay approximately radial relative to the centre of the surface to which the symbol is applied,e.g. grinding on a turntable, indexed on end mill,

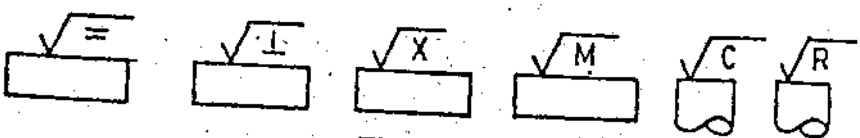


Fig.7.4

v. Sampling length : It is the length of profile necessary for the evaluation of the irregularities to be taken into account. It is measured in a direction parallel to the general direction of the profile.

vi. Mean Line of Profile : It is the line dividing the effective profile such that within the sampling length the sum of the squares of vertical ordinates(y1-y2....) between the effective profile points and the mean line is minimum.

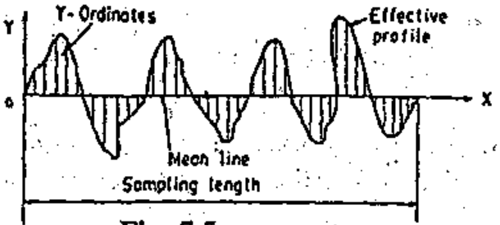


Fig. 7.5

vii.Centre Line of Profile : It is the line dividing the effective profile such that the areas embraced by the profile above and below the line are equal, For repeatitive wave form (profile) the centre line and mean line are equivalent. Though true repetitive profile is impossilbe in any manufacturing process, mean line and centre line are assumbed to equivalent for practical purposes.

Q.6. What do you mean by Ra and Rz values ?

Ans : Ra value : Roughness average (Ra) is the arithmetical mean deviation of the surface profile from the mean line. It is defined as the arithmetic average of the vertical ordinates (y_1, y_2, y_3....) from the mean regard less of the arithmetic signs.

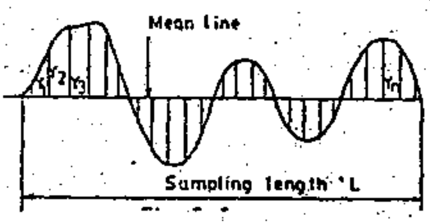


Fig.7.6

$$Ra = \frac{1}{L}\int_0^L Y.dL = \frac{\int_0^n |y|}{n}$$

Where n = number of divisions in sample length L.

Rz value : It is ten point height of irregularities and is defined as the average difference between the five highest peaks and five lowest valleys on the surface profile within the sampling length from a line parallel to the mean line and not crossing the profile, Mathematically,

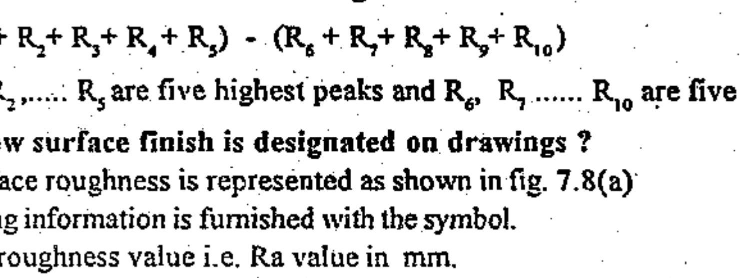


Fig.7.7

$$Rz = \frac{1}{5}(R_1 + R_2 + R_3 + R_4 + R_5) - (R_6 + R_7 + R_8 + R_9 + R_{10})$$

where R_1, R_2,..... R_5 are five highest peaks and R_6, R_7 ...... R_{10} are five lowest valleys.

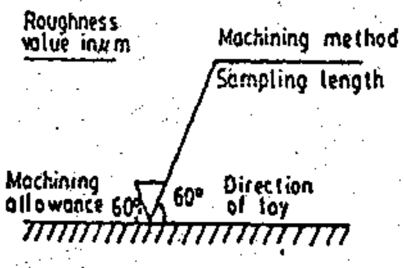
Q.7. State how surface finish is designated on drawings ?

Ans : The surface roughness is represented as shown in fig. 7.8(a)

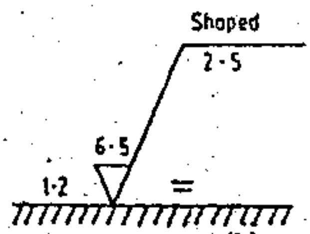
The following information is furnished with the symbol.

i. Surface roughness value i.e. Ra value in mm.

ii. Machining allowance in mm.



(a)



(b)

Fig. 7. 8

iii. Sampling length or instrument cut-off length in mm.

iv. Method of machining such as milled, ground, lapped, shapped etc.

v. Direction of lay in the symbol form as =, ⊥, X, M, C, R.

e.g. a milled surface having Ra value 6.3 m, with cut-off length 2.5mm and direction of lay parallel will be represented as shown in fig. 7.8 (b)

The surface roughness on drawing is represented by the symbols given below.

Symbol	Ra value in µm.
∇	8 to 25
∇ ∇	1.6 to 8
∇ ∇ ∇	0.025 to 1.6
∇ ∇ ∇ ∇	<0.025

Q.8. State and explain the methods of mesuring primary texture (roughness) of a surface.

Ans : In practice, three methods of measuring primary texture(roughness) of surface are used.

1. Ten point height method : (refer fig.7.7)

In this method, the average difference between the five highest peaks and five lowest valleys of surface texture within the sampling length, measured from a line parallel to the mean line and not crossing the profile is used to denote the amount of surface roughness. Mathematically,

Rz = ten point height of irregularities.

$$Rz = \frac{1}{5} \cdot (R_1 + R_2 + R_3 + R_4 + R_5) - (R_6 + R_7 + R_8 + R_9 + R_{10})$$

This method is relatively simple method of analysis and measures the total depth of surface irregularities within the sampling length. But it does not give sufficient information about the surface as no account is taken of frequency of the irregualrities and the profile shape. It is used when it is desired to control the cost of finishing for checking the rough machining.

2. R.M.S. Value : (refer fig.7.9)

In this method roughness is measured as the average deviation from the nominal surface. Root mean square value measured is based on the least squares.

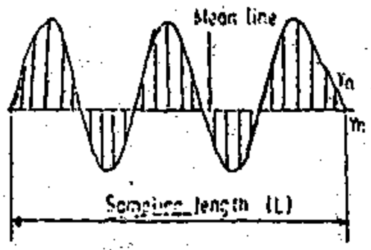


Fig.7.9

RMS value is defined as the square root of the arithmetic mean of values of the sqaures of ordinates of the surface measured from a mean line. It is obtained by setting many equidistant ordinates on the mean line ($y_1, y_2, y_3 + ...$) and then taking the root of the mean of the squared ordinates.

Let us assume that the sample length "L' is divided into "n' equal parts and y_1, y_2, y_3 ...are the heights of the ordinates erected a those points Then

$$\text{RMS average} = \sqrt{\frac{y_1^2 + y_2^2 + y_3^2 + ...}{n}}$$

3. **CLA value :** In this method also, the surface roughness is measured as the average deviation from the nominal surface.

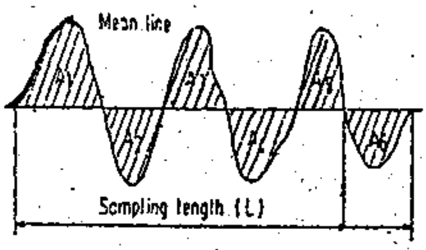


Fig.7.10

Centre Line Average or Arithmetic Average (AA) is defined as the average values of the ordinates from the mean line, regardless of the arithmetic signs of the ordinates.

$$\text{CLA Value or AA Value} = \frac{y_1 + y_2 + y_3 + ...}{n}$$

$$= \frac{A_1 + A_2 + A_3 + ...}{n}$$

$$= \Sigma \frac{A}{L}$$

CLA value measure is preferred to RMS value measure because its value can be easily determined by measuring the areas with planimeter or graph or can be readily determined in electrical instruments by integrating the movement of the stylus displaying the result on an average meter.

Q.9. What is meant by RMS value and CLA value ?

Ans : Refer Q. 8

Q.10. State the methods of measuring surface finish. Show by proper symbols and values the different surface finish.

Ans : The following two methods are used for measuring the surface finish of surfaces.

1. **Inspection by comparison methods :** In these methods, the surface texture is assessed by observation of the surfaces. These are the methods of qualitative analysis of surface texture. The texture of the surface to be tested is compared with that of a specimen of known roughness value and finished by similar machining process. Though these methods are rapid, the results are not reliable because they can be misleading if comparison is not made with the surfaces produced by similar techniques. The various methods available for comparison are :

i. Visual inspection,
ii. Scratch inspection,
iii. Touch inspection,
iv. Microscopic inspection,
v. Surface photographs,
vi. Micro-interferometer,
vii. Wallace surface Dynamometer and
viii. Reflected light intensity.

2. **Direct instrument measurements :** These are the methods of quantitative analysis. These methods enable to determine the numerical value of surface finish of any surface by using instruments of stylus probe type operating on electrical principles.e.g. profilometer, Tomlison surface meter, etc.

For symbols and values of surface finish refer Q.7

Q.11. Followings are the Ra values for jobs. Mention the method of manufacturing - with 3, 6. 4, 1.6 and 0.08 microns.

Ans :

Ra value in microns	**Mathod of manufacturing.**
3	Broaching or reaming.
6.4	Shaping, Drilling
1.6	Milling, grinding
0.008	lapping, superfinisheing.

Q.12 In the measurement of surface roughness, heights of successive 10 peaks and troughs were measured from a datum and were 33, 25, 30, 19, 22, 27, 29, and 20 microns. If these measurements were obtained on 10 mm length, determine CLA and RMS values of surfaces roughness ?

Ans : CLA value or Ra value or AA value =

$$\frac{y_1 + y_2 + y_3 + \ldots\ldots}{n}$$

$$\frac{33 + 25 + 30 + 19 + 22 + 18 + 32 + 27 + 29 + 20}{10}$$

$$= 25.5 \text{ microns.}$$

RMS Values

$$= \sqrt{\frac{y_1^2 + y_2^2 + y_3^2 + \ldots\ldots}{n}}$$

$$= \sqrt{\frac{33^2 + 25^2 + 30^2 + 19^2 + 22^2 + 18^2 + 32^2 + 27^2 + 29^2 + 20^2}{10}}$$

$$= 26.03 \text{ microns}$$

Q.13 Describe the comparison methods used for measuring the surface finish.

Ans. In inspection by comparison methods, the surface texture is assessed by observation of the surface. These are methods of qualitative analysis of the surface texture. The texture of the surface to be tested is compared with that of a specimen of known roughness value and finished by similar machining processes. Though these methods are rapid, the results are not reliable because they can be misleading if comparison is not made with the surface produced by similar techniques. The various methods available for comparision are :

1. Visual Inspection
2. Touch Inspection
3. Scratch Inspection
4. Microscopic Inspection
5. Surface Photographs
6. Micro-Interferometer
7. Wallace Surface Dynamometer
8. Reflected Light Intensity

Touch Inspection : This method can simply assess which surface is more rough, it cannot give the degree of surface roughness. Secondly, the minute flaws can't be detected. In this method, the finger tip is moved along the surface at a speed of about 25 mm per second and the irregularities as small as 0.0125 mm can be detected. In modified method a tennis ball is rubbed over the surface and surface roughness is judged thereby.

Visual Inspection : In this method the surface is inspected by naked eye. This method is always likely to be misleading particularly when surfaces with high degrees of finish are inspected . It is therefore limited to rougher surfaces.

Scratch Inspection : In this method a softer material like lead, babbit or plastic is rubbed over the surface to be inspected. The impression of the scratches on the surface produced is then visualised.

Microscopic Inspection : This is probably the best method for examining the surface texture by comparison. But since, only a small surface can be inspected at a time several readings are required to get an average value. In this method, a master finished surface is placed under the microscope and compared with the surface under inspection. Alternatively, a straight edge is placed on the surface to be inspected and a beam of light projected at about 60° to the work. Thus the shadow is cast into the surface, the scratches are magnified and the surface and the surface irregularities can be studied.

Surface Photographs : In this method magnified photographs of the surface are taken with different types of illumination to reveal the irregularities.

If the vertical illumination is used then defects like irregularities and scratches appear as dark spots and flat portion of the surface appears as bright area. In case of oblique illumination, reverse is the case. Photographs with different illumination are compared and the result is assessed.

Micro Interferometer : In this method, an optical flat is placed on the surface to be inspected and illuminated by a monochromatic source of light. Interference bands are studied through a microscope. The scratches in the surface appear as interference lines extending from the dark bands into the bright bands. The depth of the defect is measured in terms of the fraction of the interference bands.

Wallace Surface Dynamometer : It is a sort of friction meter. It consists of a pendulum in which the testing shoes are damped to a bearing surface and a predetermined spring pressure can be applied. The pendulum is lifted to its initial starting position and allowed to swing over the surface to be tested. If the surface is smooth, then there will be less friction and pendulum swings for a longer period. Thus, the time of swing is a direct measure of surface texture.

Reflected Light Intensity : In this method a beam of light of known quantity is projected upon the surface. This light is reflected in several directions as beams of lesser intensity and the change in light intensity in different directions is measured by a photocell. The measured intensity changes are already calibrated by means of reading taken from surface of known roughness by some other suitable method.

Surface Roughness Comparison Specimen : The roughness comparison specimens are either flat or segmented cylindrical pieces having known roughness value. They are used for quantitative assessment of surface roughness of a finished product by comparison. These specimens are made up of hard, wear resistant materials such as steel having hardness of about 400 HB, nickel alloy or metallised plastics. They are rigidly supported on a base to prevent warping or distortion during use.

The assessment of surface roughness of a finished product is done by comparison with the specimen of known roughness value and finished by machining process similar to that of the product under test. The comparison may be made by visual inspection or touch inspection.

In visual inspection, the product and the specimen are seen simultaneously and the roughness of the product is compared with that of the specimen by naked eye. In touch inspection, the feel of the surface is experienced by moving finger naily lightly across the lay of the roughness of the product to be tested and afterwards moving across the surface of the specimen of known roughness value. Then the two feels are compared to assess the surface roughness of the product.

These specimens have also proved to be very good devices for training the personnel to judge the R_a value by feel and appearance of the surface. It should be noted that the surface being compared should be clean and dry. However, the results obtained by comparison vary from person to person. Errors may also be caused due to difference in the material, shape, method of machining, method of finish, etc. of the product and the specimen.

Q.14 The surface finish on the milled surface is not to exceed 5 mm Ra with a cut-off length 2 mm, machining allowance 0.5 mm and direction of lay parallel. How will you represent it on a drawing ?

Ans.

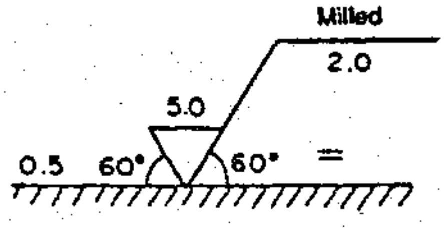


Fig. 7.11

Q.15. Describe any one method of checking the surface finish of a mechined surface.
Ans : There are two methods used for measuring surface finish of machined surfaces,viz. comparison methods and direct instrument measurements. Comparative methods are used for qualitative analysis of surface texture while instruments are used for quantitive analysis i.e. to determine numerical value of the surface finish. Nearly all the instruments used are stylus probe type of instruments, operating on electrical principles. The output signal is amplified and then used to operate a recording or indicating instrument. One of the direct measuring instruments is explained below.

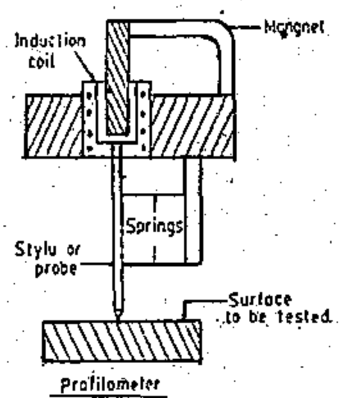


Fig.7.12- Profilometer

It is an indicating and recording instrument used to measure roughness in microns. The principle of the instrument is similar to gramophone pick up. The instrument consists of two principle units; a tracer and an amplifier. Tracer is a finely pointed stylus. It is mounted in the pick up unit which consists of an induction coil located in the field of a permanent magnet. When the tracer is moved across the surface to be tested, it is displaced vertically up and down due to the surface irregularities.This causes the induction coil to move in the field of the permanent magnet and induces a voltage. The induced voltage is amplified and recorded.

This instrument is best suited for measuring surface finish of deep bores.

Q.16 Describe the construction and working of the Taylor-Hobson-Talysurf.
Ans. The Taylor-Hobson-Talysurf : Taylor-Hobson Talysurf is a stylus and skid type of instrument working on carrier modulating principle. Its response is more rapid and accurate as compared to Temlinson Surface Meter. The measuring head of this instrument consists of a sharply pointed diamond stylus of about 0.002 mm tip radius and skid or shoe which is drawn across the surface by means of a motorised driving unit.

In this instrument the stylus is made to trace the profile of the surface irregularities, and the oscillatory movement of the stylus is converted into changes in electric current by the arrangement as shown in Fig. 7.13. The arm carrying the stylus forms an armature which pivots about the centre piece of E-shaped stamping. On two legs of (outer pole pieces) the E-shaped stamping there are coils carrying an a.c. current. These two coils with other two resistances form an oscillator. As the armature is pivoted about the central leg, any movement of the stylus causes the air gap to vary and thus the amplitude of the original a.c. current flowing in the coils is modulated. The output of the bridge thus consists of modulation only as shown in Fig. 7.13. This is further demodulated so that the current now is directly proportional to the vertical displacement of the stylus only.

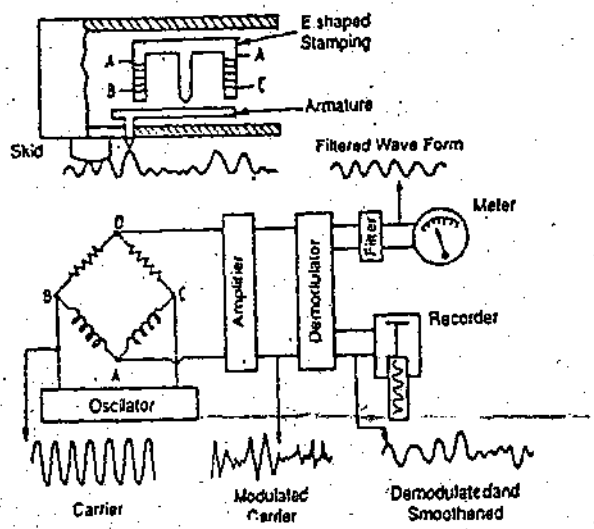


Fig. 7.13 Taylor-Hobson-Talysurf

The demodulated output is caused to operate a pen recorder to produce a permanent record and the meter to give a numerical assessment directly.

Chapter..... 8

MACHINE TOOL TESTING TECHNIQUES

Q.1. What is straightness? Explian briefly how the striaghtness is measured.

Ans : It is not easy to define what is meant by straightness. In metrology a line is said to be straight over a given length if its deviations w.r.t. the ideal reference line are within specified tolerence limits or if the variations of the distances of its points from two planes perpendicular to each other and parallel to the general direction of the line remain within specified tolerence limits.

The most convenient method of testing straightness of a surface of any length to a high degree of accuracy is by using spirit level or auto-colimator.

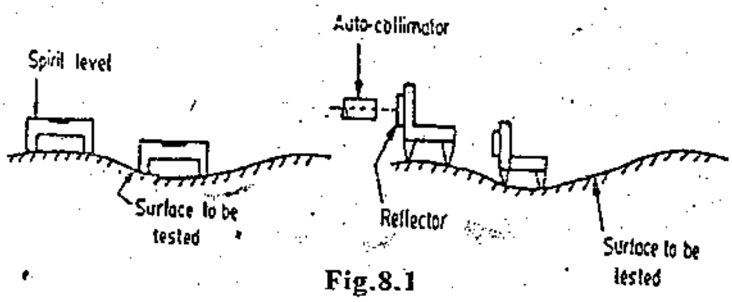


Fig.8.1

A straight line is drawn on the surface whose straightness is to be checked. A sensitive spirit level,fitted with two feet at a convenient distance apart is moved along this line in steps equal to the pitch distance between the centre lines of the feet. For each position, the reading is noted. Variations in the bubble position represent angular variations in the surface and these are converted into differences in height of the feet above or below the starting point.

If auto-colimator is used, then a block fitted with feet at convenient distance apart and carrying a plane reflector is moved along the surface in steps equal to the pitch of the feet. Angular variations are measured with auto-colimator.

Spirit level can be used to check only horizontal surfaces, but auto-collimator may be used on a surface in any plane.

Q.2. State the various methods used to test straightness of a surface and explain briefly any one of them.

Ans : The following methods are used to measure the straightness of a surface.

i. Using straight edges
ii. Spirit level method.
iii. Auto-colimator method
iv. Liquid gauge method.
v. Beam comparator method.

Straight edge method : This is simplest method of testing straightness of a surface. A straight edge of known accuracy is applied to the surface to be tested and degree of contact is determined by marking, feelers or light gap. The more accurate method of measuring straightness by a straight edge is wedge method.

A straight edge is supported at the points for minimum deflection on two unequal piles of slip gauges so that it is at a slight inclination to the surface to be tested. The distance between the supports is divided into number of equal parts and marked on the straight edge. If both straight edge and surface are perfectly straight,the gap at each point will vary uniformaly.

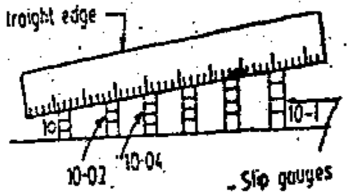


Fig.8.2

Assume that the slip gauges used have values 10mm and 10.1mm as shown in the Fig.8.2 Let the distance between the slip values be divided into 5 number of equal parts. The gap at each point will, therefore, vary by 0.02 mm (0.1/5). Now we can determine the value of pile of slips required for exact contact at each position,e.g. at the first position it is 10mm; at the second position it will be 10.02mm; at the third it will be 10.04 mm and so on. Insert the slip gauges of appropriate value at each marked position. If there is no error, the slips will make contact with both the surfaces exactly at the marked positions. If, however, there are errors in straightness, the slips will not fit exactly at their marked positions, but will be displaced one way or other along the stright edge by amounts proportional to the errors.

This is very sensitive method of measurement and can be made as sensitive as desired by choosing a small wedge angle and large number of measuring positions. Care must be taken to see that the slips do not wring to the surface, otherwise the whole sensitivity will be lost.

Q.3. Describe briefly Beam comparator method of testing straightness.

Ans : This method uses an instrument of Beam type designed by Rochdale Technical College and manufactured by the sigma Insturment Company, Ltd., under the name " Rochdale Flatness Tester ". Beam comparator was originally designed for testing the flatness of surface tables, but can also be used for testing the straightness of surfaces.

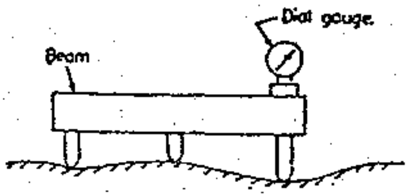


Fig.8.3

The instrument consists of a light, rigid beam on the underside of which are fitted two ball-ended feet;one at the centre and other near one end. At the other end of the beam,a dial gauge is fitted. The axis cf the dial guage plunger is vertical and in line with the two fixed feet. The instrument is placed on the surface to be tested on the two feet and moved along the surface in steps equal to the pitch of the feet. At each position the reading of the dial gauge is taken. The readings give the heights at different positions, above or below the line through the two points on which the fixed feet rest.

This instrument can be used to check the straightness of long surfaces in any position.

Q.4. Explain how the flatness of a surface can be tested.

Ans : Flatness testing is nothing but extension of straightness testing. A surface can be considered to be formed by infinitely large number of lines. The surface will be truly flat only if all the lines are straight and they lie in the same plane. Therefore, to test the flatness of a surface it is essential to measure the straightness of some of the number of lines forming it.

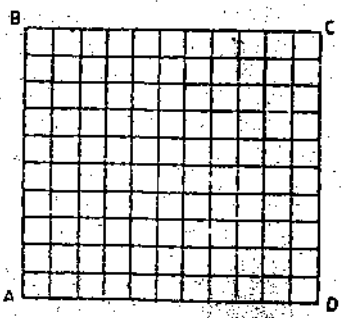


Fig.8.4

The deviation of a large surface such as surface table or machine table from the true plane can be determined by the use of spirit level, auto-colimator or Beam comparator. The principle of the method is same for all the instruments.

First number of lines parallel to the sides of the surface to be tested are drawn on the surface, at distances equal to the pitch distance of the base of the instrument used. The straightness of all these lines is determined by moving the instrument along the lines and then those lines are related with each other in order to verify whether they lie in the same plane or not. Thus the whole surface is surveyed along a number of lines and the variation in heights of the points of instersection of the lines is detemised w.r.t.a datum plane. This datum plane is then adjusted to become the mean true plane for the surface.

Q.5 Describe the methods of checking :

i. Parallelism of two axes,

ii. Parallelism of an axis to a plane.

Ans : Parallelism of two axes :

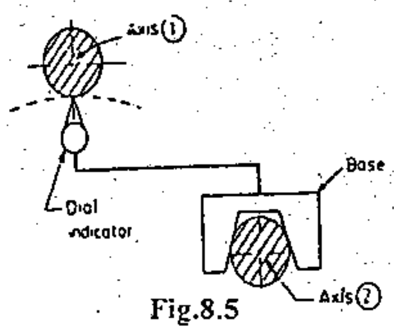


Fig.8.5

Assume that the parallelism of axes of two cylinders is to be tested. The instrument used for the test is dial indicator. It is supported on a base of such shape that the base slides along one of the cylinders. The dial indicator is so adjusted that its feeler (plunger) slides along the another cylinder. The maximum deviation between the axes of the cylinders at any point may be determined by gently rocking the dial indicator in a direction perpendicular to the axes.

Parallelism of an axis to a plane : In this test, a dial indicator is held on a support with a flat

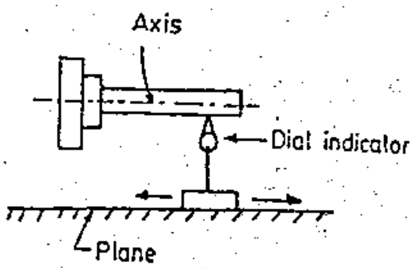


Fig.8.6

to touch the surface of the cylinder representing the axis. The insturment is moved along the plane for a distance over which parallelism test is to be performed. At each point of measurement, readings of the instrument are noted. If the maximum difference between the several readings taken at number of points does not exceed a predetermined value, the axis can be said to be parallel to the plane.

Q.6. Explain how the squareness of an axis of rotation with a given plane can be tested?

Ans : Assume that squareness of axis of rotation of a spindle with a plane is to be tested. A dial indicator is mounted on the arm attached to the spindle. The feeler (plunger) of the dial indicator is adjusted parallel to the axis of rotation of the spindle, so that as the spindle revolves, the plane of rotation of free end of the plunger is perpendicular to the axis of rotation. Now the plunger of the dial indicator is made to touch the plane under test. The spindle is slowly revolved and readings are noted at various positions. The variations in the readings of the instrument represent the deviation of parallelism between the plane of free end of the plunger and the plane under test or deviation in the squarencess of the axis of rotation of the spindle with the plane under test.

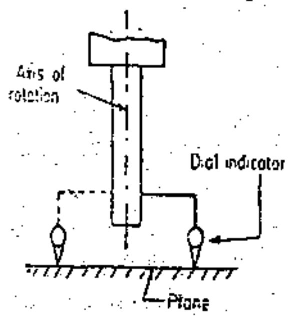


Fig.8.7

Q.7. Axis of rotation of live centre of lathe machine is required to be checked for parallelism with respect to lathe bed surface. State the instruments required and describe method with sketch ?

Ans :

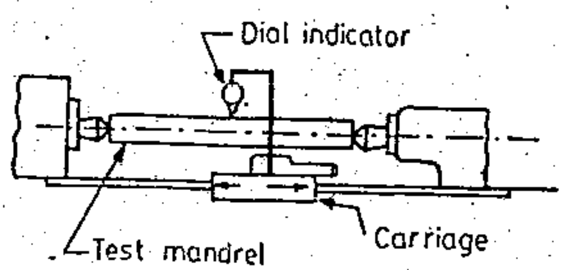


Fig.8.8

The instruments required for the test are a test mandrel and a dial indicator.

The test mandrel is held between the centre on the lathe machine. Dial indicator is held in the compound rest and adjusted so that its feeler (plunger) touches the mandrel surface, first above the bar and then on the side of it. The mandrel is kept stationary and dial gauge is moved along by traversing the carriage. Any inaccuracy either in the vertical or horizontal plane is indicated on the dial gauge.

Q.12. What is optical flat? Explain how interferecne fringes are formed when optical flat is placed ona surface to be tested ?

Ans : Optical flat is a cylindrical piece of a transparent material usually glass or quartz, with one or two highly polished working surfaces. It is used to check the flatness of pieces, gauge blocks, micrometer anvils, erc.

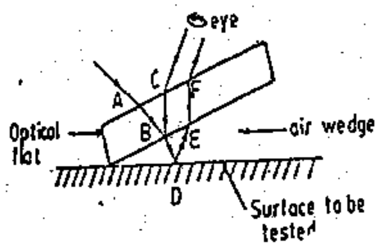


Fig.8.13

When an optical flat is placed on work piece surface it will not form an intimate contact, but will be at slight inclination to the surface, forming an air wedge between the surfaces. If optical flat is now illuminated by monochromatic (single wave length) source of light, interference fringes will be observed. These are produced by the interference of light rays reflected from the bottom face of the optical flat and top face of the work piece being tested through the layer of air.

Consider a ray of light incident at A on an optical flat placed over a work piec. to be tested. It passes through the optical flat and at its bottm face it is divided into two components. One comonent of the incident rays gets reflected from the bottom of the optical flat at B in the direction BC and the other portion, transimtted through the layer of the entrapped air will be reflected by the top face of the work piece at D in the direction DEF. The paths travelled by both the reflected rays differ by an amount BDE i.e. the second component of the ray lag behind the first by an amount equal to twice the air gap. Though both the components have the same wave length and start in phase, the difference in their paths causes them to be either in phase or out of phase at C and F. If the path difference between the reflected rays is even multiple of half wave length, the extra distance the ray reflected from the work piece surface has to travel will cause it to be 180° out of phase with the ray reflected from the lower face of the optical flat and the reflected rays will cancel each other and darkness will be observed. If the path diference is an odd multiple of half wave length they will be in phase with each other and will reinforce each other. So brightness will be observed. Depending upon the air gap between surfaces, we will get alternate dark and bright bands due the interference of light.

Q.13. With what instrument and how you will take finish maesurement of micrometer anvil surfaces ?

Ans : Deviations of flatness of the micrometer anivl surfaces are tested with an optical flat. Optical flat is brought into contact with each of the two anvil surfaces in turn and moved till minimum number of interference fringes are observed. i.e. closed curves are observed. The number of interference fringes observed on each of the two anvil surfaces should not be more than 2 for all ranges of Grade - I micrometers.

The parallelism of the anivl surfces is also tested with optical flat (of type B). Optical flat is placed in contact with the fixed anvil and moving anvil is brought in contact with the opposite face of the optical flat. Interference fringes produced are observed. The sum of the interference fringes observed on the two surfaces should not exceed 6,8 and 10 for ranges 0-25,25-75 and 75-100 mm micrometers.

Q.14. By using optical flat and monochromatic light state how you will determine whether the given flat or curved sufaces are concave or convex

Ans : When an optical flat is placed on a surface to be tested and illuminated by a monochromatic light interference fringes i.e. alternate dark and bright bands are observed. The fringe pattern represents the contour map of the surface under test. Each band indicates a path of constant seperation between the optical flat and the surface under test.

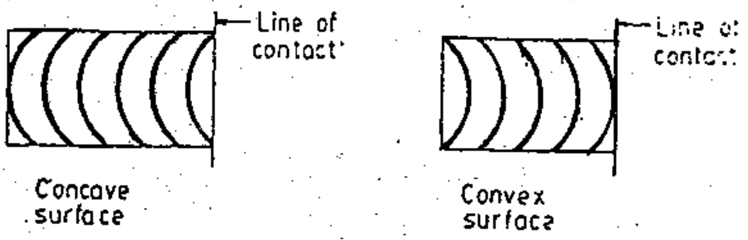


Fig. 8.14.

If the surface to be tested is perfectly flat the fringes or bands produced will be straight and even after applying light pressure at any edge there will not be change in the fringe pattern. But if the surface is not flat, the bands obtained will be curved. (refer fig 6.) If the band curve around the point or line of contact, the surface is convex and if the bands curve in the opposite direction. The surface is concave. If the curvature of bands is more, it indicates more convexity and vice-versa.

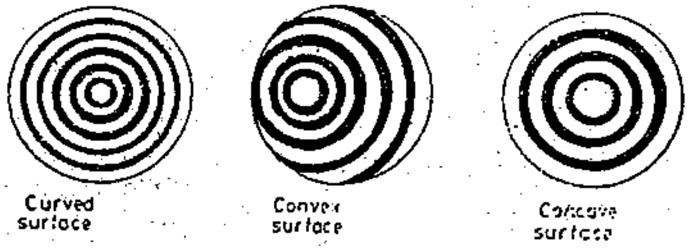


Fig.8.15

When the surface under test is curved, circular bands with a central bright spot at the point of contact are observed. To determine whether the surface is concave or convex, it is pressed lightly with finger tip at one edge. If the centre of the bands is displaced and the fringes come closer, the surface under test is convex. If application of light presure at edge makes no change, then light pressure is applied at the centre. If the bands move apart and number of bands is reduced the surface to be tested is concave.

Q.15. List the various geometrical checks made on machine tools ?

Ans : The various geometrical/alignment checks generally carried out on machine tools are:

1. **Straigthness :** Straightness of guide ways and slide ways of machine tools.
2. **Flatness :** flatness of machine table and slide ways.
3. **Parallelism Equidistance and alignment :** of slide ways and axes of various moving parts with reference to some standard planes.
4. **True running and alignment :** of shafts and spindle relative to other axes and surfaces.
5. **Pitch or Lead error :** i) of lead screw ii) of gears.
6. **Eccentricity, out of roundness, periodical axial slip camming etc.**
7. **Dividing errors :** of dividing heads ; indexing heads.

Q.16. Name the equipment required for geometrical tests ?

Ans : The measuring equipment used for alignment tests are :

1. Dial gauge.
2. Test mandrels.
3. Straight edges and squares.
4. Spirit level.
5. Auto collimator.
6. Waviness meter etc.

Q.17. Distinguish between alignment test and performance test of a machine tool?

Ans : The alignment test is carried out to check the grade of manufacturing accuracy of the machine tool. It consists of checking the relationship between various machine elements (such as bed, table, spindle etc.) when the machine tool is idle and unloaded.

Performance test consists of chekcing the accuracy of the finished components and is known as practical test. The performance test therfore, consists of preparing the actual test jobs on the machine and checking the accuracy of the jobs produced. It is carried out to know whether the machine tool is capable of producing the parts within the specified limits or not.

Q.18. Describe how you would perform the following alignment tests.

i. Straightness of saddle level in horizontal plane.

ii. Alignment of both centres in vertical plane.

iii. **Parallelism of main spindle to saddle movement.**

iv. **True running of head stock centre.**

v. **Parallelism of tail stock sleeve with saddle movement / machine bed guides.**

Ans : i. Straightness of saddle level in horizontal Plane.

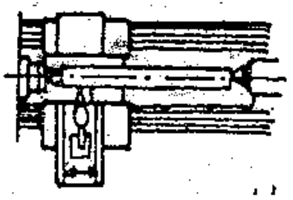


Fig. 8.16

Measuring Instruemnts : Cylindrical test mandrel. (600mm long), dial indicator.

Procedure : The mandrel is held between centres. The dial indicator is mounted on the saddle. The spindle of the dial indicator is allowed to touch the mandrel. The saddle is then moved longitudinally along the length of the mandrel. Readings are taken at different places.

Permissible error : 0.02 mm over length of mandrel.

ii. **Alignment of both the centres in the vertical plane :**

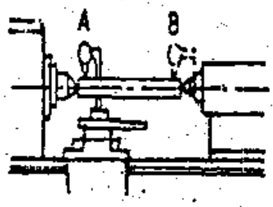


Fig 8.17

Measuring instruments : Cylindrical mandrel 600 mm long, dial gauge.

Procedure : The test mandrel is held between centres, on the saddle in vertical plane as shown in Figure. Then the saddle along with dial gauge is travelled longitudinally along the bed ways, over the entire length of the mandrel and the readings are taken at different places.

Permissible error : 0.02 mm over 600 mm length mandrel. (Tailstock centre is to lie higher only).

iii. **Parallelism of main spindle to saddle movement :**

a. In vertical plane b. In horizontal plane.

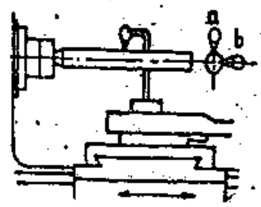


Fig 8.18

Measuring Instruemnts : Test mandrel with taper shank and 300 mm long cylindrical measuring part, dial gauge.

Procedure : The dial gauge is mounted on the saddle. The dial gauge spindle is made to touch the mandrel and the saddle is moved to and fro. It is checked in vertical as well as in horizontal plane.

Permissible error : a) 0.02/300 mm (Mandrel rising towards free end only. (b) 0.02/300 mm (Mandrel inclined at free end towards tool pressure only.

iv. **True running of head stock center :**

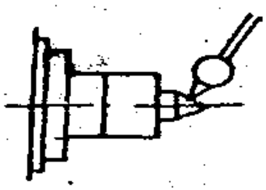


Fig 8.19

Measuring Instruement : Dial gauge.

Procedure : The live centre is held in the tailstock spindle and it is rotated. Its trueness is checked by means of dial gauge.

Permissible error 0.01 mm.

v. Parallelism of tailstock sleeve to saddle movement :

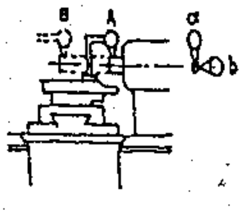


Fig. 8.20

Measuring Instruments : Dial indicator.

Procedure : Tailstock sleeve is fed outwords. The dial gauge is mounted on the saddle. Its spindle is touched to the sleeve at one end and then saddle is moved to and fro, it is checked in H.P. and V.P. also.

Permissible error : a) 0.01/100 mm. (Tailstock sleeve inclined towards tool pressure only. (b) 0.01/100 mm (Tailstock sleeve rising towards free end only.)

Q.19. Describe how you would perform the following alignment tests.

i. **Movement of upper slide parallel with main spindle in vertical plane.**
ii. **Parallelism of tailstock sleeve taper socket to saddle movement.**
iii. **Levelling of lathe.**
iv. **True running of locating cylinder of main spindle.**
v. **True running of taper socket in main spindle.**

Ans : i. Movement of upper slide parallel with main spindle in vertical plane :

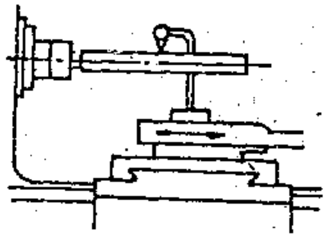


Fig. 8.21

Measuring Instruments :

Test mandrel with taper shank and 300 mm long cylindrical measuring part, dial gauge.

Permissible error : 0.03/100 mm.

ii. Parallelism of tailstock sleeve taper socket to saddle movement : a) V.P. b) in H.P.

Measuring Instruments : the mandrel with taper shank and a cylindrical measuring part of 300 mm length, dial indicator.

Procedure : Test mandrel is held with its taper shank in a tail stock sleeve taper socket. The dial gauge is mounted on the saddle. The dial gauge spindle is made to touch with the mandrel. The saddle is then travelled longitudinally along the bed way and readings are taken.

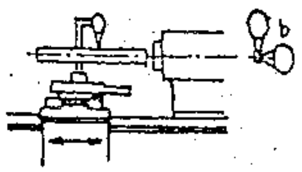


Fig. 8.22

iii. Levelling of Lathe : a. in longitudianl direction.
b. in transverse direction.

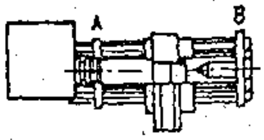


Fig.8.23

Measuring Instruement : Spirit level, gauge block to suit the guide ways of the lathe bed.

Procedure : The gauge block with the spirit level is placed on the bed ways on the front position, back position and in cross wise direction. The position of the bubble in the spirit level is checked and the readings are taken.

v. Parallelism of tailstock sleeve to saddle movement :

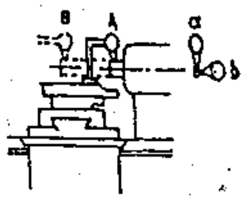


Fig. 8.20

Measuring Instruments : Dial indicator.

Procedure : Tailstock sleeve is fed outwords. The dial gauge is mounted on the saddle. Its spindle is touched to the sleeve at one end and then saddle is moved to and fro, it is checked in H.P. and V.P. also.

Permissible error : a) 0.01/100 mm. (Tailstock sleeve inclined towards tool pressure only. (b) 0.01/100 mm (Tailstock sleeve rising towards free end only.)

Q.19. Describe how you would perform the following alignment tests.

i. Movement of upper slide parallel with main spindle in vertical plane.

ii. Parallelism of tailstock sleeve taper socket to saddle movement.

iii. Levelling of lathe.

iv. True running of locating cylinder of main spindle.

v. True running of taper socket in main spindle.

Ans : i. Movement of upper slide parallel with main spindle in vertical plane :

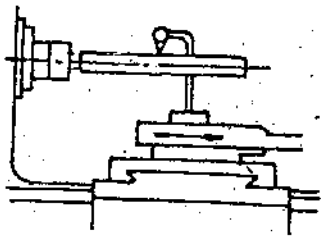


Fig. 8.21

Measuring Instruments :

Test mandrel with taper shank and 300 mm long cylindrical measuring part, dial gauge.

Permissible error : 0.03/100 mm.

ii. Parallelism of tailstock sleeve taper socket to saddle movement : a) V.P. b) in H.P.

Measuring Instruments : the mandrel with taper shank and a cylindrical measuring part of 300 mm length, dial indicator.

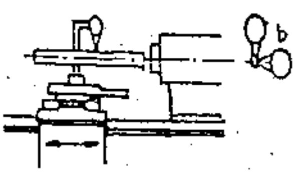


Fig. 8.22

Procedure : Test mandrel is held with its taper shank in a tail stock sleeve taper socket. The dial gauge is mounted on the saddle. The dial gauge spindle is made to touch with the mandrel. The saddle is then travelled longitudinally along the bed way and readings are taken.

iii. Levelling of Lathe : a. in longitudianl direction.

b. in transverse direction.

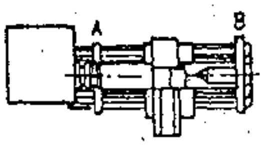


Fig.8.23

Measuring Instruement : Spirit level, gauge block to suit the guide ways of the lathe bed.

Procedure : The gauge block with the spirit level is placed on the bed ways on the front position, back position and in cross wise direction. The position of the bubble in the spirit level is checked and the readings are taken.

Permissible error : Front guide ways : 0.02 mm/m convex only. Rear guide ways, 0.01 mm/m convex only to .02 mm/m convex only cross wise direction : 0.02 mm/m. No twist permitted.

iv. True running of locating cylinder of main spindle :

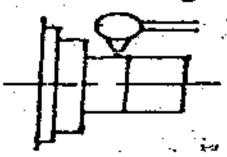


Fig. 8.24

Measuring Instrument : Dial gauge.

Procedure : The dial gauge is mounted on the bed, touching at a point on main spindle. The main spindle is rotated by hand and readings of dial gauge are taken.

Permissible error : 0.01 mm.

v. True running of taper socket in main spindle :

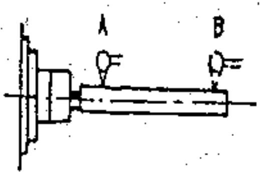


Fig. 8.25

Instruments Required : Test mandrel with taper shank and 300 mm long cylindrical measuring part, dial guage.

Procedure : The test mandrel is held with its taper shank in a head stock spindle socket. The dial gauge is mounted on the saddle. The dial gauge spindle is made to touch with the mandrel. The saddle is then travelled longitudinally along the bed ways and readings are taken at the point A and B shown in figure.

Permissible Error : Position A 0.01 mm, Position B 0.02 mm.

Q.20. Describe in detail, how would you check ?

i. The flatness of clamping surfaces of base / table.

ii. True running of spindle taper.

iii. Perpen - dicularity of drill head guide to the table.

iv. Squareness of spindle axis with table.

Ans : i. Faltness of clamping surface of base/table : Refer figure below. The test is performed by placing a straight edge on two gauge block on the base plate (on table) in various positions and the error is noted down by inserting the feeler gauges. This error should not exceed 0.1/100 mm clamping surface should be concave only.

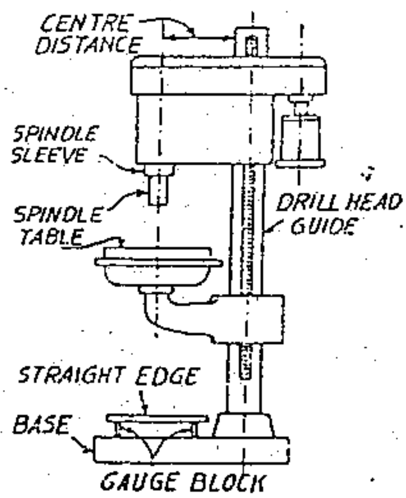


Fig. 8.26(a)

ii. True running of spindle taper : For this test, the test mandrel is placed in the tapered hole of spindle and a dial indicator is fixed on the table and its feeler made to scan the mandrel. The spindle is rotated slowly and readings of indicator noted down. The error should not exceed 0.03/100 mm for machines with taper upto Morse No.2 and 0.04/300 mm for machines with taper larger than Morse No.2.

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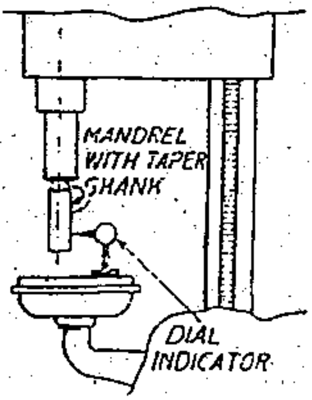
Assistant Manager - QA/QC



(b)

iii. Perpendicularity of drill head guide to the table : The squareness (perpendcularity) of drill head guide to the base plate is tested :

a. in a vertical plane passing thourgh the axes of both spindle and column, and

b. in a plane at 90^0 to the plane at (a).

The test is performed by placing the frame level (with graduations from 0.03 to 0.05 mm/m) on guide column and table and the error is noted by noting the difference between the readings of the two levels. This error should not exceed 0.25/1000 mm guide column for (a) and the guide column should be inclined at the upper end towards the front only, and 0.15/1000 mm for (b).

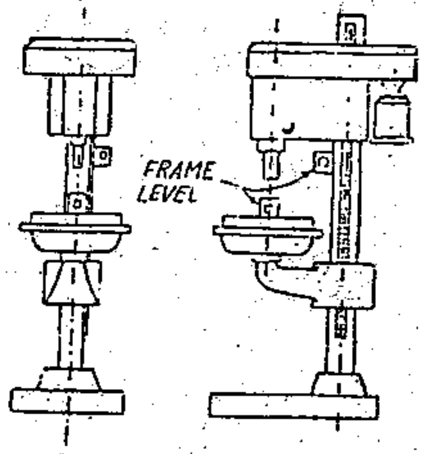


Fig. 8.26(c) Test for perpendicularity of drill head guide with table.

iv. Squareness of spindle axis with table : For this test a straight edge is placed in positions AA' and BB'. Work table is arranged in the middle position of its vertical travel. The dial indicator is mounted in the spindle tapered hole and its feeler made to touch the straight edge first say at A and reading noted down. The spindle is rotated by 180^0 so that the feeler touches at point A' and again reading is noted down. The difference of two readings gives the error in squareness of spindle axis with table. Similar readings are noted down by placing the straight edge in position BB'.

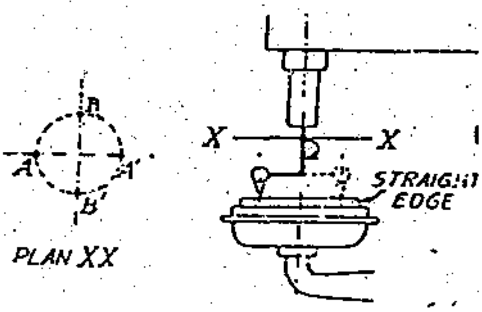


Fig. 8.28

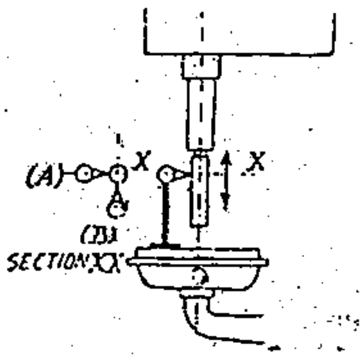
The permissible errors are 0.08/300 mm with lower end of spindle inclining towards column only for set up AA' and 0.05/300 mm for set up BB'.

Q.21 Describe in detail the following alignment tests on drilling machine.

i. Parallelism of the spindle axis with its vertical movement.

ii. Squareness of clamping surface of table to its axis.

Ans : i. Parallelism of the spindle axis with its vertical movement : This test is perfomred into two planes (A) and (B) at right angles to each other. The test mandrel is fitted in the tapered hole of the spindle and the dial indicator is fixed on the table with its feeler touching



the mandrel. The spindle is adjusted in the middle position of its travel. The readings of the dial indicator are noted when the spindle is moved in upper and lower directions of the middle position with slow vertical feed mechanism. The permissible errors are : for plane (A) for plane (B)

0.03/100 mm	0.03/100 mm
0.05/300 mm	0.05/300 mm

Fig. 8.29 For machines with taper upto Morse No. 2 For machines with taper larger than morse No. 2.
(Lower end of mandrel can be inclined towards column only.)

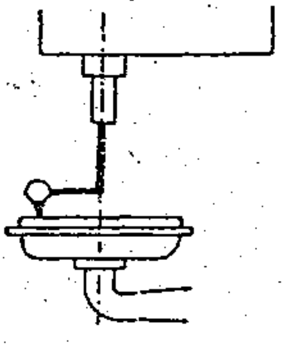


Fig. 8.30

ii. Squareness of clamping surface of table to its axis : For performing this test, the dial indicator is mounted in the tapered hole of the spindle and its feeler is made to touch the surface of table (refer Fig.10.16). Table is slowly rotated and the readings of dial gauge noted down, which should not exceed 0.05/300 mm diameter.

Q.8. Describe the following alignment test on knee type horizontal milling machine ?

i. Flatness of work table.

ii. Parallelism of the work table surface of the main spindle.

iii. Parallelism of the clamping surface of the work table in its longitudinal motion.

iv. Parallelism of the cross (transverse)

Ans : i. Flatness of work Table :

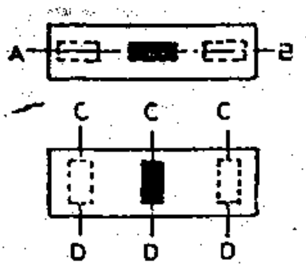


Fig. 8.31

a. In longitudinal directions.

b. In transverse direction.

Measuring Instruements : Spirit level.

Procedure : A spirit level is placed directly on the table at points about 25 to 30 cm apart, at A,B,C for longitudinal test, and at D,E and F for the transverse test. The readings are noted.

Permissible error : Direction A -B - C ± 0.04/mm Direction D-E-F + 0.04/mm.

ii. Parallelism of the work table surface to the main spindle :
Measuring Instruments : Dial indicator, test mandrel 300 mm long spirit level.

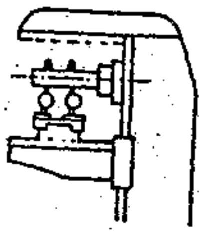


Fig. 8.32

Procedure : The table is adjusted in the horizontal plane by a spirit level and is then set in its mean position longitudinally. The mandrel is fixed in the spindle taper. A dial gauge is set on the machine table, and the feeler adjusted to touch the lower surface of the mandrel. The dial gauge readings at (A) and (B) are observed, the stand of the dial gauge being moved while the machine table remains stationery.

Permissible error : 0.02/300 mm.

iii. Parallelism of the clamping surface of the work table in its longitudinal motion :

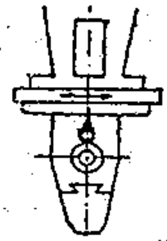


Fig. 8.33

Instruments : Dial gauge, straight edge.

Procedure : A dial gauge is fixed to the spindle. The dial gauge spindle is adjusted to touch the table surface. The table is then moved in longitudinal direction and readings are noted. If the table surface is uneven it is necessary to palce a straight edge on its surface and the dial gauge feeler is made to rest on the top surface of the straight edge.

Permissible error : 0.02 upto 500 mm length of traverse, 0.03 up to 1000 mm and 0.04 above 1000 mm length of traverse.

iv. Parallelism of the cross (transverse) movement of the work table to the main spindle :

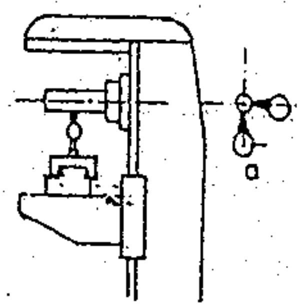


Fig. 8.34

a. in vertical plane

b. in horizontal plane.

Instruments : Dial gauge, test mandrel with taper shank.

Procedure : Work table is set in its mean position. The mandrel is held in the spindle. A dial gauge fixed to the table is adjusted so that its spindle touches the surface of the mandrel. The table is moved crosswise and the error is measured in the vertical plane and also in the horizontal plane.

Permissible error : 0.02 for the overall transverse movement of work table.

Q.22. Describe the following alignment tests on knee type horizontal milling machine ?

i. True running of the internal taper of the main spindle.

ii. Squareness of the centre T slots of work table with main spindle.

iii. Parallelism of the T-slots with the longitudinal movement of the table.

iv. Parallelism between the main spindle and the guiding surface of the overhanging arm.

Ans : i. True running of the internal taper of the main spindle :

Instruments : 300 mm long test mandrel, dial gauge. The test mandrel with its taper shank is held in the main spindle. Dial gauge is kept scanning the periphery of mandrel, spindle

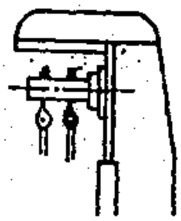


Fig. 8.35

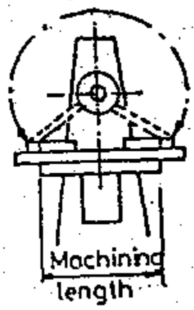


Fig. 8.36

is rotated and dial gauge readings are noted at different points say A & B as shown.

Permissible error : Position A : 0.01, Position B : 0.02

ii. Squareness of the centre T-slots of worktable with main spindle :

Instruments : Dial, gauge, special bracket.

Procedure : To check the perpendicularity of the locating slot and the axis of the main spindle, the table should be arranged in the middle position of its longitudinal movement, and a bracket with a tenon at least 150 mm long inserted in the locating slot, as shown in Fig. 10.18

A dial gauge should be fixed in the spindle taper, the feeler being adjusted to touch the vertical face of the bracket. Observe the reding on the dial gauge when the bracket is near one end of the table, then swing over the dial gauge and move the bracket so that the corresponding readings can be taken near the other end of the table.

Permissible error : 0.025 mm in 300 mm.

iii. Parallelism of the T-slots with the longitudinal movement of the table :

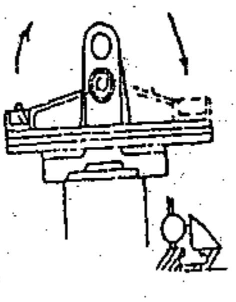


Fig. 8.37

Instruments : Dial gauge special bracket.

Procedure : The general parallelism of the T-slots with the longitudinal movement of the table is checked by using a 150 mm long bracket having a tenon which enters the slot. The dial gauge is fixed to the spindle taper and adjusted so that its feeler touches the upper surface of the bracket. The table is then moved longitudinally while the bracket is held stationary by the hand of the operator and dial gauge deviations from parallelism is noted down.

Permissible error : 0.0125 mm in 300 mm.

iv. Parallelism between the main spindle and the guiding surface of the overhanging arm :

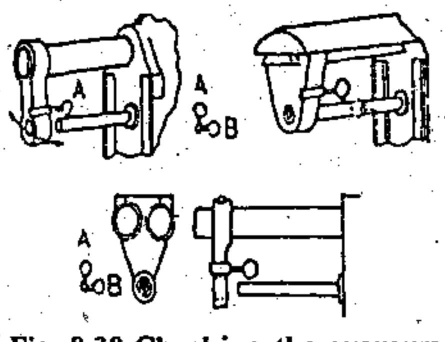


Fig. 8.38 Checking the overarm to the cutter spindle.

Instruments : Dial gauge, mandrel.

Procedure : The overhanging arm is clamped in its extreme extended position. The dial gauge is fixed to the arbor support. The feeler of the dial gauge is adjusted to touch the top or ride of the test mandrel. The arbor support can then the moved along the overhanging arm and the deviations from parallelism observed on the dial gauge.

Chapter 9

GEAR MEASUREMENT

Q.1. Define an involute and show how will you check the involute profile of a spur gear ?

Ans : Involute is a curve traced by a point on a straight line which rolls around a circle without slipping or may be defined as the curve traced by a point on a piece of string which is unwound from a stationary cylinder,keeping the string always tight.

The following methods are used to check the involute profile of a spur gear.:

1. Optical projection method :- In this method, the profile of the gear under test is magnified by optical means and projected on a screen. It is then compared with master profile. This method is quick and suitable for checking the profile of small thin instrument gears.

2. Using involute measuring machine:- The principle of involute measuring machine is illustrated in Fig.9.1. If a straight edge is rolled around a base circle without slipping, the stylus of the dial gauge attached to the straight edge would traverse a true involute.

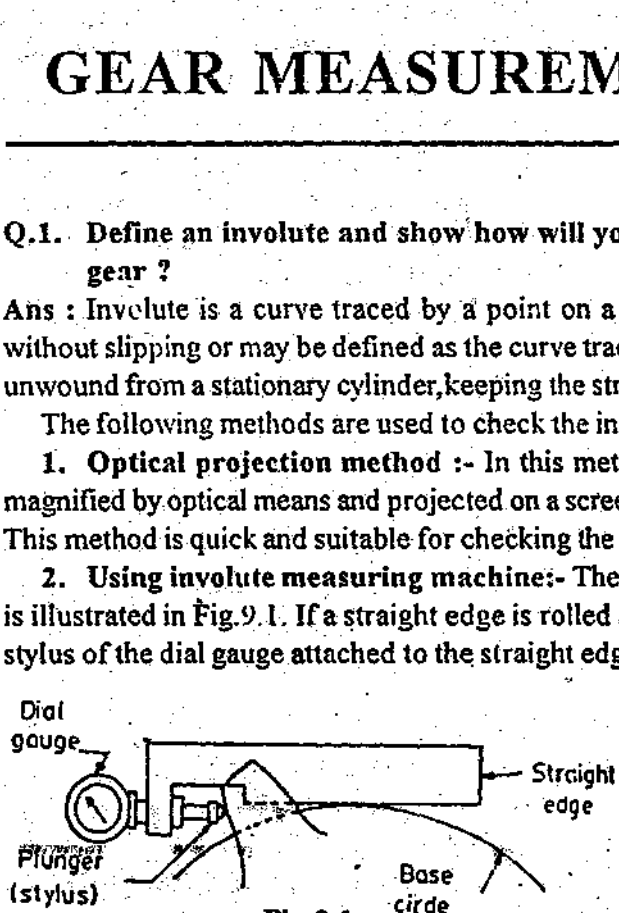


Fig.9.1

In this method, the gear to be tested is held on a mandrel. A ground circular disc having exactly the same diameter as the base circle of the gear under test is also mounted on the mandrel. The straight edge of the instrument is brought in contact with the base circle of the disc. As the gear and disc are rotated, the straight edge moves over the disc without slip. The stylus of the dial gauge is brought in contact with a tooth profile. When the gear and disc are rotated, the stylus moves over the tooth profile and the deviations from the true involute profile are indicated by the dial gague.

This method is rapid and accurate upto 0.002mm.

3. Tooth displacement method :- When the involute measuring machines are not avaiable, the profile of large gear is checked by using a dividing head and a vertical measuring machine (height gauge). The gear is rotated through small angular increments and the readings of the vertical measuring machine or the height gauge are compared with the theoretically calcutated values at about five to ten places along the tooth flank.

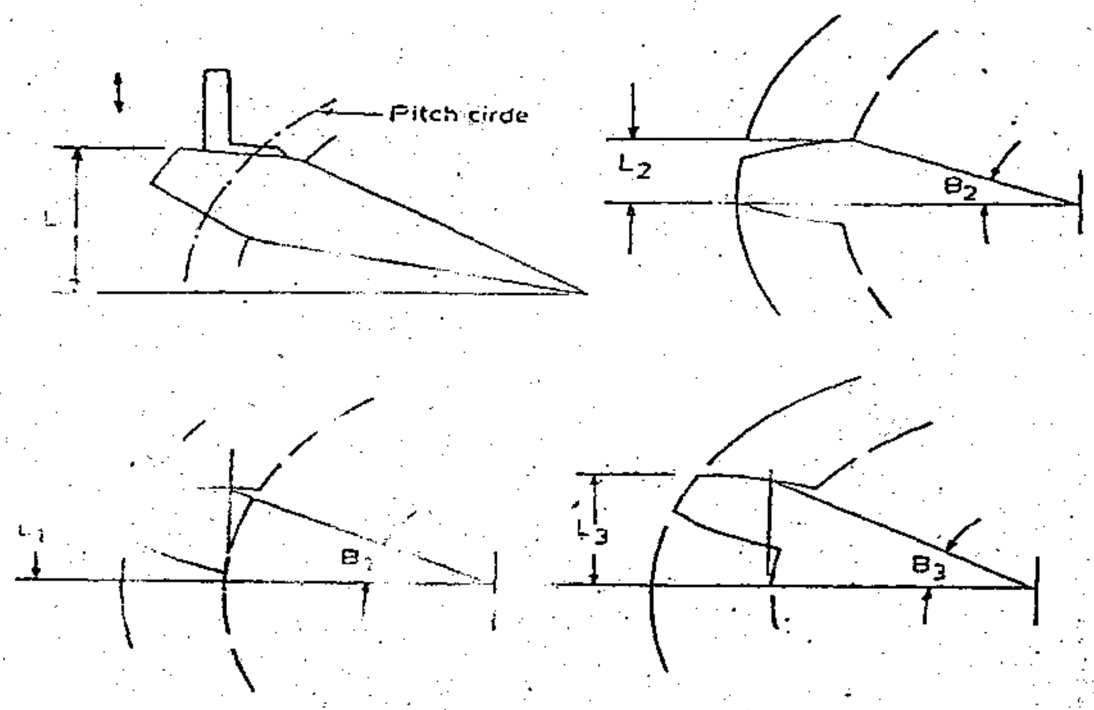


Fig. 9.2 Tooth displacement method.

$$L_1 - L_2 = r_p \cos\phi\,(\theta_1 - \theta_2)$$

$$L_3 - L_1 = r_p \cos\phi\,(\theta_3 - \theta_1)$$

This method is very time consuming but is best suited for cailbration of master involute, so it is used only for very precision components.

Q.2. What are the sources of errors in manufacturing gear ?

Ans : The variation in manufacturing methods and conditions lead to many types of errors such as error of eccentricity, run out, pitch error, error in tooth thickness, etc.

The gears are generally manufactured by reproducing method or generating method. In reproducing method, a formed involute cutter is used to cut gear teeth. The various sources of errors when gears are made by this method are.:

i. Errors in manufacture of the cutting tool,
ii. Errors in positionting the tool relative to the work and
iii. Errors due to the incorrect indexing of the gear blank.

In gEnerating method the cutting tool (hob) forms the profile of several teeth simultaneously during constant relative motion of the tool and blank. The sources of errors in this method are:

i. Errors in the manufacture of hob,
ii. Error in positioning the tool (hob) relative to the work and
iii. Errors in the relative motion of the tool and blank during the cutting operation.

Q.3. Draw a neat sketch of a gear tooth and mention on it two important dimensions. State the names of the instruments for measuring these dimensions.

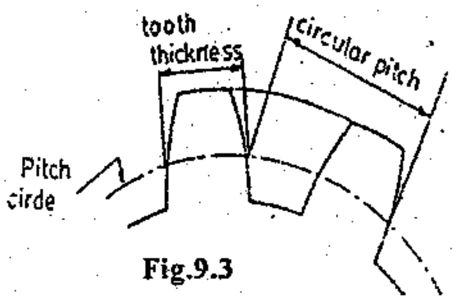


Fig.9.3

Ans : Tooth thickness : Instruments used for measuring tooth thickness are gear tooth vernier caliper, gear tooth micrometer, addendum comparator, etc.

Pitch : Instruments used for pitch measurement are gear tooth tangent micrometer, pitch measuring machines etc.

Q.4. Name the various elements of a spur gear which are to be inspected for possible errors.

Ans : Spur Gear Measurement : The analytical inspection of the gears consists in determining the following teeth elements in which manufacturing errors may be present.

1. Run out, 2. Pitch, 3. Profile, 4. Lead, 5. Back lash,
6. Tooth thickness, 7. Concentricity 8. Alignment, 9. Composite errors.

Q.5. Name and descirbe the various methods used to measure the errors in pitch of the gears.

Ans : Pitch Measurement : Errors in the tooth spacing or pitch of the gear may be measured by :

a) Measuring the distance from a point on the tooth to a point on the next tooth (step by step method)

b) Measuring the position of a suitable point on a tooth after the gear has been indexed through a suitable angle (Direct angular measurement)

Tooth to tooth pitch measurement (step by step method) :

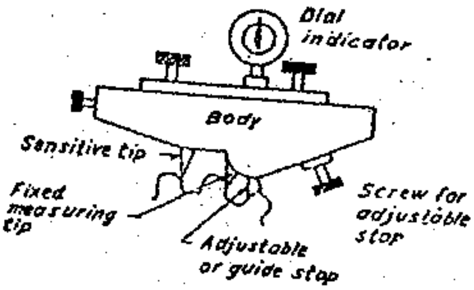


Fig.9.4 Portable hand-held base pitch measuring instrument

This method involves the measurement of variations in pitch between successive teeth of the gears. The differences obtained in this way are relative to the tooth spacing of the arbitarily chosen datum position.

The portable hand-held instrument which measures the base pitch errors is shown in Fig.9.4

The instrument has three tips. One is fixed measuring tip. The second is sensitive tip whose position can be adjusted by a screw and the further

movement of it is transmitted through a leverage system to the dial indicator. The third tip is adjustable or guide stop. It is meant for the stability of the instrument and its position can also be adjusted by a screw.

The distance between the fixed and sensitive tip is set to be equivalent to the base pitch of the gear with the help of slip gauges. This properly set instrument is applied to the gear so that all the three tips will contact the tooth profile. The reading on the dial indicator is the error in the base pitch.

Another method is to use two dial gauges on adjacent teeth with the gear mounted in centres. The gear is indexed through successive pitches to give a constant reading on dial A. Any change in the reading on dial B indicates that pitches errors are present. The actual error can be determined by deducting the individual reading on a dial B from the mean of the readings.

Direct Angular measurement : The simplest method of determining pitch errors is to set a dial gauge against a tooth and note the reading. If gear is now indexed through the angular pitch the reading differes from the original reading. The difference between these is the cumulative pitch error. The problem is to index through the exact angular pitch because an error in indexing will induce an error in pitch. It is therefore, necessary to use suitable indexing device to obtain accurate results.

Q.6. Describe briefly the methods of checking the following elements of a spur gear.
i. Run Out, ii. Lead.

Ans : i. Run Out : Run out means the eccentiricity in the pitch circle. Gears that are eccentric tend to have periodic variation in sound (vibration) during each revolution. A badly eccentric tooth may cause an abrupt gear failure. The runout in the gears is measured by means of gear eccentricity testers. The gear is held in the mandrel in the centres. The dial indicator of the tester possesses special tip depending upon the module of the gear to be checked. The tip is inserted in between the tooth spaces. The gear is rotated tooth by tooth. The maximum variation is noted from the dial indicator reading which gives the runout of the gear. The runout is twice the eccentricity.

ii. Lead Checking : Lead is the axial advance of a helix for one complete turn as in the threads of cylindrical worms and teeth of helical gears.

Control of lead is necessary to ensure adequate contact across the face with gear and pinion are properly mounted with axes parallel and in the same plane.

Lead may be checked by lead cheking instruments. The instrument advances a probe along a tooth surface, parallel to the axis while the gear rotates in a specified timed revolution, based on the specified lead.

Q.7. Define back-lash. Describe the method of determining the back lash in gears.

Ans : Back Lash Checking : Back lash in gears is the play between measuring tooth surfaces. Back lash is defined as the amount by which tooth space exceeds the thickness of an engaging tooth. Numerical values of backlash are measured at the lightest point of mesh on the pitch circle, in a direction normal to the tooth surface.

However, a tight mesh is objectionable, because of gear sound, increased power losses, overheating and rupture of lubricant film, over loaded bearing and premature gear failure. Hence, some backlash is necessary.

I.S. specifies two types of backlash.

1. Circumferential back lash.
2. Normal backlash.

The desired amount of back lash is difficult to evaluate. It is therefore, recommended that when a designer, user, or purchaser includes a reference to backlash in gearing specification and drawing, consultation be arranged with the manufacturere.

I.S. therefore does not specify the tolerance etc. Backlash is determined as follows : One of the two gears of the pair is locked, while the other is rotated backwards and forward as far as possible, the maximum displacement recorded by a comparator whose stylus is locked near the reference cylinder and a tangent to this is called the circular backlash.

For spur gears, the normal back lash is equal to circular backlash multifilled by the cosine of pressure angle.

Q.8 Name the various methods of tooth thickness measurement.

Ans : Tooth Thickness measurement : Since the tooth thickness is defined as the length of an arc, it is not possible to measure it directly. It is generally measured at pitch circle and is therefore, the pitch line thickness of the tooth. In most of the cases, it is sufficient to measure the chordial thickness i.e. the chord joining the intersection of the tooth profile with the pitch circle.

There are various methods of measuring the gear tooth thickness.

i. Chordal thickness method (measurement of tooth thickness by gear tooth vernier calliper).
ii. Constant chord method.
iii. Base tangent method.
iv. Measurment over pins or balls.

Q.9. Describe fully the method used to measure the chordal thickness of a gear tooth on the pitch circle.

Ans : Chordal Thickness Method : In this method, gear tooth vernier calliper is used to mesure the thickness of gear tooth at the pitch line. The gear tooth vernier calliper consists of two perpendicular vernier arms with vernier scale on each arm. One of the arm is used to measure the thickness of gear tooth and other for measuring depth. The calliper is so set that its slides on the top of tooth of gear under test and the lower ends of the calliper jaws touch the sides of the tooth at the pitch line. The reading on the horizontal vernier scale gives the value of chordal thickness (W) and the reading on the vertical vernier scale gives the value of chordal addendum (A). These measured values are then compared with the calculated values.

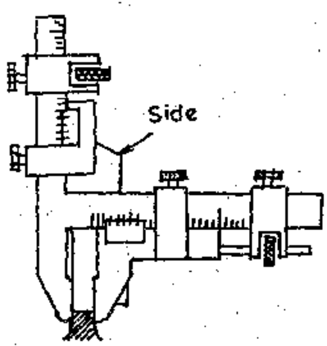


Fig : 9.5

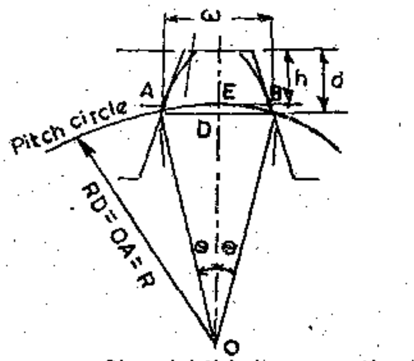


Fig.9.6

Considering one gear tooth, the theoretical values of w and d can be found out. In fig.9.6. w is a chord ADB, but tooth thickness is specified as an arc distance AEB. Also the distance d adjusted on instruement is slightly greater than the addendum E, w is therefore called chordal thickness and A is called chordal addendum.

Now, from fig.9.6

$$w = AB = 2AD$$

$$\text{Angle AOD} = Q = \frac{360}{4T}$$

Where T = Number of teeth

$$W = 2AD = 2 \times AO\sin\frac{360}{4T}$$

$$\text{i.e.} = W = 2R\sin\frac{360}{4T} \quad (R = \text{Pitch Circle Radius})$$

$$\text{Module } m = \frac{\text{P.C.D.}}{\text{No.of teeth}} = \frac{2R}{T}$$

$$\text{Therefore, } R = \frac{Tm}{2}$$

$$\text{and } W = 2\frac{Tm}{2}\sin\left(\frac{360}{4T}\right)$$

$$\text{i.e. } W = Tm\sin\left(\frac{90}{T}\right) \text{ --------------} \rightarrow 1$$

Also from fig.9.6

$$d = OC - OD$$

But $OC = OE + \text{addendum} = R + m$

$$= \frac{Tm}{2} + m$$

and $OD = R\cos\theta$

$$= \frac{Tm}{2}\cos\left(\frac{90}{T}\right)$$

Therefore, $h = \frac{Tm}{2} + m - \frac{Tm}{2}\cos\left(\frac{90}{T}\right)$

$$h = \frac{Tm}{2} + \left[1 + \frac{2}{T} - \cos\left(\frac{90}{T}\right)\right]$$

$$h = m + \frac{Tm}{2}\left[1 - \cos\left(\frac{90}{T}\right)\right] \text{ ----------------} \rightarrow 2$$

Q.10. State the limitation of vernier method for measuring the tooth thickness. State how these can be over come.

Ans : The vernier method described above is not very satisfactory because of the following reasons.

i. The vernier itself is not reliable to closer than 0.05 mm or perhaps 0.025 mm with practice,

ii. The measurements depend on two vernier readings, each of which is a function of the other,

iii. Measurment is made with an edge of the measuirng jaw, not its face, which again does not lead it self to accurate measurement.

These problems can be overcome by measuring the span of a convenient number of teeth with a vernier calliper.

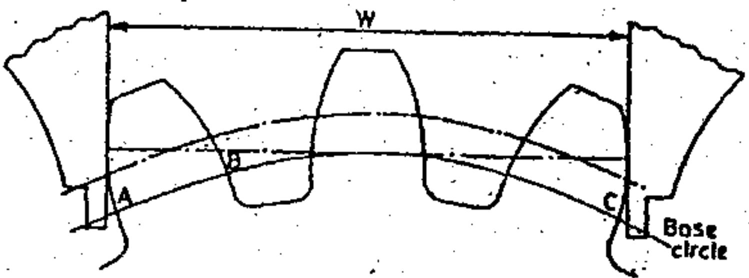


Fig. 9.7 Measurement over a number of tooth.

Q.11. Describe the constant chord method of measuring tooth thickness. What are its advantages ?

Ans : Constant Chord Method : In gear tooth calliper method, both the chordal thickness and chordal addendum are dependent upon the number of teeth. Hence, for measuring a large number of gears for set, each having different number of teeth would involve separate calculations. Thus the procedure becomes labouries and time consuming.

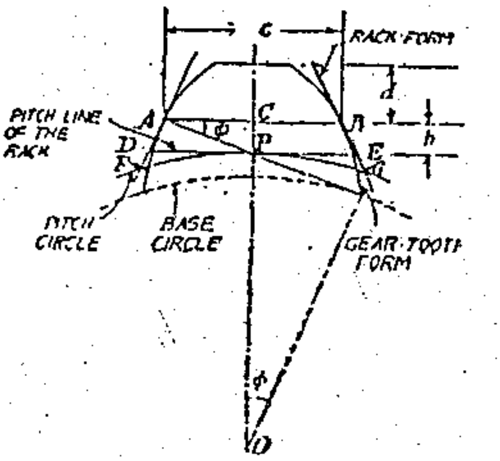


Fig.9.8

The costant chord method does away with these difficulties. It enables to employ one setting for all the gears having the same pitch and pressure angle irrespective of the number of teeth.

Constant chord is defined as be chord joining those points, opposite faces of tooth, which make contact with the mating teeth when the line of the teeth lies on line of the gear centres.

In fig.9.8 AB is known as constant chord. The value of B and its depth from the tip, where it occurs can be calculated mathematically and then verified by instruement.

The advantage of the constant chord method is that for all number of teeth (of same module) value of constant chord is same. Secondly, it readily leads itself to a form of comparator which is more sensitive than the gear tooth vernier.

Q.12. Describe the Parkinson's gear tester and state its limitations.

Ans : Pakrinson Gear Tester : Working Principle : A standard gear (master gear) is mounted on a fixed vertical spindle and the gear to be tested on another similar spindle mounted on a sliding carriage. These gears are maintained in mesh by spring pressure. As the gears are rotated the movements of the sliding carriage are indicated by a dial indicator, and these variation are a measure of any irregulaties in the gear under test; alternativley a recorder can be fitted, in the form of a waxed circular chart and records made of the gear variation in accuracy of mesh.

Fig.9.9 shows a gear tester for testing spur gears. (Testers are available for bevel, helical and worm gears also). The gears are mounted on two spindles so, that they are free to rotate without measurable clearance. The master gear is mounted on a adjustable carriage whose portion can be adjusted to enable a wide range of gear diameters to be accomodated and it can be clamped in any desired position. The gear under test is mounted on a floating spring loaded carriage so that the master gear and the gear under test may be meshed together under controlled spring pressure.The two spindles can be adjusted so that their axial distance is equal to the desinged gear centre distance. A scale is attached to one carriage and a vernier to the other, this enables centre distance to be measured to within 0.025 mm.

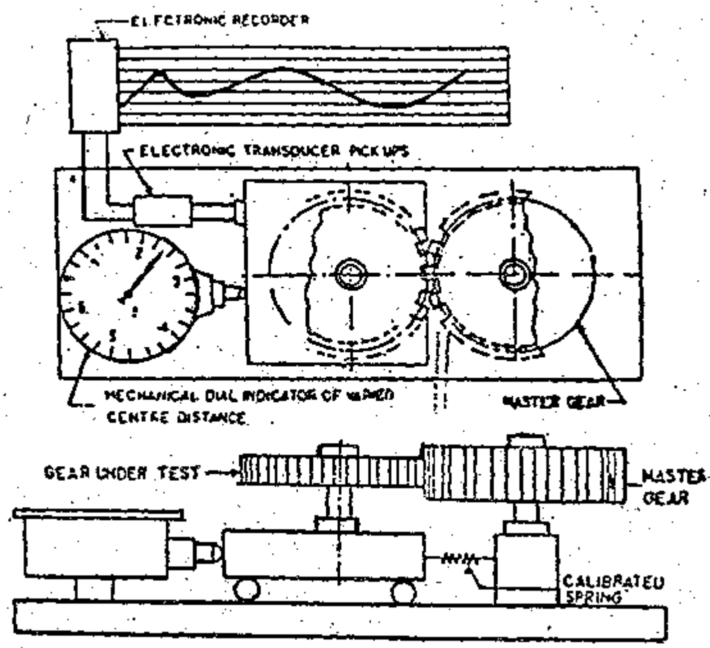
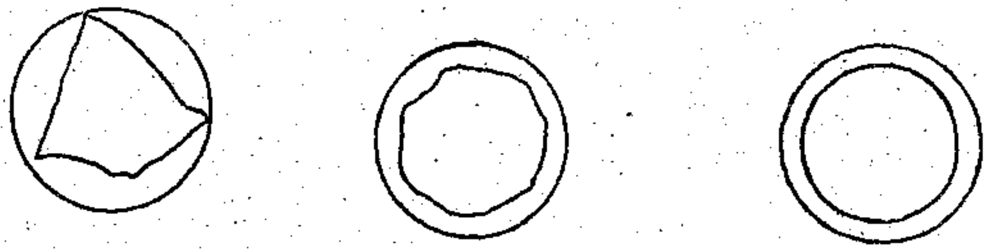


Fig 9.9 Parkinson Geat Tester.



Gear unsatisfactory **Gear moderatre** **Geae fully satisfactory**

Fig.9.10

When these gears are in close mesh and rotated any errors in the tooth form, pitch or concentricity of pitch line, will cause a variation in centre distance. Thus, movements of the carriage, as indicater to the dial gauge shows the errors in the gear under test.

Alternatively a recorder can be fitted as shwon in fig.9.9 in the form of a waved circular or rectangular chart and records made of the irregulaties in the gear under test fig 9.9. shows a reproduction of a two typical charts with a reduced scale and the magnified radial errors, Gear 1 is an unsatisfactory. Gear 2 is moderate gear and gear 3 is fully satisfactory.

Some limitations of Parkinson gear tester are :

1. Generally, 300 mm diameter gear is maximum that can be tested, usually, 150 mm or smaller diameter gears are also tested.

2. There is a low friction in the movement of the floating carriage and a high sensitivity of the sensing unit is important.
3. The accuracy is of the order of ± 0.001 mm.
4. Rolling test does not reveal all errors, since the device is sensitive to cumulative position erros.
5. Errors are not clearly identified for type profile, pitch, helix and tooth thickness and are indistinguishably mixed.
6. Measurements are directly dependent upon the master gear or reference gear.

PART - II

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24 NOV 05

QUALITY CONTROL

Chapter 10

QUALITY FUNCTION

Q.1. Define the term quality.

Ans : Quality is a relative term, it is generally used with reference to the end use of the product.Quality can be defined as :

i. Fitness for purpose : The component is said to possess good quality, if it works well in the equipment for which it is meant. Quality is thus defined as fitness for purpose.

ii. Grade : Quality is a distinguishing feature or grade of the product in appearance, performance, life, reliability, taste, odour, maintainability etc. This is generally called as quality characteristics.

iii. Degree of perference : Quality is degree to which a specified product is preferred over competing products of equivalent grade,based on consumer's preference.

iv. Degree of excellence : Quality is a measure of degree of general excellence of the product.

Q.2. Define the term "Quality control"and state its objectives.

Ans : The term Quality control can be defined in number of ways :

i. Quality control can be defined as an effective system for integrating the quality development,quality maintenace and quality improvement efforts of the various groups in an organization, so as to enable production and services at the most economical levels,which allow full customers satisfaction.

ii. It can be defined as the tools,devices or skills through which quality activities are carried out.

iii. It is the name of the department which devotes itself full time to quality functions.

Objectives of Quality control :

1. **Improved income :** To improve company's income by making the product more acceptable to the customers.
2. **Cost reduction :** To reduce company's cost through reduction of losses due to defects. For example,to achieve lower scrap,less rework ,less sorting,fewer customer returns etc.

3. **Interchangeability :** To achive interchangeability of manufacture in large scale production.
4. **Optimum Quality :** To produce optimum quality at minimum price.
5. **Customer's satisfaction :** To ensure satisfaction of customers with products or services of high quality level,to build customers good will,reductions of returns and complaints etc.
6. **Prompt Inspection :** To make inspection prompt to ensure quality control.
7. **Integration of quality effects :** To integrate the quality development,quality maintenance and quality improvement efforts of the various groups in the organization.
8. **Quality mindness :** To create quality mindness in all the persons working in the organization.

Q.3. Name the various stages (steps) of quality control programme in an industry.

Ans : The stages in quality control programme are :

1. Formulation of quality policy.
2. Work out details of product requirement,set the standards (specifications) on the basis of curstomers preference,cost and profit.
3. Select inspection plan and set up procedure for checking,specify inspection stages,tools devices etc.
4. Detect deviations from set standards or specifications.
5. Take corrective action through proper authority and make necessary changes to achieve standards.
6. Decide on salvage method i.e.decide how the defective parts are disposed off entire scrap or rework.
7. Co-ordination of quality problems.
8. Developing quality consciousness in the organization.

Q.4. Describe the importance of quality and quality objectives for an organisation.

Ans : Every manufacturing organisation is concerned with the quality of its product. While it is important that quality requirements be satisfied and production schedules met, it is equally important that the finished product meet established specifications. Because customer's satisfaction is derived from quality products and services. Stiff competition in the national and international level and consumers awareness require production of quality goods and services for survival and growth of the company. Quality and productivity are more likely to bring prosperity into the country and improve quality of work life.

However, the management looks to achieve customer satisfaction by running its business at the desired economic level. Both these can be attained by properly intergrating quality development quality maintenance and quality improvement of the product. The integration of these three aspects of a product can be achieved through a sound quality control system.

Quality depends mainly on customer's perception. Hence, it is essential that all these features must be built in the design and maintained in manufacturing which the customer would like to have and willing to pay for it. Thus the quality objectives of the company are concerned with imparting certain abilities in the product to perform satisfactorily in a stated application at the most economical manner.

These abilities may be categorised in to ten factors as under :

1. **Suitability :** For specific application.
2. **Reliability :** It should give efficient & consistent performance.
3. **Durability :** It should have reasonable life.
4. **Safe and fool proof working.**
5. **Affordability :** It should be economical.
6. **Maintainability :** It should be easy to maintain.
7. **Aestheic look :** It should look attractive.
8. **Satisfaction to customers :** It should satisfy the customers requirements.
9. **Versatility :** It should serve number of purposes.

A product can be said to posses good quality if all the above requirements are properly balanced while designing and manufacturing it.

Q.5. What is Quality Policy? Describe the factors to be considered while foamulating the quality policy of a company.

Ans : Quality Policy : Quality policy refers to the basic principles which are used to guide the actions of the company, in order to meet the quality objectives. However, economy may be the additional factor while determining the quality policy. Quite logically, the cost of production will increase as the level of accuracy or quality of product is raised. Thus functional use of the product and cost should be considered simultaneously while formulating the quality requirements or policy.

The quality policy should always be formulated with reference to its effect on :

1. Manufacturing process.
2. Effect on sales.
3. Changing nature of customers.
4. Inspection costs.
5. Optimum use of resources.

The policy once decided must be laid down in clear cut words framing working specifications and should be communicated to all concerned from top to bottom.

Applied to quality function some of the basic questions which often require policy determination are :

1. The standard of outgoing quality : Four competing theories have been developed which may guide the policy for the outgoing level of quality of the product.

a. A capability theory : According to this theory the plant should keep the available machines running through reasonable maintenance and it is the responsibility of the sales department to sell the product.

b. Usage theory : It is applicable when the liking of the customers differs for the same design. Some customers may give emphasis on appearance,others on dimensions,strength,life etc.So,it is necessary to meet the needs of various customers,which may result in several levels of outgoing quality for the same design.

c. A competitive theory : When similar products are manufactured by number of firms,the customers have choice or multiple sources for supply and hence they will make competitive comparison and the plant managers may feel that they have no alternative but to face the competition with other similar firms.

d. An excellence theroy : This was generally held by top management and sales organisation who wanted the company to be known as "Quality House"but without knowing whether an excellence level would cost more or less than other levels and whether it will result in increased profit or otherwise.

2. The pattern of customer relation : This includes the extent of advertising truthfully, the extent of guarantees of the product, and the extent of rigidity or flexibility in setting customer"s claims for defectives.

3. The extent of leadership in adopting to recognize,and meet customer quality needs. For example, making maintance free goods, market survey, and leadership in solving such quality problems of customers.

4. The pattern of vendor relations :

i. Personal ii. Entertainment

iii. Visits iv. Contractual Obligations etc.

5. The extent of use of impersonal methods of supervision i.e. objectives, planning, reports, goals, charts, controls, audits etc. as agasint personal supervision.

Q.6. Explain the meaning of quality specification and its need.

Ans : A specification is a definition of design. The design remains a concept in the mind of the designer until he defines it through verbal description, sample drawing etc. As already explained, the demands of the application are translated into the requirements and the requirements are quantified. These quantified requirement are called specifications. The specifications thus contains the list of essential characteristics and their tolerances.

The subject matter of quality specifications may include :

1. The material specifications, (e.g. components, ingredients and finished products)
2. Process specifications.
3. Method of Test.
4. Criteria for acceptance and rejection.
5. Method of use.
6. Complete programmes.

One specification may be sufficient or separate specifications may be necessary to describe the desired quality characteristics in the material, product etc.

Once a definition is available any one of the parties in the industry can communicate any other and use shorthand of the specification to define a complex product. A buyer can order a No.392 blower or a ton of steel per specification No. EN 32, and in each case seller will understand what is the exact requirement of buyer. With the help of specifications, the production departments will know what materials, machines, tools are to be used and what to make, the receiving inspector of the buying company will know what to test for and so on.

Thus, the need for specification can be summarised as, Need for specifications :

1. It helps the manufacturing department to know what exactly is to be produced.
2. The raw material, process, equipment, skill etc. required to produce the product of designed quality.
3. To descriminate between defective and nondefective products.
4. To decide test standards, inspection and test devices required.
5. To decide what is the exact requirement of the buyer.

Q.7. Name the various types of specifications.

Ans : The various types of specification may be of the following types :

1. Standard specifications.
2. Consumer specifications.
3. Company specifications.
4. Process specifications.
5. Test specifications.

Q.8. Describe the following types of specifications.

Ans :

1. Standard specifications.
2. Consumer specifications.
3. Test specifications.

1. Standard Specifications : The work of specifications has been greatly simplified by the growth of standards for materials, components, processes, tests, products etc. Most of the countries have their own Stnadard Bodies. These standard bodies formulate the specifications for a variety of products. In our country. "Bureau of Indian Standards" (BIS) is the National Standards Body. There are number of technical committees working within the framework of BIS for standardising the specifications for consumer's as well as producer's products. The members of this committee are taken from manufacturers, users, research organisations. Govt. departments or other interested individual experts of organisations. BIS specifications are only voluntary not mandatory.

2. Consumer Specifications :

When BIS specifications are not available or not suitable for a particular customer needs, the customer provides the specifications to suit his particular needs and the manufacturer may agree and, produce the product as per the specifications given by the customer.

Test Specification : These normally include :

1. Scope of the test specifications.
2. Purpose of test.
3. Apparatus to be used, i.e. instruments, reagents etc.
4. Method of selection and preparation of sample or specimen.
5. Test procedure.

Q.9. Describe the following.

Ans :

1. Company specifications
2. Process Specifications

1. Company Specifications : Where a company manufactures products to its own specifications due to varied constraints and the customer accepts them, the specifications may be called company specifications.

Contract specifications are the specifications decided by contract reached between the manufacturer and customer. These specifications are the compromise between the consumer specifications and company or manufacturing specifications.

Product and materials specifications :

1. **Specification Identification :** This includes the name of the product, a number which serves as shorthand description, date and issue number etc.
2. **Product description :** This describes the product completely, utilizing shorthand designations, e.g. make, size, grade, number of components and their description etc.

All divisions (departments) have something to contribute to the decision of what should be the characteristic of the product. Sales presents the view of the customers. Design presents the technical limitations. Manufacturer presents the cost and personnel limitations. The final design specification is properly a composite of these and other views.

2. Process Specifications : It is necessary to specify the process to produce the particular product with the specified quality. The evidence of conformance to the specification is also evidence of conformance to the process specified quality. The evidence of conformance to the product specification.

The process specifications commonly include :

1. Specification identification.
2. Material used, identified by their shorthand designation and quantities of each.
3. Sequence of operations to be performed.
4. Description of each operation, including machines and tools to be used.
5. Process conditions to be maintained to produce the product with stated quality (time cycle, temperature, pressure, humidity etc.).
6. Process testing to be perfomred-test of process acceptance.

Q.10. Define inspection. Describe the objectives of inspection.

Ans : Inspection means checking of the material, products or components of product at various stages in manufacturing.

The inspection act always includes :

1. The interpretation of a specification.
2. Measurement of the product.
3. Comparision of 1. and 2. to check whether the product conforms to the set standards or not.

Objectives of Inspection :

1. **Receiving Inspection :** Inspection of incoming materials and purchased parts to ensure that they are according to the required specifications.
2. **Inprocess Inspection :** Inspection of raw materials as it undergoes processing from one operation to another. This will help to isolate the faulty semi-finished goods before it enters for the next operation.
3. **Finished good Inspection :** To inspect the final finished product (after assembly) to detect the defects and its sources. It may also be necessary to carry out the functional test to ensure that the product functions properly.
4. **To Maintain Customer Relations :** To ensure that no faulty or defective product reaches the customers.
5. **Gauge Maintenance :** Control and maintenance of measuring instruments and inspection gauges.
6. **Test Equipment Maintenance :** To maintain the equipment, (e.g. profile projector, ultrasonic flaw detector, tool makers microscope, strength tester etc.)
7. **Decision on salvage :** It is necessary to take decision on the defective parts. Some of these parts may be made acceptable after minor repairs.

Q.11. Define inspection planning. Suggest the inspection stations for the fairly big manufacturing industry.

Ans : Inspection planning is a part of planning for quality It includes.

1. Selection of inspection stations and,
2. The planning of activities at each inspection station.
3. Selection of inspection plan.
4. Decision on requirements of tools. gauges & test devices required for inspection.

The most appropriate places for inspection stations are :

1. At receipt of goods from vendors usually called vendor inspection.
2. During the progress of high quality or expensive operations.
5. Upon completion of all fabrication operations called finished good Inspection.
6. Before completing and irreversible, expensive operations (e.g. pouring a melt of steel)
7. At natural peepholes in the process, sometimes it may be necessary to carry out the inspection at vendor's plant.

Alternatively the difference between Inspection & Quality Control can be stated more precisely as follows :

S.No.	Parameters	Inspection	Quality Control
1.	Scope	Inspection is a part of quality control.	Quality control is a broad term, it involves inspection at particular stages, but mere inspection does not mean quality control.
2.	Definition	Inspection is an act of checking materials, parts, components or products at various stages in manufacturing and sorting out the faulty or defective items from good items.	Q.C. is an effective system for integrating quality development, quality maintenance and quality improvement efforts of various groups in an organisation to enable the production to be carried out at most economical level and to achieve satisfaction of customers.
3.	Devices	Inspection uses precision measuring instruments such as vernier callipers, micrometers etc. and devices such as tool makers, microscope, profile projector, flaw detector etc.	Q.C. uses devices such as statistics, control charts, acceptance sampling, process capability study, V.Q.R., V.R. Quality audits, field complaints
4.	Applicability	Inspection is concerned with quality of past production to judge conference with specifications and sorting out defective items from good items.	Q.C. is concerned with quality of future production. For example, take a sample, inspect it, if it is defective find out the reasons and take corrective action so that such type of defects will not occur in future. What is learned from inspection is used as a basis to ascertain whether the quality of products to be produced will meet the specifications or it is necessary to make changes in production process.
5.	Concern	Inspection is mainly the responsibility of the inspectors.	Everbody working in an organisation is responsible for quality of products produced.

Q.12. Differentiate between Inspection and Quality Control?

Ans : For any manufacturing organisation, both inspection and quality control are essential. However, there is a marked difference between the two. Quality control is a broad term, it involves inspection at particular stage but mere inspection does not mean quality control.

Inspection is an act of checking materials product or components at various stages and detecting and sorting out the faulty or defective items.

Inspection is concerned with the quality of past production. For example, if the production schedule calls for manufacturing 1,000 spindles with a diameter of 50 ± 0.05mm the inspector will concern himself only with whether the spindles produced meet this specification. Those that do not will be rejected and will continue until 1000 good units have been produced. As opposed to inspection, quality control is concerned with the quality of future production. For example, as the spindles are being produced periodic samples may be taken form the output and spindles in each sample inspected. If the quality of the items in a particular sample is satisfactory, production will be allowed to continue. But if it is not, corrective action may be immediately taken. This action may involve adjusting the machine, eliminating defects in raw materials, instructing or replacing the operator, selection of better machine etc.

In brief, what is learned from inspection of a sample of the product is used as a basis to ascertain whether the quality of the products produced will be as per the specifications or it is necessary to make changes in the production processes. Hence, in short, in inspection quality of past production is ascertained, and in quality control quality of future production is regulated. Secondly, inspection is merely an act of checking and sorting out the defective items whereas quality control is a broad term which includes number of activities (including inspection) in order to build up and regulate the quality of product.

Q.13. Explain the meaning of quality of design and state the factors controlling it.

Ans : Quality of Design :- The quality of design of a product is concerned with the tightness of specification for the manufacture of the product.For example,a part which has a drawing tolerance of 0.001 mm would be considered to have a better quality of design than another with a tolerance of 0.01 mm.

The factors controlling the quality of design are :

1. Type of customers in the market.
2. Intended life, enviornmental conditions, reliablity, Importance of continuity of service.
3. Profit considerations.
4. Special requirements of the product such as strength, fatigue resistance,life, interchangeability of manufctue of item etc.
5. Economic considerations and feasibility.

Q.14. Explain the term quality of peformance and the factors which controls it.

Ans : The quality of performance is concerned with how well the manufactured product gives its Performance.

It depends upon :

a. Quality of design and,

b. Quality of conformance.

It can be a best design possible but poor conformance control can cause poor performance, conversely the best conformance control can not make the product funtion correctly if the design itself is not right.

If the quality of performance of the product is not good customer's complain and returns will increase. It badly affects the reputation of the firm and the sale's volume of the product.

Q.15. What is the meaning of quality of conformance? state the requirements for good quality of conformance.

Ans : The quality of conformance is concerned with how well the manufactured. Product conforms to the quality of design.

For good quality of conformance with the design the following factors are important.

1. The raw material,machines,tools,measuring instruments should be of adequate quality and should be maintained properly.
2. A proper process should be selected,and their should be adequate process control during manufacturing.
3. Operators should be well trained and experinenced.
4. Proper care should be taken in shipment and storage of finished goods.
5. Inspection programme should be planned properly.

Q.16. Discuss the statement "Higher quality of design means higher costs, quite often if also means higher values".

Ans : The quality of design of a product is concerned with the tightness of the specifications for the manufacture of the product. Therefore, high quality of design means closer tolerances. The relationship between tolerance and cost of manufacture is shown in the fig 1.1.

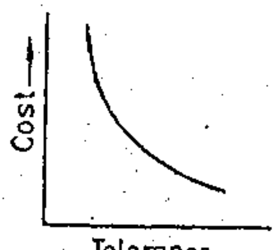

Fig 10.1

As the tolerances are made closer and closer the cost of production goes on incressing, because to manufacture the components with close tolerance we need :

1. Precision machines, tools, materials, etc.
2. Trained and highly skilled operators.
3. Tight inspection and good inspection and testing devices.
4. Closer tolerances : Manufacture of the parts with closer tolerances needs more concentration, frequent checks therefore the rate of production also decreases.
5. Close supervision is essential.

However, higher quality of design increases the grade of the product, by providing additional features in the product such as reliability, appearnce, interchangebility, luxury features, versatality etc. This helps to increase the utility of the product and thus increases the value of the product. With superior quality of design the company can earn higher share of market, firmer prices, few returns and complaints from the customers, less scrap and rework etc.

Q.11. Explain the concept of Reliability in details.

Ans : Reliability is ordinarily associated with the performance of the product. However, there would be little point in having an electric lamp which may light at the time of purchase but which may burn off after 200 hours of use. Whenever the customer purchases a product he expects that it should give satisfactory performance over a reasonably long period. hence, what is important is that a product should function and continue to function for a reasonable time.

In practice, in majority of the cases it may not be possible to test each and every product for its life or other performance requirements. Neverthless, it is a well known experience that each individual unit of product varies from the other units, some may have relatively longer life. In view of the existence of this variation there would always be a chance or probability that the product would function in the intended manner for the intended length of time.

More specifically, "Reliability is the probability of a product functioning in the intended manner over its intended life under the environmental conditions encountered.

From this defination,there are four factors associated with reliability. These are.

1. Numerical Value.
2. Intended function.
3. Life.
4. Environmental conditions.

The intorduction of this element of probability really makes the quantitative measurement of reliability possible. In other words such measurements help to make reliability a number - a probability that can be expressed as a standard.

They make it possible to ojbectively evaluate the reliability to predict it and to balance it with the other quality requirements, such as maintainability and appearance.

The second consideration for a product to be reliable is that it must perform a certain function or do a certain job when called upon. The phrase functioing in the intended manner (satisfactory performance) implies that the device is intended for certain application. For example, in the case of electric iron, the intended application is that of applying intended degree of heat to the various types of fabrics. If instead it is used to keep a room at a certain temperature, the electric iron might be inadeqnate because of the greater area to be heated and the change in environment.

The third element in the definition of reliability is that of time which ensures that the product is capable of working satisfactorily throughout the expected life. Many companies frequently concentrate on testing their product at the start only and do not evaluate the performance at the various stages during the life of the product. As a result they experience extremely difficult reliability problems when their increasingly complex products are put to use by the consumers.

The fourth consideration in the definition is that of the environment conditions which have to be viewed broadly so as to include storage and transport conditions. Since these conditions too have significant effect on product reliability.

Q.18. Give some important definitions of Reliability. what is the main cause of unreliability?

Ans : Many formal definitions of reliability have been proposed that are similar in their general intent but differ a bit in their exact phrasing. Some of the other definitions are as follows :

"Reliability is the probability of a device performing its purpose adequatly for the period of time intended under the operating conditions encountered.'

The realibility of a system or device, is the probability that it will give satisfactory performance for a specified period of time under specified conditions.'

Reliability of a product is " a measure of the ability of the product to function successfully, when required for the required period in the specific manner.'

Stated simply, "reliability is the capability of an equipment not to breakdown in operation.'

When an equipment works well, and works whenever called upon to do the job for which it is designed, such equipment is said to be reliable.

Failure is defined as the inability of an equipment not to breakdown in operation.

"Reliability may also be defined as the probability of no failure throughout a prescribed operating period.'

The causes of unreliability of the product are many one of the major causes is the increasing complexity of product. The multiplication law of probability illustrates this very simply. Given an assembly made up of five components, each of which has a reliability of function of 0.95, the reliability of function of assembly is $(0.95)^5$ or about 0.78. Many assemblies which are electronic in nature involve thousands of parts (a ballistic missile has more than 40,000 parts). Therefore, to have reasonable chance of survival for such assemblies the components reliability is of prime importance.

Q.19. State the basic elements of Reliability.

Ans : Basic Elements of Reliability are :

The basic elements required for an adequate specification or definition of reliability are as follows :

1. Numerical value of probability.
2. Statement defining successful product performance.
3. Statement defining the environment in which the equipment must operate.
4. Statement of the required operating time.
5. The type of distribution likely to be encountered in reliability measurement. Reliability follows the distribution of Poisson $e^{-T/\theta}$.

Where, θ = mean life

T = required life.

Q.20. State the effective areas to be considered for the achievement of reliability.

Ans : There are five effective areas for the achievement of reliability of the product. They are :

i. Design,
ii. Production
iii. Measurement and testing
iv. Maintenance and,
v. Field operation.

Design is the main cause of unreliability and a greater percentage of causes of unreliability can be traced out in this area.

Q.21. Differentiate between Quality Control and Reliability.

Ans : Quality Control and Reliability : Quality control maintains the consistency of the product and thus affects reliability. But it is entirely a separate function. Reliability is associated with quality over the long term where as quality control is associated with the relatively short period of time, required for manufacture of the product. The task of reliability is to see that in a product design, full account has been taken of every contingency which may cause a breakdown in use and to forecast the components or assembleis that are likely to become defective in service. However well, the equipment is designed, still it may be unreliable, if some component has not been fully evaluated under all service conditions, even if the production standards have been maintained by quality control during manufacture. Fig.13.1 shown the intergration of quality and reliability function.

Q.22. Explain the need of reliable product?

Ans : The reliability of a system, equipment or product is very important aspect of quality for its consistent performance over its expected life span. In fact, uninterrupted service and hazard free operation is the essential requirement of large complex system like electric power generation and distribution plants or communication network such as railways, aeroplane, automible vehicles etc. In these cases a sudden failure of even a single component, assembly or system results in a health hazard,accident, or interruption in continuty of servece.

Thermal power plants provide electric power for domestic, commercial, industrial and agricultural use. Reliability problems may cause shut down or reduced generation of power resulting in load shedding and many other problems including loss of productive activities.

Failure of any one system of an air-craft may result in forced landing or an accident.

Sudden stoppage of subruban railway train due to fault in the single system faulty carriage, interruption in the power supply or faulty track, sets up a chain of event leading to distruption of service or accident.

Similarly, sudden failure of a car break system while it is running may cause severe accident.

Unpredicted failure of a single critical component may be cause of any one of the above.

What is true of power plants, air-crafts, railways etc. is also true for other products like washing machine, mixer grinder, T.V. sets,Refrigerators etc. though failure of such products may cause incovenience on a smaller scale.

The problem of assuring and maintaning has many responsible factors, including original equipment design, control of quality during manufacture, acceptance inspection,field trials, life testing and design modifications.

Therefore, deficiencies in design and manufacture of products which go to build such complex system needs to be detected by elaborate testing at the development stage and later corrected by a planned programme of maintenance.

Q.23. Define the term maintainability. State the relationship between maintenance and Reliability.

Ans : Maintenance and Reliability : Approximately twice the original cost of complex equipment is expended each year to support the equipment. Much of this cost is the result of up-keep and maintenance. The total reliability of the equipment in the field is a function of design, maintenance and field operation reliability ; that is,

$$R_F = f(D, M, FO)$$

Maintenance is a production type of activity at or near the place of use, which is confined to repair or replacement of failed, marginal or time change units.

Maintainability : "Maintainability" is defined as the probability that a device will be restored to its operational effectiveness within the given period; when maintenance action is performed in acordance with the prescribed procedure.

Maintenance action is the prescribed operation to correct an equipment failure.

Chapter 11

QUALITY ASSURANCE

Q.1. Define the term "Quality Assurance Function". Describe briefly the stages involved in Total Quality Assurance. State the advantages of Quality assurance?

Ans : "Quality assurance engineering" deals with assuring the desired quality, reliability, service and other aspects in the manufactured product, through scientific techniques. The job of evaluating the companys activities with respect to quality, reporting the results of evaluation to all concerned for information and necessary action, and the subsequent action takes is called as "Quality Assurance Function".

The three stages in consideration of total quality assurances are :

1. **Design Stage :** To check and ensure whether the quality of design is according to the needs of the maximum number of customers.
2. **Manufacturing Stage :** To check and ensure whether the quality of the manufactured products conforms to design specifications.
3. **Field Observations :** (Reliability and performance analysis, observing the performance in actual field, studying and analysing the preformance, maintenance, life etc in view of improvement in the product in the next manufacturing cycle. There fore.

   Total Quality Assurance = Quality of design + Quality of manufacturing conforming to design + Quality of performance

Advantages of Quality Assurance :

1. Fewer defects.
2. Fewer customer's complaints.
3. Better Quality.
4. Less scrap.
5. Good customer relations.
6. Higher productivity.
7. Less inspection reject,

Q.2. What is "Quality Mindness" ? How does it help in improving the quality of th product ?

Ans : Quality Mindness : The term quality mindness means person's attitude toward quality. It is actually a state of mind in which the awareness of quality is constantly presen Every one working in the organisation or all departments are responsible for the broad qualit function Therefore, to maintain quality or to improve quality it is necessary to stress th importance of quality in the minds of the various persons working the the organisation (Manager foremen, supervisors, workers etc). Quality mindness is also called as quality consciousnes or quality awareness.

Quality mindness helps to achieve the desired results with a minumum of risk, man hours materials and time. The principle force for meeting the quality lies not in the gauges instruments or other facilities for inspection. It lies in the state of mind of the persons workin in the organisation, from the top executive down to the worker. The most expensive equipmen can not produce quality products if handled by the person who lacks quality mindness. Quality mindness of the personnel in the firm is an index of the firms quality.

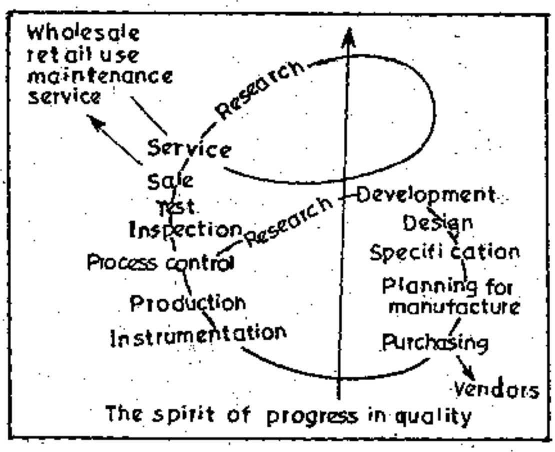

Fig. 11.1

Quality mindness helps to achieve the spiral of progress in quality as explained belw.

1. With the help of market survey a com pany determines, what qualities are needed by the customers.
2. Research and development specialists create a product concept which can meet these quality need of the user.
3. Design engineers prepare product and mateial specifications considering the quality requirements.
4. Process engineers specify the processes, machines and instrument capable of producing appropriate qualities economically.
5. Purchasing speciist buy materials and components possessing appropriate qualities.
6. Personnel department selects and trains the workers to make product as per design.
7. Quality conscious operators make efforts to make the parts, components to meet the quality standards.
8. Inspectors exămine the product to judge the conformance with the design. Thus the efforts of all quality conscious persons from top to bottom results improved quality of the product at minimum possible cost of production.

Q.3. How quality mindness can be created in the organisation? Explain or state the activities of organising quality campaign in the company.

Ans : For creating quality mindness it is necessary to organise the quality improvement campaign in the company, the objectives are :

1. To make every employee aware of the company's reputation for the quality.
2. To make every employee realize that the company's reputation is important to his personal well-being.
3. To make every employee understand that he in his daily work is contributing to company's quality for better or worse.
4. To show each employee how he can improve his contribution to the company's quality.
5. To provide means for receiving employee ideas and suggestions on how to improve quality.
6. To record best way of doing the job as reference for future training and check.
7. To provide a score board or means for measuring quality performance for departments and individuals.
8. The following methods are generally used for creating psychological climate favourable for quality mindness.

a. To Attract Attention : The management sholud try to make the workers realize that employees furture is dependent on company's future, companys future is dependent on quality, therefore quality is important for every person working in the company. With the help of bulletins, printed slogans or messages, stickers such as "Up with quality," Down with rejects" letters to employees homes from company president, articles with pictures in company newspaper etc. The company can attract attention of the persons towards quality mindness.

b. To generate interrest about quality : The following measures can be taken to generate interest about quality. Displays to shows how company products are used. Rating sheets for foremen to rate themselves on quality.

Slogans contest, with prizes. The slogan contests always yield well worded slogans which reflects the importance of quality. For example ""quality makes sales-sales make job security,". "Quality depends on me" Satisfied customers are job insurance. 'Beauty you can see-Quality you can trust.' Extra awards may also be given for suggestions on quality improvements.

Q.4. What do you mean by Quality survey or Quality Audit. State the activities involved in Quality Audit.

Ans : The quality audit or survey is an appraisal of the quality system of an entire plant. The quality audit is analogous to an accounting audit. The audit checks the books, the book keeper, and accounting system. the quality audit evaluates the products, the inspector, inspection devices and the entire system for achieving quality. It enquires about the adequacy of all the entire system of handling quality function.

A quality survey may be conducted on a scheduled periodic basis or only when needed by the existence of symptoms of quality problems. the audit team consists of the company president as chairman and several assistants with out side consultants as observers. The audit is conducted at the plant, sales office, design office, inspection department, quality control department etc. At each level appropriate subjects are chosen for review. The audit team members discuss their findings and report their recommendations.

Quality audit include the following activieties :

A. To examine whether :-

1. The design meets the functional requirements completely.
2. Design specifications are clearcut without ambiguity.
3. The design fullfills the customer's requirements.

B. To examine whether :

1. Manufacturing specifications conforms with the functional design specifications.
2. The manufacturing specificatios are complete and clearcut.

C. To examine :

1. Customers quality complaints.
2. And the adequacy of the corrective action taken by the company.

D. To examine : The various phases of quality performance such as :

Cheack inspection data
Control charts
Inspection policies and implementation etc.

E. To examine activities in shops such as :

1. The adequacy of gauges and test equipment used.
2. Completeness and sequence of performance of inspection procedure, data collection system and action.

F. To examine whether :

1. Shop personnel possess adequate quality consciousness.
2. The scope and organization of the programme to ensure that all personnel understand the actions they must take to achieve the quality needs of the customers.

Q.5. What do you understand by vendor Quality Rating ? Explin the need of V.Q.R.

Ans : The quality of the products manufactured largely depends on the quality of the raw materials, tools, equipments etc purchased form the vendors, Therefore, the quality of the products submitted by vendors is evaluated for making purchasing decisions. For this purpose vendor quality rating formulas are used, which provides a quantitative measure of the vendor quality. In fact V.Q.R. is an evaluation of vendor's ability to meet quality requirements. These rating are used in reviewing, comparing and selecting vendors.

Need of V.Q.R.

The vendor quality rating provides a basis for :

1. Measuring how well each vendor is doing, quality wise.
2. Comparing various vendors with one another for the quality of the raw materials, tools, equipment etc. they are able to supply.
3. Judging the progress or lack of it of each individual vendor over an extended period of time.
4. For eliminating those vendors who repeatedly fail to meet competitive quality levels.

The V.Q.R. is an important defect prevention device.

Q.6. Differentiate between Vendor Quality Rating (V.Q.R.) and Vendor Rating (V.R.).

Ans : In vendor quality rating the quality of the products submitted by vendors is evaluated and compared for making purchasing decisions V.Q.R. is only one of the factors for taking purchasing decisions regarding the choice of vendors. The quality of the products submitted by particular vendor may be excellent, but the price of his products may be quite high or he may not be keeping delivery promises. Hence there are other factors, principally, prices, service rendered, capability of the supplier to supply the required quality, delivery promises, discount allowed etc. Which must be considered for selectiing the proper vendors. The vendor rating takes into account all such factors for selecting a proper vendor. Therefore, the purchasing agents who have responsibility for co-ordinating all these factors and take purchasing decisiions have developed vendor rating plans. These plans take into account the subrating from all specialists, including quality specialists.

Q.7. Define Quality Circle.

Ans : A quality circle is a small group of volunteers (usually 3 To 12 employees) doing similar work. They meet regularly under the leadership of their immediate supervisor, or some one chosen among the circle to identify problems, set priorities, discover causes and propose solution. These may concern quality, productivity, safety, job structure, process flow, control mechanism, aesthetic of the work area etc.

According to Maurice Alston,

Quality circles are small groups of people doing similar work who, together with their supervisors volunteer to meet for an hour a week to study and solve work related problems which affects them. Circle leaders and members are trained in simple problem solving techniques which identify causes and develop solutions. At an appropriate time, presentations are made by trhe quality circle to the management who decide whether to accept, modify or decline the proposals".

Dewar president of the international Association of Quality circle defines Quality Circles as "a way of capturing the creative and innovative power that lies within the work force."

Quality circle is a participative management system in which workers make suggestions and improvements for the betterment of organisation.

Q.8. Explain the basic concept of Quality Circles .

Ans : The quality circle concept has three major attributes. These are

1. Q.C. is a form of participative management
2. Q.C. is a human resource development technique.
3. Q.C. is a problem solving technique.

It is based on the concept that suggestions affecting the work place should come from those who have the greatest knowledge about the job. The concept assumes that people close to the problem better understand the nature of the problem and what is or is not a feasible solution.

It assumes that a group of individuals working together will invariably come up with better solution than one individual working alone. Quality circles are specifically structural form and mode of participative management. It implies the development of skills, capabilities, confidence and creativity of the people through cumulative process of education, training; work experience, and participation. It also implies, the creation of facilitative conditions and environment of work. Which creates and sustains their motivation and commitment towards work experience.

Quality circles have emerged as a mechanism to develop and utilize the tremendous potential of people for improvement in product quality and productivity.

The philosophy of quality circle is to make better use of human resourse. It is based on the belief that every organisation has a vast store of untapped talent, brains abilities and ideas.

Q.9. Enumerate the characteristic of Quality Circle.

Ans : The characteristics of quality circles as a management tool for improving productivity and quality may be listed as below :

1. Quality circles are small primary groups of employee/workers whose lower limit is four and upper limit ten.
2. The memebership of quality circles are most Voluntary. The workers/employees in terested in some area of work, improvement may come together to form a circle.
3. Each circle is lead by area supervisor. Also, they are normally coordinated in organisation by a person who has been trained as a "Facilitator".
4. The memers meet regularly every week or according to an agreed schedule.
5. The circle members are specially trained in techniques of analysis and problem solving in order to play their role effectively.
6. The basic role of QC's is to indentify and solve work-related problems for improving quality and productivity.
7. QC's enables their members to exercise their hidden talents, creative skills and competence for tackling challenging tasks and thus contribute to their self development.
8. It also promotes the mutual development of their members through co-operative participation.
9. The circle work is characterised by the attributes of high skill variety, task identity, task significance, autonomy, goal setting, and feed back.
10. It also contributes to job satisafaction of their members by creating feeling of accomplishment from indentifying and solving challenging problems.

11. The members also receives recognition in the form of members, certifictes and privileges, In some cases they also share in productivity gains that might be the result of their work.
12. It also contributes to their self esteem and self confidence through acceptance of their recommendations by management.

Q.10. State the objectives (purpose) of Quality Circles.

Ans : The objectives of QC'S which contribute to the improvement of the enterprise and indirectly the interest of the employee are:

1. The improve the quality and productivity and thus contribute to the improvement and development of the enterprise.
2. To reduce cost of products or services by waste reduction, safety, effective utilization of resources, avoiding un-necessary errors and defects.
3. To indentify and sole work related problems that interfere with production.
4. To tap creative intelligence of the persons working in the organisation and to make full use of the its human resources.
5. To permit employees to develop and use greater amount of knowledge and skill and motivate them to apply to a wide range of challenging task.
6. To improve communication within the organisation.
7. To increase employees loyalty and comitment to the organisation and its goals.
8. To respect humanity and built a happy bright work place environment which is meaningful to work in.
9. To enrich human capability, confidence, moral, attitude and relationship.
10. To satisfy the human needs of recogniition, achievement and self development.

Quality circles are not limited to manufcturing firms only. They are applicable for variety of organisation where there is a scope for group based solution of work related problems. Quality circles are thus relevat for factories, firms, schools, hospitals, universities, reserach institutions, banks, government office etc. i.e. any place where people are involved in the solution of problems and development of work.

Q.11. Descirbe the functioning (process of operation) of Quality Circles.

Ans : The basic purpose of quality circle is to identify and solve work related problems. The circle members normally meet once a week for one hour. In the early meetings, time is devoted mainly to train the circle members.Once they have acquired the fundamental problem solving and quality analysis techinque they start working on problems.

The operation of quality circles involve a set of sequential steps as under.

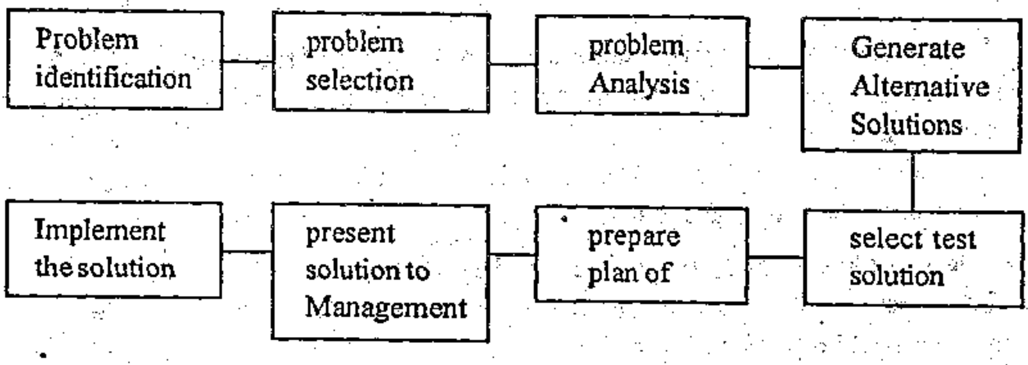

Fig.11.2 Process of operation of Quality Circles

Steps in Quality Cricle Operation :

1. **Problem identification :** The circle members identifies a number of problems that need to be solved pertaining to their work area.
2. **Problem Selection :** They decide the priority and select the problem they wish to take up first.
3. **Problem Analysis :** The problem is classified and analysed by basic problem solving techniques such as :
   a. Brain storming b. Pareto diagrams
   c. Cause ad Effect diagram d. Data collection
4. **Generate Alternative Solutions :** Identify and evaluate causes and generate number of possible alternative solutions.
5. **Select the most appropriate solution :** At this stage the circle numbers discuss and evaluate the alternative solutions by comparison in investment and the return from the solution under the existing circumstances.
6. **Prepare plan of Action :** The circle numbers then prepare plan of action for making the solution reality. The action plan includes the critical examination i.e. the consideration of who, what, when, where, how and why of solving problems.
7. **Present solution to Management :** the Circle members present the solution and action plan to the management for approval.
8. **Implementation of solution :** The management then evaluate the recommended solution. Depending upon the nature and magnitude of the problem, a small scale pilot test run may be essential before a full scale implementation of the solution is attempted.

Once a solution is successfully tested and approved it is implemented on a full scale at the earliest. A decision should be communicated to quality circle generally in two weeks.

The cycle of circle functioning is repeated as they solve one problem and begin work on another.

Chapter 12

QUALITY ECONOMIES

Q.1. Explain the meaning of i. Cost of Quality ii. Value of quality.

Ans : i. Cost of Quality : The cost of carrying out the company's quality functions (meeting the quality needs of the customers) are known as costs of quality.

This includes : 1. Market research costs of discovering the quality needs of the customers.

2. The product research and development costs of creating product concept which will meet these quality needs.
3. The design cost of translating the product concept into information, which permits planning for manufacture.
4. The cost of manufacturing planning in order to meet required quality specifications.
5. Cost of inspection and test.
6. Cost of defect prevention.
7. Cost of scrap, quality failures.
8. Cost of quality assurance.
9. Field service and such other functions attributed to the quality improvement and maintenance.

Value of Quality : With superior quality the company can earn higher share of market, firmer prices, few returns and complaint form the customers. It is this effect on income which makes quality to have value. Hence, value of quality can be defined as the return direct or indirect gained by the manufactures due to missions of quality control.

Value of quality is composed of :

1. Value inherent in the design :
2. Value inherent in the conformance to that design.

The value inherent in the design is usually called as "grade". Grade is the variation in specifications for the same functional use. Difference in grade may involve diffrences in :

Life of the product	Extent of maintenance required
Appearance	Reliability
Interchangebility	Luxury features

Factor of safety Ease of installation or use

Ability to take occasional overloads etc.

As a rule, higher quality of design means higher costs. Quite often it also means higher values.

It is comparatively easy to evaluate the cost of quality but it is difficult to assess the value of quality , as the information is widely scattered.

The value of quality is to be assessed considering various factors, a few of which are as under:

1. The saving due to increased production.
2. Reduction in scrap and re-work cost.
3. Increased sales of good quality product.
4. Indirect factors such as :

a. **Reputation of the manufacturer and good will of the customer.**

b. **Psychological stability in the enterprise due to increased sales and security of jobs to workers.**

Q.2. How to obtain the balance between the cost of quality and value of quality ? Explain.

OR

Explain the meaning of optimum quality of design with the help of graph.

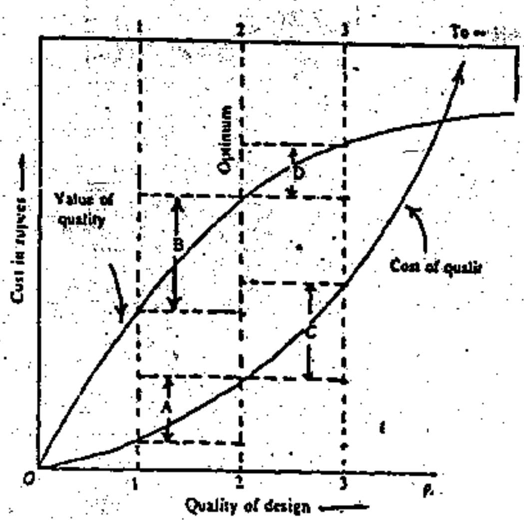

Fig. 12.1 Balance between Cost of quality and value of quality.

Ans : The balance between the cost of quality and value of quality gives optimum quality of design.

From company's point of view profit is more improtant. It is not necessary that the company should manufacture 100% quality product. The study of optimum quality of design involes "Market Survery". While carrying out market survey expected sale for particular quality, profit and competition in the market is to be considered. The quality of design should meet the needs of the customer and at the same time its manu facturing cost should be such that it will yield maximum profit. The aim should be to improve quality at lower cost.

The curves representing the cost and value of quality of design are shown in figure 12.1 If we want to improve the quality of design from point 1 to point 2 the cost of quality will increase by amount A. Where as the value of quality will increase by an amount B. Now B>A and therefore, improvement in quality at this level will yield more income.

However, if the quality is to be improved from the point 2 to point 3 then from the figure 1.3 D < C i.e. the increase in the value of quality is less than the increase in the cost of quality. So, the quality level at point 2 is optimum quality of design. Below this optimum the profit that can be earned is not maximized and above this optimum it is uneconomical to improve the quality of design.

Q.3. Discuss the economics of quality of design.

Ans : The quality of design of a product is concerned with tightness of specifications for manufacture of product. Therefore, higher quality of design means closer tolerances. The relationship between tolerance and cost of manufacture is shown in fig. Fig. 12.2

As tolerances are made closer and closer the cost of production goes on increasing, because to manufacture the components with close tolerances we need :

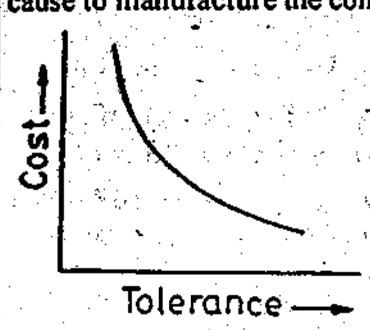

Fig. 12.2

1. **Precision machines and tools, materials etc.**
2. **Trained and highly skilled operators.**
3. **Tight inspection and good inspection and testing devices.**
4. **Manufacture of parts with closer tolerance needs more concentration, frequent checks which may slow down the rate of production.**
5. It also needs close supervision.
6. Special, costly tools jigs and fixture may also be necessary.

The design engineers are tempted to specify very close tolerances and large margin of safety. However, for sake of economy the quality of design should be realistic which are tightly enforeced so as to achieve conformance to design.

The manufactuer should produce the products in different grades to suit the variety of customers (rich, middle class, poor).

Modern techniques of standardization, simplification and specialization are at the root of economic analysis of design of the product.

Q.4. Discuss the statement higher quality of conformance costs less.

Ans : We know that the quality of conformance is concerned with how well the manufactured product conforms to the quality of design. non conformance to quality of design will involve rejection of the product, and involve unsatisfactory product costs.

Rejection may mean.

1. Non acceptance
2. Return of all goods.
3. Return of defectives only.
4. Non acceptance unless certain conditions are met.

The nonconforming products are to be reworked, reparied to make them suitable if possible or they are to be treated as scrap. The cost of rework, repairs, scrap causes reduction in revenue as well as increase in expences, the firm may also loose reputation which may hamper the sell and price of the product.

However, if the manufactured product conforms to the quality of design there will be a large saving by reducing the number fo defective products and rejection. The cost associated with the conformance is quite less as compared to the cost of unsatisfactory product, rejection rework, repairs, returns etc.

Q.5. Explain the following terms :

1. Cost of Prevention. 2. Cost of appraisal. 3. Cost of failures.

Ans : Cost of Prevention : It consists of the cost associated with preventing the production of defective parts.

Cost of prevention includes.

1. **Cost of quality planning :** The cost of market research and product development departments, which is done for achieving fitness for use.
2. **Process quality control costs :** The costs associated with implementing the quality plans and procedures.
3. Engineering, technical and supervisory costs of preventing of recurring defects.
4. Cost of investigation, analysis and correstion of causes of defects by quality control department.
5. Cost of investigation, analysis and correction of cause of defects by engineering department.

Cost of Apprasial : The costs associated with the measuring, evaluating or auditing or product, components and purchased materials and performance requirements are called cost of appraisal.

In other words, it is the cost of evaluating quality and of identifying and separating nonconforming parts and assemblies. It consists of costs associated with :

1. Receiving or incoming test and inspection.
2. Laboratory acceptance testing.
3. Inprocess inpection and test.
4. Set up for inspection and test.
5. Maintenance and calibration of test and inspection equipment.
6. Quality audit.
7. Review of test and inspection data.
8. Evaluation of field stock and spare parts.

Cost of Failures : It can be classfied as : a) Cost of internal failures.
b) Cost of external failures.

Cost of Internal Failres : The cost associated with defective products, components and materials that fail to meet quality requirements and result in manufacturing lossess are called as cost of internal failures.

This inclues :

1. Cost associated with scrap, i.e. cost of material, labour and burden of nonusable parts.
2. Cost of rework and repair i.e. the cost of making defective parts and assemblies good.
3. Cost of reinspection and retest after the defective parts are repaired.
4. Cost associated with material review activities.

Cost of External Failures : It consists of costs which are generated because of defective products being shipped to customers. This includes :-

1. Cost of processing complaints from customers.
2. Cost of service of customers who receive defective items.
3. Cost of inspecting and repairing the defective items returned by the custormers.
4. Cost of replacing the defective materials or products.

Chapter 13

QUALITY ORGANISATION

Q.1. State the activities or functions related to quality organisation.

Ans : The organisation for quality function should cater to activities related to :

i. **Planning for quality (prevention)**

ii. **Monitoring and control of quality and**

iii. **Improvement in quality (innovation changes)**

The quality organisation is responsible for :

a. Co-ordinating the activities of design, purchasing, Engineering, production, Finance, product development and service function by forming a Quality committee.

b. Utilise the experts from statistical process control, reliability, technical experts and other functional areas by forming a task group for quality improvement.

c. Report on quality cost, identify problems and implement quality improvement process.

d. Identify training needs and co-ordinate with training function to implement quality.

Q.2. Give a typical organisation for quality.

Ans : The following chart shows a typical quality control organisational chart on level with the production organisation. In this type improcess quality is a responsibility of shops.

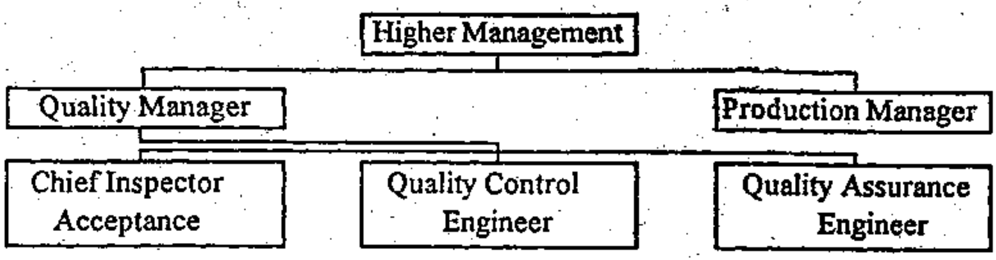

Fig. 13.1 Organisation for quality function.

Q.3. What do you mean by manufacturing planning for quality ? State the quality aspects of planning for manufacture.

Ans : Planning Consists of utilizing prior knowledge to control future events. It consists of preparations necessary to carry out the objectives of the company. Planning starts with clear objectives and ends when everything is ready for execution. Planning for manufacture constists of the activities required to put factory in readiness to meet its standard of quality, cost and delivery dates.

The specific quality aspects of planning for manufacture includes :

1. Choice of machines, processes and tools capable of meeting the specified tolerances.
2. Choice of measuring instruments, gauges and other inspection devices adequate to control the process.
3. Planning the flow of manufacturing information and inspection criteria.
4. Planning of process quality controls.
5. Selection and training of production personnel.
6. Planning the quality aspects of packing and shipping.

Q.4. What do you mean by planning through trial lots ? why is it necessary ? State its limitations?

Ans : Planning through trial lots means to plan only for trial lots before planning for full scale production. The manufacture may desire to introduce a new manufacturing process, complete new functional features and large investment, for such product prior knoweledge is not available on which the production can be planned. Such product involes a serious risk for the company if the planning goes wrong. Hence, for such products it is necesssary to plan for trial lots before planning for full scale production. The trial lots after production are introduced in the market and the reactions of the customers, their complaints regarding the functional and other aspects of the product are carefully studied.

Therefore, trial lot is used to clear the track for full scale production, for the following reasons:

1. To ensure that the tools and processess selected are capable of producing this products economically.
2. Providing on test, that the product possesses the essential functional qualities.
3. Providing on use, that the product will achieve the intended field of performance and is acceptable to the customers.
4. To trace out the deficiencies in process or product which should be corrected before starting full scale production.

Limitations of trial lots :

1. The time required for trial lots is considerably large, there is a delay in starting the production.
2. The cost is high, and hence it may be economical only for large scale production.

Q.5. List out the activities involved in

1. Acceptance, 2. Prevention, 3. Assurance as the function of quality control

OR

What are the three main element of quality function ? Explain.

Ans : 1. Acceptance Function : The term "acceptance' is the activity of making decisions on whether the product, materials tools, etc are acceptable for use or not.

The product aceptance consists of Acceptance of

i. Purchased goods.

ii. Goods in process, when the raw material undergoes processing.

iii. Finished goods.

In addition to above inpsection activities such as :

1. Maintenance of gauges, measuring instruments.
2. Storage and disposal of non-acceptable products.
3. Recording the data are also grouped with acceptance functions.

2. Prevention Function : It is based on the principle that it is better to prevent defects from happening than to cure them.

The defect prevention consists of :

1. Planning new products, processes, procedures, etc. Such that the defecs are avoided in the first place, itself.
2. Eliminating the defects as they arise.
3. Take suitable actions to avoid the occurance of such defects in future.

Satistical quality control is the important device for defect prevention The defect prevention activities include

i. Economic studies

ii. Process capability studies.

iii. Design of experiments.

iv. design of sampling plans.

v. Analysis of data

vi. Training in quality control.

3. Assurance Function : Quality assurance function deals with assuring the desired quality, reliability, service and other aspects in the manufactured product, through scientific techniques.

The job of evaluating the company's activities with respect to quality, reporting the results of evaluation to all concerned for information and necessary action, and the subsequent action taken is called as quality assurance function. The activities assigned to the assurance function usually include.

1. Processing of the field complaints.
2. Quality rating of outgoing product.
3. Quality survey or audit.
4. Prepartion of executive report on quality.
5. Setting up quality levels.

6. Inspection planning.
7. Market quality determination.
8. Disposition of non-conforming products.

In short the activities involved in three main elements, acceptance, prevention, assurance can be listed as follows:

Inspection	Quality Control	Quality Assurance
Receiving inspection	Economic studies	Field complaints.
Inprocess inspection	Process capability studies	Quality rating of outgoing
Finished good inspection	Design of Experiments	Products Quality survey or
Gauge maintanance	Analysis of Data	audit.
Test equipment	Design of sampling plans	Preparation of Executive
maintenance	Statistical Techniques	report on Quality
Storage and disposal of	such as control charts to	Setting up quality levels.
non acceptable product	be used and their	Inspection planning
etc.	frequency	Market Quality determination.
	Training in quality	
	Control etc.	Disposition of non
		comforming products,
		Depreciated equipment,
		tools etc.
Acceptance Function	**Prevention Function**	**Assurance Function**

Q.6. Expalin the need of organisation for co-ordination in an industry. How is it achieved ? or justify the statement quality is everybody's business.

Ans : Every person working in the industry is responsible in the task of obtaining satisfactory quality. The salesman who sells the product, production engineer, tool enginer, purchase officer, production, machine operator, inspector, personnel who trains the employees everybody has his own contribution in maintaining or improving the quality of the poroducts. If the work of any person in the organisation goes worng, it will affect the quality of the product produced and the efforts of all other will be in vain. Thus there is hardly a single individual in the entire company who in one way or the other does not contribute to the quality of the company's product or services. Thus it is rightly said that quality is everybody's business. This fact can be explanined clearly with the help of spiral of progress in quality. (Refer fig. 2.1 Question number 5 ...)

From the above discussion it is necessary to co-ordinate the efforts of all these individuals for building up and maintaining quality of product.

The Co-ordination in various groups may be achieved by various means such as :

1. Co-ordination through a common boss which forms a link and whose decision is final to be followed by all concerned.

2. Self Co-ordination i.e. to leave it to individual supervisors to identify the need for co-ordination as they arise and to conduct a meeting of whatever people are needed to solve the qualty problems.
3. Co-ordination through written procedure.
4. Co- ordination through staff specialists.
5. Co- ordination through joint committes (Quality improvement commitee. Quality motivation committee and engineering change committee etc.)

Q.7. What is defect prevention ? State its objectives.

Ans : Defect prevention is based on the principle that it is better to prevent defects from happening than to cure them. Defects in the poducts manufactured do not just happen they have causes. A few defects account for the majority of losses.

The defect prevention activities consist of :

1. Planning new products and processes such that defects are avoided in the first place itself. Before they occur and make the product defective.
2. Eliminating defects as they arise.

This involves :

1. Establish correct level of performance.
2. Establish measure of current performance.
3. Collect data on current performance.
4. Compare the current performance and expected performance.
5. Take suitable action to eliminte difference to maintain the quality of future production.

Objectives of defect prevention :

1. To prevent the defects from occuring in the first place. This helps to reduce scrap, rework and also the cost of production.
2. If the defects are detected as soon as they occur it saves the man hour, machine hours which would have been wasted while working on already defective products.
3. It helps to maintain the reputation of the firm and increases the demand for the product in the market.
4. It increases the competitive strength of the firm with rival companies producing similar products.

Q.8. State the functions of a quality control engineer (magager) in an industry.

Ans : The function of the quality control engineer can be listed as :

1. Draft a company's policy on quality.
2. Draft the company's major quality objectives.
3. Establish optimum quality of design.
4. Conduct quality audit and surveys.
5. Co-ordinate the preparation and execution of the quality plans including the tasks required during design, drafting purchasing, manufacturing and usage of the products :

6. Conduct process capability and machine capability studies.
7. Design of sampling plans, control charts and other statistical techniques.
8. Approve design of gauges, inspection and test devices.
9. Prepare job specifications for selecting and training of personnel for quality matters.
10. Plan and allot the quality functions to various persons in the department.
11. Collaborate in disposition of non- conforming products and materials.
12. Recommand new quality objectives based on consumers need.
13. Collaborate with poroduction, purchase, and other departments in solving quality problems and in matters requiring a team apporach.
14. Keep informed on new industrial developments in inspection methods. processes, materials, satistical techniques and other matters affecting quality of the products.

Q.9. Define Quality system state its importance.

Ans : Quality system : To assure quality one has to ensure the quality. To ensure quality it is necessary to adopt a standard procedure and to make systematic control at every stage and to take critical review of efforts and achievements of company with respect to quality of the product.

A comprehensive quality sytem covers all aspects of company's operation from the preparation of tenders to the eventual delivery. Installation and commissioning of products and also its after sales service.

According to Dr. Feiginbaum, "A total quality system is the agreed companywide and plantwide operating work structure documented in an effective and integral technial and managerial procedures for guiding the co-ordinated efforts best and most practical ways to ensure customer quality satisfaction and economical costs of quality."

Through the adaption and implementation of formal documented procedures, the system imposes discipline upon all aspects of company's operations with a view to ensuring that each task is performed correctly, first time and every time consistently. This will reduce rework, cutting waste by reducing rejections and scrap on the shop floor. It will also lead to prompt delivery by reducing delays to minimum. Hence operating efficiency will improve resulting in an improvement in overall profitability.

Q.10. Explain the term total Quality Control.

Ans : Total Quality Control : As already defined in Charpter 1, "Total Quality Control" is an effective system of intergrating qulity development, quality maintenance and quality improvement efforts of the various groups in an organisation, so as to enable production and services at the most economical levels, which allow full customers satisfaction.

Total Quality Control gives stress on prevention of defects rather than setting it right by rectification. The concept of total quality is different from product quality. It incliudes product quality and much more. Its approach towards quality is in all its forms in perople and processes, in products and costs, in planning and management. All the operations of a company market research, the needs of the customer, the optimal use of raw materials and other inputs, products development and design, manufacturing process, sales, service after sales the whole of it comprise total quality.

Total quality can be achieved only through total Employee Involvement. It starts with people. Total quality comes from employees creativity, team work, participation, continuous improvement, leadership, motivation etc.

There are six identifiable phases to achieve Total Quality control.

1. Comprehension 2. Commitment
3. Competence 4. Communication
4. Correction 6. Continuance.

1. Comprehension : What is quality, it should be definable and measurable.
2. Commitment : clarity of concepts and policies, organisation for it.
3. Competence : Develop method, tests, procedures to evaluate quality, understand the price of non-conformance to quality.
4. Communication : Create awareness, resolve conflicts, co-ordinate activities, create an image of product quality and reliability.
5. Correction : Solve problems of non-Conformance. Problems are largely due to lack of knowledge or lack of facilities.
6. Continuance : Maintain its importance, ensure exposure to sustained programmes, innovation (Introduction of new methodes, techniques).

TQC covers the above concepts and envelops all activities of product quality such as product design, product development, proto-type development and testing, manufacturing planning, production and inservice performance, testing and training etc.

It provides feedback at various stages for comparison with standards and for initiating control action to bring about modification and changes at appropriate stages. It involves all departments at various levels and provides for interaction, co-ordination and monitoring of various activities through prompt communication and control system.

Q.11. Define T.Q.M. State how it can be ensured.

Ans :

Total Quality Management (TQM) :

Definition 1. Total Quality Management refers to the total involvement of staff in an organisation together, which includes suppliers, distributors and even customers
in bringing about quality satisfaction by promoting quality cultures through quality circles, job enrichment and effective purchasing. Workers and supervisors have to be trained to solve the problems in product/process variations.

2. According to Prof. Leopald S. Vasin, "TQM is the control of all transformation processes of an organisation to best satisfy customers needs in the most economical manner".

The management can ensure this through :

a. Team Effrot.

b. Satisfying workers emotional and intellectual needs for better working conditions. The worker's attitude towards his products and their quality is also dependent on the industrial relations climate in the organisation. If the climate reflects a feeling of fair ness in personnel decisions, prompt redressal of grievances and open cummunication, the probability will be high that workers will be responsible and responsive to man agements advice.They may develop pride in their organisation and its products. Such a pride and sense of belongingness will have a great impact on product quality and productivity.

c. Installing motivation system, to include collective achievement and quality excellence.

d. Integration and co-ordination of activities of various departments such as product design, R and D, production planning, manufacturing/processing, technical services, sales etc. to attain the desired goals economically.

e. Maintaining a sound quality system, to ensure each task is performed correctly.

All this requires complex changes in product/processes to be effectively managed by top management through people involvement. Parameters responsible for product quality and qualty concepts need to be clearly understood by management if the marketed products are to satisfy the users and a good image of quality is to be developed to strive for excellence.

Q.12. What are ISO 9000 series standards ? State its equivalent standards.

Ans : ISO : 9000 series of standards on quality system was formulated by International Organistion for Standardization in order to meet the requirements of internationally uniform quality system. The European Nation trade has reached an understanding that the post 1992 trade transaction would be dealt only with those companies who have registered ISO:9000 quality system.

ISO : 9000 Series Standards in General : International Organisation for Standardization has developed the following standards on quality systems, the corresponding Indian standards are given in the brackets. Fig. 13.2.

ISO : 9000 quality standards stipulate certain management lines and minimum requirements for making quality of products and services conforming to the needs of customers. These are developed for facilitating international exchange of goods and services. All these systems are essentially self-disciplined standards based on the principles of harmonization of specification and continuous surveiliance by thirds party.

ISO:84021 (IS:13999)	VOCABULARY

ISO:9001 (IS:14000)	SELECTION AND USE OF QUALITY SYSTEM STANDARDS

NON-CONTRACTUAL SITUATIONS

ISO:9004 (IS:14004)	QUALITY MGMT SYSTEM STDS.

CONTRACTUAL SITUATIONS

ISO:9001 (IS:14001)	Q.A. MODEL FOR DESIGN DEVELOP/PRODN/IN STALLATION AND SERVICING
ISO:9002 (IS:14002)	QUALITY ASSURANCE MODEL FOR PRODUCTION AND INSTALLATION
ISO:9003 (IS:14403)	Q.A.MODEL FOR FINAL INSPECTION AND TESTING
ISO:10011-1 to ISO:10011-3 (IS:14011-1 to 14011-3)	GUIDELINES FOR AUDITING QUALITY SYSTEM

Fig. 13.2 Structure of Quality system Standards.

Q.13. Describe ISO :9000 series in brief .

Ans : ISO : 9000 (IS 14000) Quality Management and Quality Assurance Standard :

ISO Standard has given different models for adoption which relate to the stage of the product or service at which the quality of the later needs assurance. This standard gives guidelines for selection and use of appropriate model.

ISO 9001 : 1987 (IS 14001 : 1988)

Model for Quality Assurance in Design/Development, Production, Installation and Servicing.

A product or a service has to pass through several stages after it is conceived and before it is supplied to the customer. Even after it is supplied to the user, a necessity may arise to keep a follow up action; so that the user does not face any problem or difficulties in using the product **ISO :** 9001 standard gives a model for quality assurance at all stages starting from designing the product and continuing even after the product is delivered to the customer.

ISO 9001 applies to industries who design, produce, instal product and provide service after sales as per the requirements of the customer. Some specific examples are heat exchangers, coolers, filters, extraction columns etc. for process industries.

In these cases the customer states his application and the supplier works out the final design, makes changes if required. A set of specifications is then prepared, after the design requirements are mutually agreed. The manufacturer has to open his manufacturing stages to the customer so as to enable the customer to judge the suppliers capability of manufacturing the product as per has requirements.

After the product is manufactured, and inspected for conformance with specifications it should be installed by the supplier at the customer's premises and a trial run should be conducted. Even after installation, the supplier has to provide necessary services for maintenance of equipment for trouble-free performance.

ISO : 9002 : 1987 (IS : 14002 : 1988)

Model for Quality Assurance in Production and Installation : Some products require quality assurance only during production and till they are delivered to the customer/or installed in his premises. ISO:9002 gives a model quality assurance for such products. In such cases the manufacturer given his own design to meet the customers requirement and has to only prove that production process is capable of producing the product/equipment as per the requirements of the customer; and that the supplier can install the product/equipment at the customer's premises satisfactorily. Civil structures, construction of bridges etc. are the examples. So, this model is applicable where the assurance on quality is required only during production and upto satisfactory installation.

ISO : 9003 : 1987 (IS 14003 : 1988)

Model for Quality Assurance in Final Inspection and Test : Cenrtain products require quality assurance only after they are manufactured i.e. at the time of supply. The customer is not concerned with how they are manufactured. He is interested only in getting the product of desired quality as stated by the supplier/or ISO 9003 standard gives a model of quality assurance in such cases. Examples of such products are : domestic appliances, pertroleum products, components used in the assembly of manufacture of bigger items such as automobiles etc. Most of the consumer items also fall in this category.

ISO : 9004 : 1987 (IS 14004 : 1991)

Quality Management and Quality System Elements Guidelines : ISO : 9001, 9002 and 9003 apply where a contract between supplier and contractor exists. In non-contrctual situations companies may adopt ISO : 9004 which gives guidelines for quality management.

It is essential to build confidence of the customer that the organisation can supply the desired quality of the products or services. The organisation has to take serveral integrated steps in managing all matters which have direct or indirect effect on its image to deliver the products of desired quality. These integraed efforts of the organisation towards maintaining the quality culture is Quality management. All these elements of quality management taken together make the quality system. ISO 9004 : 1987 gives guidelines comprising different elements of a quality management system.

Q.14. Stae the outstanding features of ISO 9000 series standrds.

Ans : Outstanding Features of ISO : 9000 Series of Standards : There are a number of outstanding features about the ISO : 9000 series of quality assurance system standards.

1. The elements if ISO:9000 quality systems are not new. Some or all the elements are always under practice by every ogranisation in its business activities. The important features of ISO : 9000 are the integration of all activities which have a direct or indirect effect on the quality of a product or service. The total system of quality is thrown open for verification by the customer and confidence is built in him that the organisation is capable of delivering the products or services of desired quality.
2. These standards have been formulated by peopole who are conversant with the problems and failures which occur in industries.
3. ISO : 9000 stndard series tells suppliers and manufacturers what is required of quality oriented working system. It does not set out extra special requirements which only a very few firms can comply with, instead it is a practical standard for quality systems which can be used by small as well as large organisations.
4. It defines the basic concepts and specifies the procedures and criteria to ensure that the outgoing product meets the customer's requirements.
5. There are no dictatorial clauses in the standards. In most cases it requires a company to establish its own procedures.
6. The standards are designed to be user friendly. They are generic in nature, and follow a logical, easily understood format. They are applicable to every product, let it be a tooth brush or a nuclear reactor.

ISO : 9000 standards are not compulsory by legislation. They are only voluntary. However, they give preference over those who do not have ISO : 9000 quality system; since the customer would be sure of the quality he gets.

Q.15. State the advantages and limitations of ISO : 9000.

Ans : Advantages or Benefits of ISO : 9000 :

1. ISO : 9000 series of standards enable to meet the requirements of an internationally uniform quality system.

2. It could enhance foreign exchange. So it is important for the industires to adopt ISO : 9000 to compete in the international market.
3. It enables the company to build customer confidence that it is capable of delivering the products or services of desired quality.
4. It reduces the need for assessment by multiple buyers. It thus avoids time and money spent on multiple inspections of products for conformance.
5. To adopt ISO : 9000 standards it is necessary to establish and maintain sound quality assurance system. This results in improvement in efficiency, and redution in inspection; scrap and rework.
6. Motivates the employees and develops pride in them for achieving excellence.
7. Once ISO : 9000 has been adopted it automatically enables the company to control its production quality and delivery schedules, cut waste and down time and boost productivity.

Limitations of ISO : 9000.

There are few disadvantages of ISO : 9000 series standards, these are :

1. The implementation of ISO:9000 series of standards is very much demanding on resources.
2. The formulating and documenting of the system is time consuming, and may involve considerable clerical expenses.
3. Assemssment and registration are also expensive.
4. The need to change attitudes and accept new working practices may strain the management capability of the company beyond its ability to cope.

Q.16. Define the following terms as per ISO : 8402 (vocabulary)

i. Quality ii. Inspection iii. Reliability
iv. Specification v. Quality loop.

Ans : Quality : Quality is the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs.

Inspection : As per ISO : 8402, inspection implies the activities such as measuring, examining, testing, grading one or more characteristics of a product or service and comparing these with specified requirements to determine conformity.

Reliability : Realibility is the ability of an item to perform a required function under stated conditions for a stated period of time.

Spicification : The document that prescribes the requirements with which the product or service has to conform.

Quality loop : (Quality spiral) It is the conceptual model of interacting activities that influence the quality of a product or service in various stages ranging from the indentification needs to the assessment of whether these needs have been satisfied.

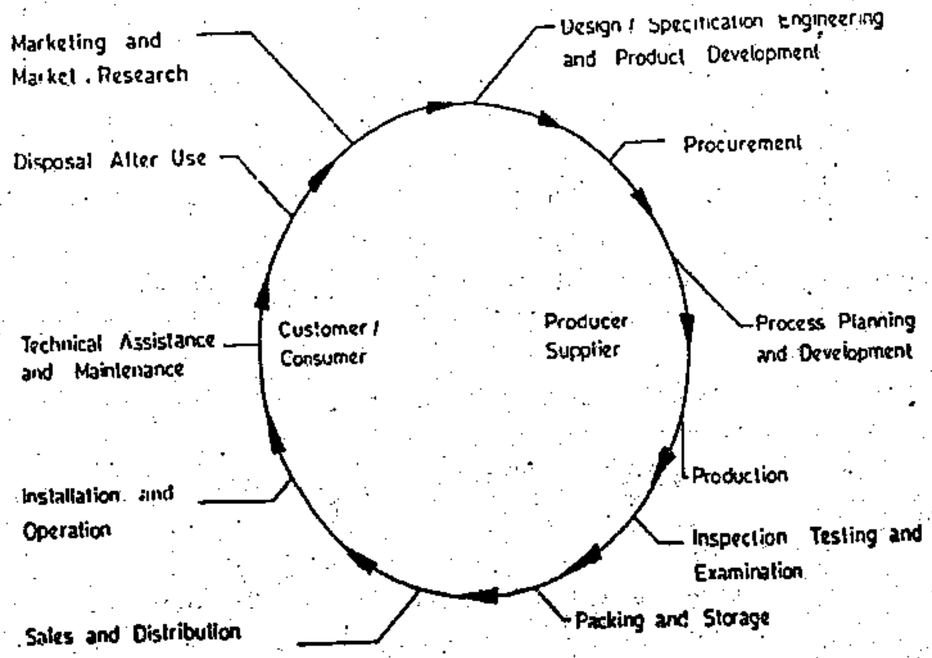

Fig. 13.3 Quality Loop

Q.17. Define the following terms as per ISO : 8402

i. Quality system ii. Quality Assurance iii. Quality control
iv. Quality Audit v. Quality management vi. Quality policy.
vii. grade

Ans : Quality system : As per ISO : 8402 vocabulary, Quality system is the organisational structre, resposibilities procedures, processes and resources for implementing quality management

Quality Assurance : All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality.

Quality control :- The operational techniques and activities that are used to full fill requirements for quality.

Quality Audit : A systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives.

Quality Management : The aspects of the overall mannagement function that determines and implements the quality policy.

Quality Policy : The overall quality intentions and direction of an organisation as regards quality, as formally experssed by top mangement.

Grade : An indicator of category or rank related to features or characteristics that cover different sets of needs for products or services intended for the same functional use.

).18. Name the various elements of ISO: 9000 series standards :

\ns : The various elements (Clauses) of quality system as per ISO : 9000 series standards re.

1. Management Responsibility.
2. Quality systems
3. Cotract Review.
4. Design Control
5. Document Control
6. Purchasing
7. Purchaser supplied Product.
8. Product Identfication and traceability
9. Process control
10. Inspection and testing
11. Inspection Measuring and Test Equipment.
12. Inspection and Test status. .
13. Control of No-conforming Products
14. Corrective Action.
15. Handling, storage, Packaging and Delivery.
16. Quality Records
17. Internal Quality Audit
18. Training.
19. Servicing
20. Statistical Techniques.

;O : 9000 standards, thus cover all aspects of functioning of any organisation. It involves :velopment of the Total organisation. The implementation of Quality management system ised on ISO : 9000 / IS : 14000 series standards is effected through a well documented uality manual along with procedures, instructions and formats for records.

.19. Describe in brief the pre-requisites for implementing ISO : 9000 Quality system.

ns : For implementing ISO : 9000 Quality systems, effectively, the organisation must meet : following requirements :

1. Development of quality Awareness.
2. Imparting Education and Training to Employees.
3. Introduction of Motivation and Incentive programme.
4. Development of measuring Euipments Laboratory.
5. Development of planning scheme for Implementation.
6. Management commitment to fully support the quality system with a strong will and faith to make it success.

:velopment of quality awareness : Everybody in the organisation from top to bottom)uld extend his willful support to the quality programme and make quality as first policy. It is necessary to convince every employee is accept quality as as part of work and get their wilful support in implementing and maintining of quality policy of the organisation as their main responsibility.

Imparting Education and Training to Employees : Education and training to the workforce at different levels is a must in order to make sure that the desired skill is available within the organisation to meet international quality standards. The education and training programme should be structured for three levels on the lines of ISO 9004, a. Training for executives, b. Training for technical personnel, c. Training to work force (shop floor) and production supervisors. Education and training must be job oriented and must be integral part of quality policy.

Motivation and Incentive programme : Quality systems have clearly recognised the importance of people in achieving product qualit consistently. It should be noted that the principle force for meeting the specifications maintaining or improving quality lies not in the gauges, instruments or other facilities for inspections; it lies in the state of mind of the persons working in the organisation from the top executive down to the workers.

Loboratory for measuring Equipments : To measure and control the quality charactristics of products test and measuring equipments are extremely important components of quality system. Therefore, a metrology and material testing laboratory is very important pre-requisite to make the quality system a success.

Planning scheme for Implementation : Quality planning (ISO : 9003 AND 9004) is a written document which must be read and understood by everybody from top to bottom in the organisation before implementing quality system. For projects relating to new products, services or processes management should prepare, appropriate, written quality plans consistent with all other requirements of a company's quality management system.

Q.20. Describe in brief the installation / Registration procedure of ISO : 9000 Quality system.

Ans : ISO : standards are adopted by National Standards Bodies of the individual countries. These bodies if mutually recognised by the countries, are the certifying or registering bodies. In our country Bureay of Indian Standards (BIS), is the National certification Body, The B/S has introduced the Quality system certification Scheme according to IS : 14000 series of standards. These standards are identical to the internationally accepted ISO :9000 series of standards of quality system.

The quality system certification scheme of BIS entails implementation in day to day operating of the organisation in conformity with the provision of ISO 9000 series standards. The quality system certification of BIS has been accredited by the Road Voor de certificate (RVC) of the Netherlands. It has also entered into mutual agreement with DQS, Germany a leading ISO : 9000 certification agency for recognition of each others certification.

The basic steps to be followed for ISO : 9000 certification are as given below.

1. Management Commitment
2. Prepare the workmen for change
3. Selection of appropriate model
4. Study the selected model
5. Set up steering Group and Sub-groups
6. Arrange Training of leaders and Co-ordinators
7. Prepare a check list
8. Prepare corporate Quality manual.
9. Prepare procedure manuals, operation manuals, work instructions etc.
10. Up date all drawings and specifications.
11. Prepare schedule of training programme and educate employees.
12. Provide Tooling, equipments, Facilities., etc. to meet standards.
13. Carry out Internal Audit.
14. Take corrective Action.
15. Apply for Trial /External Audit.
16. Implement Recommendation
17. Apply for Registration / Accreditation
18. Grant of Lincence.

Once The trial audit result is positive, the organisation is in a position to apply for registration BIS/or any other internationally recognised Body.

After the application has been accepted, the documented quality system will be examined certifying agency to veritfy the conformance to the relevant standard. Descrepencies if y, will have to be corrected by the applicant.

The corrective action taken by the firm on the discrepancies observed during assessment ll have to be verified by the certifing agency. Based on the findings of the assessment team d satisfaitory report, licence will be granted to the firm by BIS/ISO: to use the certification rk in letter heads, quality certificates etc.

21. Name the standard bodies in India which provides guidance in connection with ISO : 9000.

s : In India the following standard bodies provides guidance to Indian industries :

1. Bureau of Indian Standards : The Bureau of Indian standrds (BIS) is the National tification Body. It gives guidance for launching quality system cerfication in the following a.

i. Quality system appreciation programme.
i. Quality system survey
ii. Trial Assessment
v. Licensing
The Bureau also coducts seminars, conferences, workshops on the standards

1. The BIS has introduced the quality system certification scheme according to IS 14000 series of standards are identical to the internationally accepted ISO : 9000 series of standard of quality system.
2. Confederation of Indian Industry (CII)
3. Breau of Veritas Quality International Ltd., Bombay
4. National Centre for Quality management
5. Quality management International
6. National Productivity council (NPC) etc. also provides guidance in some areas related to ISO : 9000.

Q.22. What is machine capability ? State its importance. Name the methods used for determining machine capability.

Ans : Machine tool selected should be able to give required machining accuracy and surface finish consistently. Hence, machine capability is the ability to produce the parts, products, components within the specified tolerance limits consistently.

But, the machine tool do not remain in the same condition due to wear, improper use, poor maintenance etc. Preventive maintenance, prope. lubrication, use of coolent, trained workers, good quality materials, tools etc. may help to maintain the machine capability for a longer period.

Machine capabilities change with time, and because the change take place in a relatively short time period, this possibility should be constantly considered by the engineer. Thus repeated runs of products manufactured do not give exactly the same results. The width of the band of each inherent variation is the important factor taht determines the capability of the machine to produce non defective products.

Capability of a new machine tool is known from the catalogues. But machine tools goes on loosing accuracy due to wear etc. Hence the machine capability determined at one time may not be an indication later on of the inherent ability to meet the tolerance.

Before selecting and buying a machine, it is nacessary to know whether the machine he is specifyig is adequate to meet the designed tolerance (assuming normal operation and maintenance of the process) several methods are in use for determining machine capability.

1. Try out the product as made by the machine in actual use.
2. Measurement (i.e. testing) of the machine itself as in case of machine tools.
3. Measurment of the product (turned out by the machine) against the product tolerances.
4. Measurement of the process capability of the machine in terms of 6σ limits as explained in Chapter 6.

Q.23 Describe in brief.

1) National codes

2) International codes

Ans. 1) National Codes : Most of the countries have their own Standards Bodies who formulate specifications for a variety of products. In India Bureau of Indian Standards (BIS) is the National Standards Body. Various technical committees work within the framework of BIS on products of not only consumer use, but also on products for consumption by various industries. Members of the committees are drawn from manufacturers, users, research organisations, Govt. departments or any other interested individual experts or organisations.

The different jobs performed by BIS are as under :

i) Providing standards in documented form for products, materials and the processes.

ii) To issue the ISI certification for industrial produdts under ISI Certification marks scheme under Act, 1952.

iii) Circulation of latest information through their journals regarding standardization.

iv) Providing international standards in India, in collaboration with ISO (International Organisationfor Standardisation) and IEC (International Electrochemical Commission) in Europe.

2) International Codes : The development of own national standards by major industrial countries for similar type of products bear little resemblance to one another. Thus standards (national) have become hinderance to easy flow of goods from country to country.

ISO : 9000 series of standards on quality system was formulated by International Organisation for Standardisation in order to meet the requirements of internationally uniform quality system.

European countries adopted these standards in their own National Standards. The European Nation Trade has reached an understanding that the post 1992 trade transaction would be dealt only with those companies who have registered ISO : 9000 quality system. India, too, adopted these standards through IS 10201 in parts in 1988 and later year which were subsequently as IS : 14000 series.

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Chapter 14

STATISTICAL QUALITY CONTROL (S.Q.C.)

Q.1. Define the term Statistical Quality Control (S.Q.C.) and state its benefits.

Ans : A quality control system is called S.Q.C. when statistical techniques are employed to control quality or to solve quality control problems. Statistic is based on law of large numbers and the mathematical theory of probability. It is in this sense that the adjective statistical is accurately used in the expression statistical quality control.

In S.Q.C. the mathematical statistical approach neutralizes personal bias and uncovers poor judgement. Modern techniques of statistical quality control and acceptance sampling have an important part to play in the improvement of quality, enhancement of productivity, creation of consumer confidence and development of the industrial economy of the country.

Benefits of Statistical Quality Control :

1. **Efficiency and cost reduction :** Since only a fraction of out put is inspected, use of S.Q.C. ensures rapid and efficient inspection at minimum cost.
2. **Reduction of Scrap :** It enables to forecast the troubles before rejections occur and reduces the amount of spoiled work.
3. **More effective pressure :** On quality improvment than 100% inspection.
4. **Easy detection of faults :** With the help of control charts deterioration in quality can be easily detected and corrective action can be taken.
5. **Adherence to specification :** So long a statistical control continues specification can be accurately predicted for future, by which it is possible to assess the capability of the process to meet the specifications.
6. Easy application
7. Reduction in scrap, rework and consumer complaints.
8. Better customer relations.
9. Creates quality awareness in employees.
10. Improves productivity and reduces wasted machine and man hours.

).2. Define central tendency and explain the meaning of mode, median and Arithmetic mean as measures of central tendency.

ins : Central Tendency : When accurately measured the dimensions of most of the components tend to concentrate close to the middle of the two extremes. This is called "Central Tendency' In other words the maximum number of components will have sizes equal to or approximately close to the midle size, and the sizes bigger or smaller than the middle size will be less frequent and lie near the two extremes.

Central tendency is usually expressed in three ways :

1. The average value (Arithmetic mean)
2. The middle value (median)
3. The most frequently occuring value (mode)

Mode :

Mode is the value that occurs most frequently,in a frequency histogram or frequency polygon,it is the observed value corresponding to the high point of the graph. In fact mode is the most unstable average and its true value is difficult to determine. For example, the recorded observations are;

2, 3, 2, 4, 5, 2, 6, 7, 2, 4, 2.

Here 2 occurs most frequently hence mode = 2.

Median :

When all the observations are arranged in ascending or descending order, then median is the magnitude of the middle case. It has half the observations above it and half below.

If there are "n' observations of the variate and they are arranged in ascending order:

The median is given by $\left(\frac{N+1}{2}\right)^{th}$ value if "N" is odd.

On the other hand the median is the average of $\left(\frac{N}{2}\right)^{th}$ and $\left(\frac{N}{2}+1\right)^{th}$ value if "N" is even.

Arithmetic Mean :

The arithmetic mean $\overline{X}$ is the average of all the values of variate in the sample.

If $X_1, X_2, X_3, X_4, \ldots\ldots X_n$ are the n values of the variate X in the sample, then A.M. is given by :

$$\overline{X} = \frac{X_1 + X_2 + X_3 + \ldots\ldots + X_n}{n} = \frac{\sum \overline{X}}{n}$$

If X_1 occurs f_1 times, X_2 occurs f_2 times etc. and lastly X_n occurs f_n times, there being n observations.

autogether then, $$\overline{X} = \frac{X_1f_1 + X_2f_2 + X_3f_3 + \ldots\ldots + X_nf_n}{f_1 + f_2 + \ldots\ldots\ldots\ldots f_n}$$

$$\overline{X} = \frac{\sum f_x}{\sum f} = \frac{\sum f_x}{n}$$

The A.M.is used to denote average size, average yield average percent defective etc.

Q.3. Define dispersion. Explain the various measures of dispersion.

Ans : Dispersion : The exent to which the data is scattered about the zone of central tendency is known as dispersion.

The various measures of dispersion are :

1. Range (R)
2. Standard deviation
3. Variance.

Range :

Range is the differnce between the largest observed value and the smallest observed value in a sample.

i.e. R = Largest value - Samllest value

Range is the simplest measure of dispersion in a sample. It is particularly used in the control chart.

Standard Deviation :

Standard deviation (σ) is the r.m.s.value. Standred deviation is defined as the root mean square of the differences between the observations and the mean.

If $X_1, X_2, X_3 \ldots\ldots X_n$ are "n' number of observations. $\overline{X}$ = Arithmatic mean

Then $\sigma = \sqrt{(X_1 - \overline{X})^2 + (X_2 - \overline{X})^2 + \ldots\ldots\ldots + (X_n - \overline{X})^2}$

$= \sqrt{(X_i - \overline{X})^2}$ Where, i varies 1 to n

Variance :

Variance is the sum of the squares of the deviations from the arithmetic mean divided by the number of observations "n_x'

In other words variance (σ^2) is the square of the standard deviation.

Q.4. Differentiate between attribute inspection and variable inspection.

OR

Differentiate between quality by variables and quality by attributes.

Ans :

Variable Inspection	Attribute Inspection
1. Variable inspection consists of measuring the quality characterstics to be inspected with the help of precision measuring instruments.	1. Attribute inspection consists of judging the conformance or non conformance of the quality characteristics with the laid down standard.

Variable Inspection	Attribute Inspection
2. Actual dimensions say diameters of number of spindles are measured with the help of micro meter, vernier calliper etc. and the data is recorded.	2. The conformance or non conformance is usually inspected with th help of Go-No-Go gaues. And items are classified as defectives or non defective.
3. It provides detailed information about the quality characteristic.	3. It just gives information about whether the parts are acceptable or not.
4. The time required and the cost of inspection is quite large	4. It requires minimum time and cost.
5. It may cause fatigue to the inspectors. Therefore the meausrements may go wrong.	5. It does not cause fatigue to the inspectors. Therefore this method is suitable in mass production, where large number of similar parts are to be inspected.
6. The data obtained from variable inspection is called as continuous data, and can have any value over certain interval.	6. The data obtained is called discrete data. The discrete data can have certain integer value. For example, a sample of 25 casting taken from a lot may contain 0, 1, or 2 defectives there can not be fracation defectives such as $2\frac{1}{2}$ defectives.
7. Example : A dimension of parts measured, Hardness in Roackwell units, Temp., tensile strength, weight etc.	7. Example : Number of defective pieces found in a sample, surface finish of furniture, cracks in sheets by spot welding etc.

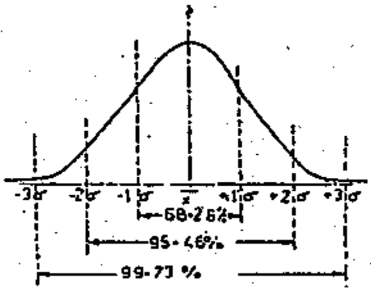
Q.5. Define frequency distribution. Draw neatly the normal distribution curve and mention its characteristics. State the uses of this curve in quality control.

Ans : Frequency distribution : When the measured sizes of all the products are plotted against the frequency of occurances of each size in the form of graph, it is known as frequency distribution. The height of the curve at any point is proportional to the frequency of occurance of that particular size.

Normal Distribution Curve : In the frequency distribution if the number of observations are increased the frequency polygon assumes a bell shape and approximates to normal distribution curve, if only the chance causes of varation are present in the quality characteristics measured.

Characteristics :

1. The normal distribution curve is bell shaped and symmetrical about its mean. The curve is fully defined by $\overline{X}$ and σ
2. **Theoretically, the N.D. curve extends from $-\infty$ (minus infinity) to $+\infty$ (plus infinity).**



However for all practical purposes we can consider normal curve as extending only 3 σ values to the left and 3 σ values to the right of the mean $(X \pm 3\sigma)$.

3. The most commonly quoted limits in connection with the curve are as follows.

Fig.14.1 Normal Curve

Specification limits	**Percent of total Area Within specified limits.**
$\overline{X} \pm \sigma$	68.26
$\overline{X} \pm 2\sigma$	95.46
$\overline{X} \pm 3\sigma$	99.73

Uses of N.D. curve in quality control :

1. When meausred sizes of parts are plotted against frequency of their occurance and if the frequency distribution curve approximates to N.D. curve it means that practically no assignable causes of variation are present.
2. It is useful in process capability study to find out whether the process is capable of meeting the specified tolerances or not.
3. The area under the curve between two limits represents the total percent of production that will fall within these limits.
4. It is useful to calculate the expected proportion or observations that will be less than or equal to specified value $\overline{X}$.
5. It also helps to calculate the expected proportion of observations that will be beyond a specified value $\overline{X}$.
6. When we select 3 σ limits, we are 99.73% sure that the observations will lie within these limits.

Q.6. What is the interpretation of three standard deviation?

Ans : Theoretically the normal distribution curve extends from . $+\infty$ to $-\infty$. However, for all practical purposes we can consider normal curve as extending only 3 σ values to the left and 3 σ values to the right of the mean.

When we select 3 σ limits, we are 99.73% sure that the observations will lie within these limits.

Q.7. Name and describe the various ways of graphical representation of frequency distribution.

Ans : The frequancy distribution can be represented graphically by the following ways :-

1. Frequency Histogram.
2. Frequency polygon.
3. Bar chart.
4. Ogive curve
   a. Less than ogive curve.
   b. More than ogive curve.

1. Frequency Histogram : Fig.14.2 shown a frequency histogram. In this graph the sides of the column represents the upper and lower cell boundries and hights are proportional to the frequencies of occurances within the cells. In drawing a histogram it is assumed that the frequency is centred at the mid value of the class or cell.

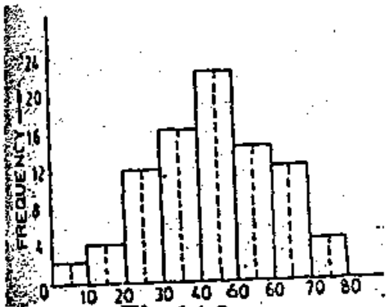


Fig.14.2
Frequency Histogram

The simplicity of construction and interpretation of the histogram makes it an effective tool in the elimentry analysis of the data. A random sample is selected from the lot under consideration and measurements are made for selected quality characteristic. When there is a large amount of highly variable data then it may be grouped in to cells, the class limits and cell boundries are decided and the frequency histogram is plotted. As a general rule,at least 50 measurements should be taken to provide sufficient data to reveal the basic pattern of variation within the lot .

2. Frequency Polygon : It consists of a series of straight lines joining points which are plotted at cell mid points with a height proportional to the frequency. The advantage of frequency polygon is that frequency polygons of several distributions may be plotted on the same axis,thereby making certain comparison possible. Fig.14.3 shown a frequency polygon.

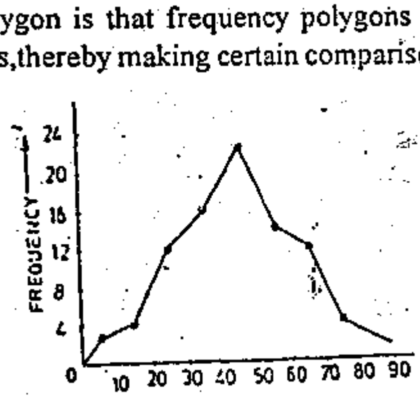


Fig. 14.3 Frequeny polygon

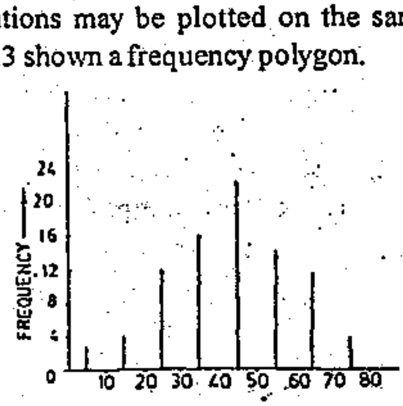


Fig. 14.4 Bar chart

3. Bar chart : A frequency bar is a graphical representation of the frequency distribution in which the bars are centered at the mid point of the cells. The heights of the bars are

4. **Ogive Curve :** Ogives are used to plot cumulative frequencies of values less than or greater than the respective cell boundries. Less than ogive curve is a graph between upper class boundary and the less than cumulative frequency. It is an "s' shaped curve which gives a cumulative frequency of a variable less than a given value of the variable.

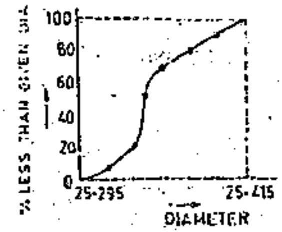


Fig. 14.5 Ogive curve

In more than ogive curve the cumulative frequency is plotted against the lower class boundry. It is an inverted "s' curve which gives a cumulative frequency of the variable more than a given value of the variable.

Q.8. Differentiate between Discrete Data and continuos Data.

b. Classify the following data as to whethere they are discrete or continuos.

Ans :

1. Weekly number of accidents in a given plant.
2. Tensile strength of cotton yarn in Kg/cm2
3. Monthly number of machines rejected.
4. Daily employment.
5. Diameters of metal cylinder.
6. Cracks in sheet by spot welding.

Discrete Data : In analyzing variability it is essential to distinguish two types of data

1. Discrere data.
2. Continuous data.

The data that arise from counting is discrete. The discrete data is obtained by attribute inspection. The discrete data can take certain integr value. For examples a sample of 25 casting taken from a lot may contain o,1,or 2 defectives there can not be a fraction defective such as $2\frac{1}{2}$ defectives.

Continuous Data : Continuous data refers to data that can potentially take on any value within a given range. This means that within that range there is no inherent restriction on the values that may be taken. Continuous data is obtained by variable inspection.

b. 1. Weekly number of accidents in a given plant-Discrect.
2. Tensile strength of cotton yarn in kg/cm^2-continuos
3. Monthly number of machines rejected-Discrete.
4. Daily Employment - Discrete
5. Diameter of metal cylinder- continuous
6. Cracks on sheet by spot welding-Discrete.

Q.9. Define the terms.

1. **Grouped frequecy distribution.**
2. **Universe or population.**

Ans : 1. Grouped frequecy distribution : Grouped frequency distuibtion of a set of obsetvation is an arrangement which shows the frequency of occurances of the values of the variables in ordered classes. The interval along the scale of measurement of each ordered class is termed as a cell. The frequency for any cell is the number of observations in that cell.

2. Universe or population : The universe can be thought of as a common source from which the total collection of units is obtained. The terms universe, population and parent distribution has the same meaning. Statistical methods are based on the concept of a distribution of an exceedingly large number of observations, termed as an infinite universe or population.

PROBLEMS & SOLUTION

6.1. Five thermostatic controls are tested to determine the "on" temperature. The measured values are 344°, 338°, 342°, 335°, and 336°,. These values contitue the first sub group for certain control chart.
Calculate the arithmetic mean, range, standard devication and variance of this subgroup.

Solution : Arithmetic mean $\overline{X} = \dfrac{344 + 338 + 342 + 335 + 336}{5}$

$$= \frac{1695}{5} = 339°$$

Arranging in ascending order the values are
335°, 336°, 342° and 344°

Median = Central value = 338°

Range = Largest value - smallest value
344 - 335 = 9°

Standard deviation : $\sqrt{\dfrac{(X_i - \overline{X})^2}{n}}$

$$\sqrt{\frac{(335 - 339)^2 + (336 - 339)^2 + (338 - 339)^2 (342 - 339)^2 + (344 - 339)^2}{5}}$$

$$= \sqrt{\frac{16 + 9 + 1 + 9 + 25}{5}} = \sqrt{\frac{60}{5}} = \sqrt{12} = 3.46410$$

variance $= \sigma^2 = 12$

14.2 For the following data calculate the Arithmetic mean and standard deviation?

Cell mid points	Cell boundries	Frequency
385	382.5	8
390	387.5	10
395	392.5	15
400	397.5	17
405	402.5	8
	407.5	

Solution :- For convenience the data may be tabulated as followes :

Cell boundries	Cell mid		Frequency		
	X	f	f_x	x^2	fx^2
382.5-387.5	385	8	3880	143225	1185800
387.5-392.5	390	10	3900	152100	1521000
392.5-397.5	395	15	5925	156025	2340395
397.5-402.5	400	17	6800	160000	2720000
402.5-407.5	405	8	3240	164025	1312200
Total		$\Sigma f = 58$	$\Sigma fx = 22945$		$\Sigma fx^2 = 9079375$

1) Arithemetic mean $\overline{X} = \frac{\sum fx}{n} \frac{22945}{58} = 395.60$

2) Standard deviation $= \sqrt{\frac{\sum fx^2}{n} - \overline{x}^2}$

$$\sqrt{\frac{9079375}{58} - (39560)^2}$$

$$= \sqrt{156540 - 1564495.36}$$

$$= \sqrt{40.58} = 6.37$$

Second method (shift of origin method) :

Standard deviation can be calculated easily by short cut calculations as under.

According to this method,

$$\overline{X} = K + \frac{\sum fd}{n}$$

Where K is assumed origin, preferably the central value of X series.

$d = X - K$

$$\text{and } \sigma = \sqrt{\frac{\Sigma fd^2}{n} - \frac{(\Sigma fd)^2}{n}}$$

In this problem let K = 375

The data can be tabulated as follows for convenience.

Cell and points x	Frequency f	d = X - K, (K = 395)	fd	fd2
395	8	-10	-80	800
390	10	-5	-50	250
395	15	0	0	0
400	17	+5	85	425
405	8	+10	-80	800
	$n = \Sigma f = 58$	$\Sigma fd = 35$		$\Sigma fd^2 = 2275$

$$\text{Arithemetic mean } \overline{X} = \frac{\Sigma fd}{n}$$

$$= 395 + \frac{35}{58} = 395.6$$

$$\text{Standard deviation } = \sqrt{\frac{\Sigma fd^2}{n} - \frac{(\Sigma fd)^7}{n}}$$

$$= \sqrt{\frac{2275}{58} - \frac{(35)^2}{58}}$$

$$= 38.864 = 6.2340$$

14.3. One hundred steel pins with the specification of 10+0.015 10.70-0.010 diameter were obtained and the data was recorded follows :

Dia in mm	No.of pins	dia in mm	no.of pins
10.60-10.65	05	10.75 -10.80	35
10.65-10.70	10	10.80-10.85	17
10.70-10.75	30	10.85-10.90	03

1. Find the Arithmetic mean and standard deviation.
2. Interpreat the results on the basis of Normal distribution and suggest the changes if any.

Solution : The data can be tabulated as follows for covenience.

nid

nid points X	frequency f	d = x-K (K = 10.775)	fd	fd2
10.625	05	-150	-0.750	0.1125
10.675	10	-0.100	-1.00	0.100
10.725	30	-0.050	-1.5	0.075
10.775	35	0.0000	0.000	0.000
10.825	17	+0.050	0.85	0.0425
10.875	03	+0.100	0.30	0.030
	n = 100	$\sum$fd = -2.100		$\sum$fd2 = 0.3600

$$\text{Arithmetic mean } \overline{X} = K + \frac{\sum fd}{n} = 10.775 + \frac{-2.100}{100}$$

$$= 10.774 - 0.021$$

$$= 10.754$$

$$\sigma = \sqrt{\frac{fd^2}{n} - \frac{(fd)^2}{n}} = \sqrt{\frac{0.360}{100} - \frac{(-2.1)^2}{100}} = 0.056$$

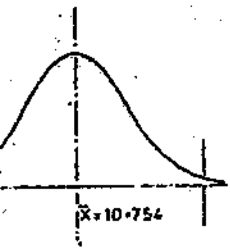


Fig.14.5

ency Distribution

3σ limits on normal curve

= 3 x 0.056 = 0.168

= X ± 3σ = 10.754 ± 0.168

Therefore maximum dimension that can be produced by usi this process

= 10.754 + 0.168 = 10.586 mm.

The specifacation limits are 10.70 + 0.015 = 10.715

and 10.70 - 0.010 = 10.640

Therefore the process is not within specification limits.

Following are the readings of 30 bars in a sample with specification 50mm?

50.3	50.1	49.8	50.0	49.9	50.0	50.3	50.1	50.1	50.2

1. Frequency Distribution Table		
	Tabulation	Frequency
49.8	||	2
49.9	~~||||~~ |||	8
50.00	~~||||~~ ~~||||~~	10
50.1	~~||||~~ ~~||||~~ ~~||||~~	15
50.2	~~||||~~ |||	8
50.3	||||	4
50.4	----	-
50.5	|||	3

2. Frequency polygram and distribution curve :

iii) Arithcmetic mean $\overline{X} = \dfrac{\sum f_i x_i}{n}$

$$= \frac{49.2 \times 2 + 49.9 \times 8 + 50 \times 10 + 50.1 \times 15 + 50.3 \times 4 + 50.5 \times 3}{50}$$

$= 50.092$

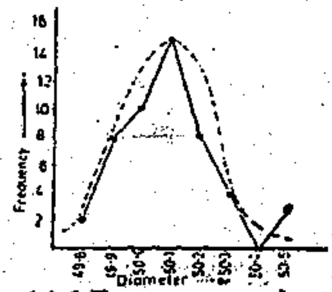


Fig. 14.6 Frequency polygaon

for calculating stadard deviation the data may be tabulated as follows.

Fig.3.6 frequency polygaon

Diameter mmx1 X_i	Frequency f_i	$(X_i - X)$	$(X_i - X)^2$	$f_i(X_i - \overline{X})^2$
49.8	2	-0.292	0.08526	0.1705
49.9	8	-0.192	0.03696	0.2949
50.0	10	-0.092	0.00846	0.0846
50.1	15	+0.108	0.00064	0.0096
50.2	8	+0.208	0.0166	0.0933
50.3	4	+0.208	0.0416	0.1664
50.4	-	-	-	-
50.5	3	+0.408	0.16646	0.4994
			$\sum f_i(X_i - \overline{X})^2 =$	1.3187

$$= \sqrt{\frac{fi\left(Xi - \overline{X}\right)^2}{n}}$$

$$= \sqrt{\frac{1.3187}{50}}$$

$$= 0.1624$$

Second Method :

Diameter mm X_i	frequency f	d = X-K k = 50.1	fd	fd^2
49.8	2	-0.3	-0.6	0.18
49.9	8	-0.2	-1.6	0.32
50.0	10	-0.1	-1.0	0.10
50.1	15	0.0	0.0	0.00
50.2	8	+0.1	+0.8	0.08
50.3	4	+0.2	+0.8	0.16
50.5	3	+0.4	+1.2	0.48
	n = 50	$\Sigma fd = 0.4$		$\Sigma fd^2 = 1.32$

1) A. M. $\overline{X} = K + \frac{\Sigma fd}{n}$

$$= 50.1 + \frac{(-0.4)}{50} = 50.092 \text{ mm}$$

$$= \sqrt{\frac{\Sigma fd^2}{n} - \frac{(\Sigma fd)^2}{n}}$$

$$= \sqrt{\frac{1.32}{50} - \frac{(-0.4)^2}{50}}$$

$$= \sqrt{0.0264 - 0.000064}$$

$$= 0.16228$$

14.5. You have collected the following data from micrometer measurements in milli -meters of a sample selected form a large lot of machined parts and have formed frequency tally sheet of the data as follows:-

Measurements	Tally	Measurements	Tally
25.70	|	25.10	卌 |
25.60	||	25.00	卌
25.50	卌	24.90	||||
25.40	卌 ||	24.80	|
25.30	卌 卌	24.80	|
25.20	卌 |||		

i. Compute the average and standard deviation of the sample .

ii. Given a specification 25+0.5mm

Interpreat the results on the basis of normal curve.

Solution : For convenience the data may be tabulated as follows.

Measurements X_i	frequency f_i	$d = X_i - K$ $k = 25.20$	fd	fd^2
49.8	2	-0.3	-0.6	0.18
49.9	8	-0.2	-1.6	0.32
50.0	10	-0.1	-1.0	0.10
25.70	1	0.50	0.50	0.25
25.60	2	0.40	0.50	0.32
25.50	5	0.30	1.50	0.45
25.40	7	0.20	1.40	0.28
25.30	11	0.10	1.10	1.11
25.20	8	0.00	0.00	0.00
25.10	6	-0.10	-0.60	0.06
25.00	4	-0.20	-0.80	0.16
24.90	4	-0.30	-1.20	0.36
24.80	1	-0.40	-0.40	0.16
24.70	1	-0.50	-0.50	0.25
	f = 50		$\Sigma fd = 1.80$	$\Sigma fd^2 = 2.40$
Let K = 25.20				

$$\overline{X} = K + \frac{\Sigma fd}{n} = 25.20 + \frac{1.80}{50}$$

$$= 25.20 + 0.036$$

$$= 25.236$$

$$= \sqrt{\frac{\Sigma fd^2}{n} - \frac{(\Sigma fd)^2}{n}}$$

$$= \sqrt{\frac{2.40}{50} - \frac{(1.80)^2}{50}}$$

$$= \sqrt{0.048 - 0.0012967}$$

$$= \sqrt{0.046704} = 0.216$$

now $3\sigma = 0.648$

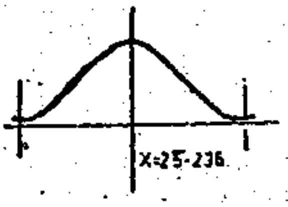


Fig. 14.7 Normal Distribution.

Maximum dimension that can be produced by the process.

$X = 25.236 + 3 \times 0.216 = \overline{X} + 3\sigma$

$= 25.884\text{mm}$

Minmum dimension that can be produced $= \overline{X} - 3\sigma$

$= 25.236 - 3 \times .216$

$= 24.588 \text{ mm}$

But the upper and lower specification limits are 25.50 and 24.50mm. Therefore, the process is not within specification limits.

The process is not capable of meeting the tolerance the suggested remedy is to reduce the dispersion or increase that tolerances and maintain the centering of the process.

14.6. The mean and standard deviation of a sample of 100 observations was calulated as 40 and 5.1 respectively. While comparing with the original data it was found that by mistake a figure of 40 was miscopied as 50 for one observation. Calculate the correct mean and standard deviation.

Solution :- Now

$$\overline{X} = \frac{\Sigma x}{N} = 40$$

$$\therefore \frac{\Sigma x}{100} = 40$$

$$\Sigma x = 4,000$$

Corrected ΣX will be $= 4,000 - 50 + 40$

$= 3,990$

and Correct $\overline{X} = \frac{3,990}{100}$

$= 39.90$

$$\sigma = \sqrt{\frac{\Sigma x^2}{N} - (\overline{X})^2} \qquad 5.1 = \sqrt{\frac{\Sigma x^2}{N} - (40)^2}$$

$$(5.1)^2 = \frac{\Sigma X^2}{100} - 1600$$

$$(1600 + 26.0.1) \times 100 = \Sigma X^2 = 162601$$

$$\text{Corrected } \Sigma X^2 = (50)^2 + (40)^2$$

$$\text{Correct } \sigma = \sqrt{\frac{16170}{100} - (39.90)^2}$$

$$= \sqrt{25} = 5$$

7. A machine shop producess steel pins. The weight of 100 pins were checked after machining and data was recored as follows.

Width in mm	Frequency	Width in mm	frequency
9.50 - 9.51	6	9.58 - 9.59	22
9.52 - 9.53	2	9.63 - 9.61	8
9.54 - 9.55	20	9.62 - 9.63	6
9.56 - 9.57	32	9.64 - 9.65	44

a. Find the arithmetic mean and standard deviation.

b. Plot the frequency histogram.

c. Plot the ogive curves.

i. Less than ogive curve.

ii. More than ogive curve.

The data may be tabulated as follows for convenience

Width in mm	all mid points	frequency	d = x - k	fd	fd²
9.50 - 9.51	9.505	6	-0.60	-0.36	0.0216
9.52 - 9.53	9.525	2	0.040	-0.08	0.0032
9.54 - 9.55	9.545	20	-0.020	-040	0.0080
9.56 - 9.57	9.565	32	0.000	0.00	0.0000
9.58 - 9.59	9.585	22	+0.020	0.44	0.0088
9.60 - 9.61	9.605	8	+0.040	0.32	0.0128
9.62 - 9.63	9.625	6	+0.060	0.36	0.0216
9.64 - 9.65	9.645	4	+0.080	0.32	0.0256
			Σ fd = 0.60		Σfd^2 = 0.1016

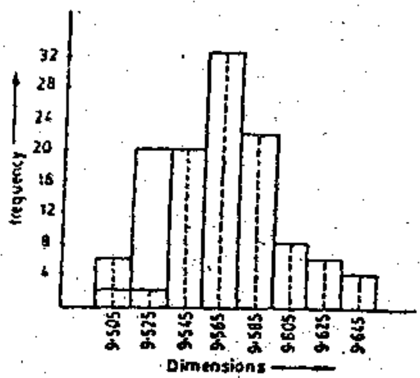


Fig.14.8 Frequency Histogram

$$\overline{X} = K + \frac{\Sigma fd}{n} = 9.565 + \frac{0.60}{100} = 9.571$$

$$\sigma = \sqrt{\frac{\Sigma fd^2}{n} - \left(\frac{\Sigma fd}{n}\right)^2}$$

$$= \sqrt{\frac{0.1016}{100} - \left(\frac{0.60}{100}\right)^2}$$

$$= 0.00098$$

$$= 0.0310$$

For plotting frequency histogram the data may be tabulated as:

width in mm	Class boundries	Cell mid points	frequency	No on pins with less class upper class boundry	No. of pins with more than lower class boundery
9.50 - 9.51	9.495 - 9.515	9.505	6	6	100
9.52 - 9.53	9.515 - 9.535	9.545	2	8	94
9.54 - 9.55	9.535 - 9.555	9.545	20	28	92
9.56 - 9.57	9.555 - 9.575	9.565	32	60	72
9.58 - 9.59	9.575 - 5.595	2285	22	82	40
9.60 - 9.61	9.595 - 9.651	9.605	8	90	18
9.62 - 9.36	9.615 - 9.635	9.625	6	96	10
9.64 - 9.65	9.635 - 9.655	9.645	4	100	4

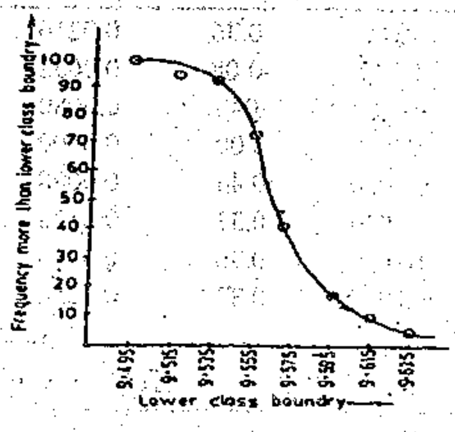


Fig.14.9 More than ogive curve

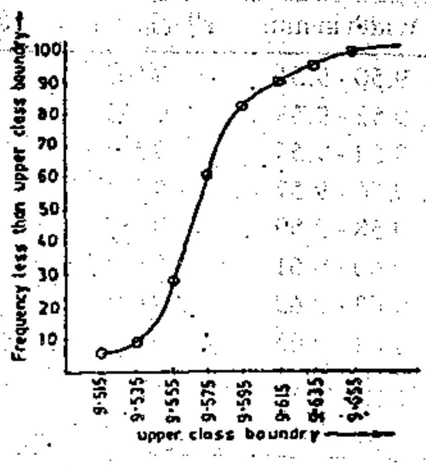


Fig 14.10 Less than ogive curve

Q.10. Define "Control chart" state the objectives of control charts for variables ($\overline{X}$, R and σ Charts).

Ans. :Defination : A control chart is a graphical representation of the collected information. The information may pertain to a measured quality characteristic (length, diameter, thickness etc.) or a judged quality characteristics.

In other words control chart is a devices.

- Which specifices state of statistical control.
- a device for attaining statistical control.
- a device to judge whether a state of statistical control has attained.

Objectives of X,R and σ Charts :

1. $\overline{X}$ and R or $\overline{X}$ and σ Charts are used in combination for the control process.
   $\overline{X}$ chart shows the centring of the process i.e. it shows the variation in the average of the samples.
   R chart shows the uniformity or consistency of the process i.e. it shows variations in the ranges of the samples.
   σ chart shows the variation of the process.
2. The control charts are used to determine whether a given process can meet the existing specifications without a fundamental change in production process.
3. To secure information to be used in establishing or changing production procedures.
4. To secure information when it is necessary to widen the tolerances.
5. To secure information to be used in establishing or changing inspection procedure or acceptance procedure or both .
6. To provide a basis for current decisions on acceptance or rejection of manufactured or purchased parts.
7. To ensure product quality level.
8. Control charts builds up the reputation of the organization through customers satisfaction.
9. To determine when to hunt for causes of variation and take action to correct them and when to leave the process alone.

Q.11. What do you understand by "statistical control of prodution process"?

Ans : From a batch of prodcuts manufactured by a certain production process. Some of the products are selected at random. Their quality characteristics say (length, diameter, thickness etc) are measured and classified according to actual dimensions.

If we tabulate these dimensions in order of size (in asending or desending order) and give the frequencies with which each size occurs, we have a frequency distribution.

If the distribution of observation follows a normal curve, then it is assumed that the variations are due to chance causes and no assignable causes of error are present. The condition which produced these variations are said to be under control and it is concluded that the process is under satistical control. On the other hand if the distribution does not follow a normal curve then it is concluded that one or more assignable causes of error are present and the process is not in statistical control.

Q.12. Describe the method of contructing $\overline{X}$ and R charts and explain how these charts helps in determining lack of control.

Ans : The various steps in contructing $\overline{X}$ and R charts are as follows :

1. Calculate the average $\overline{X}$ and range R for each subgroup

A good number of samples of items manufactured are collected at random at different intervals of time and their quality characterstics (diameter, thickness, weight etc) are measured.

For each sample; average value and range is calculated for example, if a sample contains five items whose dimension are X_1, X_2, X_3, X_4, X_5 .... then

$$\text{The sample Average } \overline{X} = \frac{X_1 + X_2 + X_3 + X_4 + X_5}{5}$$

Range = Largest value - smallest value.

2. Calculate the grand average $\overline{\overline{X}}$ and average range $\overline{R}$

The grand average $\overline{\overline{X}}$ is the average of averages.

It is obtained by dividing the sum of $\overline{X}$ values by the number of samples (subgroups)

i.e. $\overline{\overline{X}} = \dfrac{\Sigma \overline{X}}{N}$ where N = Number of samples.

Similarly $\overline{R} = \dfrac{\Sigma R}{N}$

Calculation of 3 sigma limits on control chart for $\overline{X}$:

The control limits are given by the relation

$$\text{Upper control limit } \overline{X} = \overline{\overline{X}} + 3\sigma\overline{X}$$

$$\text{Lower control limit } \overline{X} = \overline{\overline{X}} - 3\sigma\overline{X}$$

Where $\sigma\overline{X}$ Standard deviation of the averages = $\sigma'/\sqrt{n}$

Where n = sample size

σ' = Standard deriation of the universe and

$\sigma = \overline{R}/d_2$ where d_2 is factor which depends on a sample size.

To shorten the calculations following formules may be used.

$$UCL\overline{X} = \overline{\overline{X}} + A_2R \quad \text{--------(2) or,}$$

$$LCL\overline{X} = \overline{\overline{X}} - A_2R$$

$$LCL\overline{X} = \overline{\overline{X}} - A_1\sigma$$

or

$LCL\overline{X} = \overline{\overline{X}} - A_1\sigma'$ -------(3)

$LCL\overline{X} = \overline{X}' + A\sigma'$ -------(4)

$LCL\overline{X} = \overline{X}' + A\sigma'$

4. Calculate 3 sigma control limits for R chart for R chart :

$UCLR = D_4\overline{R}$ or $D_2\sigma'$

$UCLR = D_3\overline{R}$ or $D_2\sigma'$

The values of the various factors $A, A_1, A_2, D_1, D_2, D_3, D_4$ are based **on normal distribution** nd can be found from standard tables for a particular sample size.

5. Plot the $\overline{X}$ and R Chart : While plotting $\overline{X}$ chart the central **line on the** $\overline{X}$ chart hould be drawn as a solid horizontral line at $\overline{\overline{X}}$. The upper and lower control limits for $\overline{X}$ hart should be drawn as dotted horizontal lines at the computed values.

Similarly, for R Chart the central line will indicate $\overline{R}$ and the control limits are shown by otted horizontal lines.

Then plot the averages of the sub-groups in $\overline{X}$ chart in the order collected and the ranges R chart. The R chart is plotted below the $\overline{X}$ chart. Points outside the control limits are licated with cross on $\overline{X}$ chart and by circle on R chart.

6. Drawing preliminary conclusions from control charts : Lack of control is icated by points falling outside the control limits on either $\overline{X}$ or R chart. When all the nts fall inside the control limits it means that the process is in control. It really means for all ctical purposes it acts as if no assignable causes of variation are present. However, 1 out 5 points or 2 out of 100 points can be tolerated and the process is said to be in control. ilarly a run of seven consecutive points on the side of central line indicates lack of control.

). What is Variability?

Differentiate between 'Chance causes' and 'Assignable causes' of variation giving suitable examples.

Variability : In nature two extremely similar things are difficult to obtain. This facts good for production process also. No production processes can produce all items of cts exactly alike. The production process consists of combination of men, materials and ne. Each of these elements has some inherent or natural variation as well as some un- l variations due to assignable causes.

example, suppose drilling operation is to be performed on castings. The first source of on is the material itself (some castings may be harder than the otheres, some of them ve internal defects) if the operations are done on a mass production by number of on different machines, the second source of variation is the machines. The conditions ines may differ. The third source of variation, man,is the most variable of them all ay be differneces in skill, experience of the workers doing the ...

The same person may act in different ways in different psychological conditions, and adds to variability in the quality characterstics of the product.

There are two kinds of variations in a production processes that causes variability in the quality characterstics of the product. These are:

1. Variations due to chance causes.
2. Variations due to assignable causes.

Variations due to chance causes (Random variation)	Variations due to assignable causes
1. These are due to the inherent or natural variability in the elements of production (Men,materials and machines)	1. These are unnatural variations in the elements of production.
2. These variations are difficult to trace. They are due to some inherent characteristic of the process or machine.	2. They can be easily traced or detected.
3. The chance factors effect each component in a separate manner they may cancel each others effect.	3. These variations possesses greater magnitude.
4. Example. a little play between nut and screw at random leads to back lash error and may cause change in dimensions of machined parts.	4. Examples : Differences among machines. Differences among workers, differences among materials, change in working conditions, mistake on the part of the operator, lack of quality mindness etc.

Q.14. What is meant by process capability? How will you determine the same. How process capability study helps in achieving desired quality?

Ans : Process capability may be defined as the minimum spread of a specific measurement variation. It includes 99.7% of the measurments from the given process. Mathematically, process capability = $6\sigma'$ since σ' is taken as a measure of the spread of the process. It is also called as natural tolerence.

While determining process capability, it is necessary to minimize the effect of factors such as un-natural material variation, process adjustment etc. and trained operators should be allowed to perform the work. A number of samples are taken over a period of time. The process capability is done in the following manner.

1. Calculate the average $\bar{X}$ and range R of each sample.
2. Calculate the grand average $\bar{\bar{X}}$ and average range $\bar{R}$. This measures the centring of the process.

i. Calculate the process capability $6\sigma' = 6(\overline{R}/d_2)$ where d_2 is a factor for a particular sample size.

process capability study helps for achieving the desired quality in the following manner.

1. It helps to find out whether the process is capable of meeting the specified limits or not.
2. To discover why a process capable is failing to meet the specifications.

When a controlled process must meet two specification limits, upper specifiaction limit l lower specification limit the possible relationship between process capability and the cification limits may be grouped in three classes as described below.

1. (Xmax-Xmin) > $6_{\sigma'}$ i.e. specified tolerance is greater than natural tolerance :

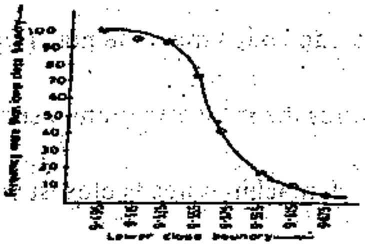


Fig.14.9

Where Xmax = Upper specifations limit.

Xmin = Lower specifation limit.

The frequency curves a,b,c and d shows various positions in which the process may be centred.

Conclusion : i. With any positions, practically all the products manufactured will meet specifations as long as the process stays in control.

ii. If the ratio $\left(\frac{Xmax - Xmin}{6\sigma'}\right)$ is considerably large frequency of control chart may be reduced.

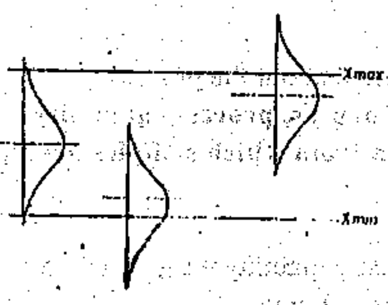


Fig.14.10

2. (x max -min) < $6_{\sigma'}$ Canclusion : In this case defective parts will always be there, therefore, the remedy will be,

i. Increase the tolerance.
ii. Reduce dispersion, by making fundamental changes in the production methods, machines used etc.
iii. Suffer and sort out the defectives, if it is eco nomical than making the fundamental changes.
iv. It is still important to maintain centring of the process.

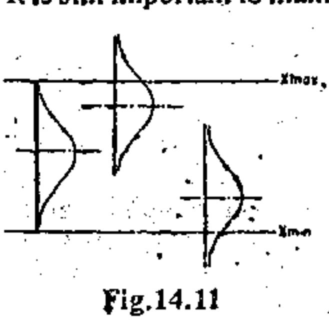


Fig.14.11

3. (X max - X min) = $6_{\sigma'}$:

Conclusion :

i. It is necessary to maintain centring of the process.
ii. If is advisable to increase tolerence if they are tighter than is really necessary.
iii. Reduce dispersion if it is economical.

Q.15. State the importance of process (machine) capability study in solving quality problems.

Ans : The information obtained from process capability is of great importance in solving quality problems as follows :

1. The design enginer, knowing the capability of the process and the available equipment, has more rational basis while selecting the specifications.
2. The planning enginner, can assign the jobs with more tight tolerances to the most capable machines and that with wider tolerance to the less precise machines.
3. The tool designer can spot the places where tooling improvements must be made to maintain the process capability.
4. The capability information helps the foremen to decide which machine may require overhaul.
5. The machine set up man learns which machine requires the most attention to set up and which one needs only normal care.
6. The machine operator and inspector can decide which machines needs closest watch in production.
7. While purchasing it provides a means to compare actual performance of equipment with the manufactures claims.

Q.16. Define process capability mathematically. For a particular process standard deviation is 0.5 with specified tolerances $T_2 - T_1 = 2$.

Ans :

i. What is the process capability in this case?

ii. If process capability is less than $T_2 - T_1$ comment about the process.

Mathematically process capability can be defined as, process capability = $6\sigma'$
Where σ' = standard deviation of the population from which samples are taken for measurement of quality characterstic.

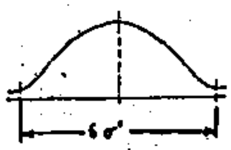


Fig. 14.11

i. When $\sigma' = 0.5$, process capability = $6\sigma' = 6 \times 0.5 = 3$ units. and specified tolerence = 2 units.

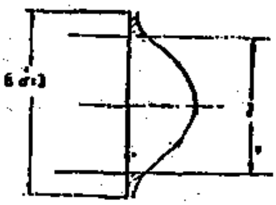


Fig.14.12

In this case $(T_2 - T_1) < 6\sigma'$ process capability is greater than specified tolerence Therefore defective parts will always be there.

ii. In this case $(T_2 - T_1)$ $6\sigma'$

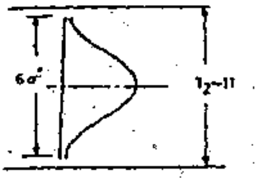


Fig. 14.13

Therefore the process is capable of meeting the specified tolerences. capability $6\sigma'$ is less than one -half of the tolerence, consider reducing the tolerence secondly 100% inspection is not necessary and a sampling prodedure should be used.

Q.17. Study the figure given above and answer the following?

i. State the tendency of this process. Is the process under control ? Give reasons.

ii. What are the possible causes of variations.

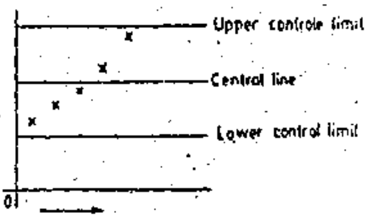
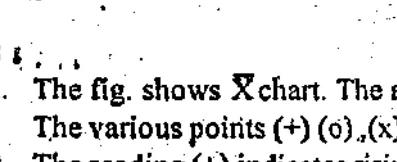


Fig. 14.14

Ans :

1. The consecutive points on the chart above tend to move from lower control limit to upper control limit. There is a rising trend. Since the change is taking place slowly and though all the points are lying within control limits, after some time it is likely that the pro cess may go out of control if proper care is not taken.
2. It indicates that some assignable causes may be present, such as change in tool setting. Therefore the tool must be set exactly at the normal. It may also be caused due to tool wear.

Q.18. Study the given figure below and answer the following :



i. Name the figure. What information is obtained from the above figure.?

ii. What is the trend of the readings indicated as(+)?

iii. Compare the trends of readings indicated by(x) and (o) with respect to (+)

iv. What is the important use of the information obtained above?

Ans :

1. The fig. shows $\overline{X}$ chart. The averages of various samples are plotted on the $\overline{X}$ chart. The various points (+) (o) ,(x) indicates various trends.
2. The reading (+) indicates rising trend. The consecutive points tend to move steadily towards upper control limit and the process is going steadily out of control as the last point goes above upper control limit.
3. The points indicated by (x) shows chance pattern of variations. Most of the points are near the centre live $\overline{X}$ no points are beyond the control limits. The process is in control.

The points indicated by (o) shows that there is an erratic change and the process may go out of control. It means some assignable causes of variation are present.

The (+) points indicates rising trend.The process is going steadily out of control.Some assignable causes of error may be present.

Q.19. Outline the theory underlying control charts for

i. Fraction defective.

ii. Defects

Ans : Control chart for fraction defective (P chart) : It is called as p chart. Fraction defective may be defined as the ratio of the number of defective articles in any inspection to the total number of articles actually inspected. Fraction defective is always expressed as decimal fraction.

P-Chart may be applied to quality characteristics that can be observed only as attributes,e.g.dimensions checked by Go and No-Go gauges.

For P chart.

$$\text{The central line, } \overline{P} = \frac{\text{Number of defective articles}}{\text{Total number of articles inspected}}$$

The control limits for P chart are

$$\text{Upper control limit UCLP} = \overline{P} + 3\sqrt{\frac{\overline{P}(1-P)}{n}}$$

$$\text{Lower control limit LCLP} = \overline{P} - 3\sqrt{\frac{\overline{P}(1-P)}{n}}$$

Purpose of P chart :

Because of the lower inspection and maintenance costs of p charts, they usually have a greater area of economical applications than the control charts for variable.

A control chart for fraction defective may have any one of the following purpose.

1. To discover the average proporation of defetive articles submitted for inspection, over a period of time.
2. In a sampling inspection of large lots of purchased articles.
3. To bring to attention of management, any changes in average quality level.
4. To discover, identify and correct causes of bad quality.
5. It provides the management with useful record of quality history.
6. To suggest where it is necessary to use $\overline{X}$ and R chart to dignose quality problems.

Control Chart for defects : (C chart)

C chart applies to the number of the defects in a subgroup of constant size. It is also an attribute chart.

$$\text{The central line, } \overline{C} = \frac{\text{Number of defects}}{\text{Total number of subgroups}}$$

$$\text{Upper Control Limit C,} \quad UCLC = \overline{C} + 3\sqrt{\overline{C}}$$

$$\text{Lower control limit C,} \quad LCLC = \overline{C} - 3\sqrt{\overline{C}}$$

Applications : Control chart for defects "C' chart and "U' chart has much more restricted field of usefulness as compared to $\overline{X}$ and R charts and P charts. The examples, of typical applications of C chart are:

1. Number of surface defects in an aircraft wing.
2. Number of surface defects observed in a galvansied sheet or a painted or enameled surfaces.
3. Number of small holes in glass bottles.
4. Number of imperfections observed in a cloth of unit area.
5. Number of loose soldered connections.
6. Number of defects such as blow holes, cracks, undercuts etc in a casting or welded piece.
7. Total number of defacts in complex assemblies such as radio receiving sets sewing machins etc. C chart techniques helps to keep the number of defects to minimum.

Q.20. Differentiate between defects and defectives. What do you mean by "U' Chart, how does it differ from "C' Chart?

Ans : Difference between defects and defectives : An item is said to be defective if it fails to conform to the specifiactions in any of the characteristics. Each characteristic that does not meet the specifications is a defect. An item is defective if it contains at least one defect. For example, if a casting contains undesirable hard spots blow holes, cracks etc. the casting is defective and the hard spots, blow holes, cracks etc. which makes the casting defective are the defects.

U Chart : C chart applies to number of defects in a subgroup of constant size however when the subgroup size varies from sample to sample U chart is used. U chart is control chart for number of defects per unit in a samaple of units.

In other words $\overline{U} = \dfrac{C}{n} = \dfrac{\text{Number of defects in a sample}}{\text{number of units in a sample}}$

The formual as for control on U chart are,

$$UCL = \overline{u} + 3\sqrt{\frac{\overline{u}}{n}}$$

$$LCL = \overline{u} - 3\sqrt{\frac{\overline{u}}{n}}$$

and the control line $\overline{U} = \dfrac{c}{n}$ as explained above

Q. 21. Differentiate between variable charts and Attribute charts?

Ans :

Variable Charts	Attribute Charts
1. Examples :- $\overline{X}$, R Chart	1. p, n p, c, u charts.
2. Type of data required variables data (Measured values of quality charac teristics)	2. Attribute data (judged values of quality : charateristics obtained by using Go NO Go gauges.
3. Field of Application; control of individual quality characteristics size or number of defect per unit.	3. Control of proportion of defectives or number of defects in a subgroup of constant
4. **Advantages :** a. Provides maximum utilization of information available from data. b. Provides detailed information on process average and variation for control of individual dimension.	4. a. Data required are often already available form inspection records. b. Easily understood by all persons since it is more simple as compare to $\overline{X}$, R and Charts. c. It provides overall picture of quality histroy. d. They involve less cost and time.
5. **Disadvantages :** a. They are not easily understood unless training is provided. b. Can cause confusion between control limits and specification limits. c. Can not be used with go-no-go type gauge inspections. d. They involve more time for measuring, calculation and plotting.	a. They do not provide detailed information for control of individual characteristic. b. They do not recognize different degree of defectiveness (Weightage of defect).

Q.22. State the advantages and limitations of $\overline{X}$ and R charts (Variable charts).

Ans :

Advantegs :

1. It enables to determine whether a process can meet the specificating or to collect further information for establishing or changing the specifications.
2. They suggest whether it is necessary to change the production procedure, process, machines etc.
3. It also provides information for changing the inspection techniques or acceptance procedures.
4. It helps to determine when to hunt for causes of variation and take action to correct them and when to leave the process alone.

. It enables to take decisions regarding acceptance or rejection of manufactured or purchased product.
. It helps to ensure product quality level.
7. Control charts in general built up the reputation.
3. $\overline{X}$ & R chart provides detailed information on process average as well as variation

nitations :

1. $\overline{X}$ and R charts can be used only for quality characterstics that can be measured and expressed in numbers. However many quality characteristics can be observed only as attributes. For example, while inspecting castings in addition to conformity to dimensions, it may be necessary to inspect other quality characterstics such as cracks, holes,swells, hard sport etc. which singly or in combination may make the castings defective.
2. $\overline{X}$ and R charts can be used only for one individual characteristic at a time. (for each quality characterstic seperate $\overline{X}$ and R charts are needed.)
3. It involves more cost and time for measuring, computing and plotting the charts.

Therefore, for the sake of economy $\overline{X}$and R charts are plotted only for the most important nd troublesome quality characteristics.

Q.23. Compare $\overline{X}$and R chart with P chart.

1. P chart is an attribute control chart, i.e. for quality characteristics that can be classified as either conforming or non-contorming to the specifiactions. For examples, dimensions checked by GO, NO-GO gagues.
   characterstics that can be measured and expressed in numbers.
2. The cost of computing and charting may also be less since P chart can be applied to any number of quality characterstics observed in article.
   But separate $\overline{X}$ and R charts are rquired for each measured quality characterstic which may be impracticable and uneconomical.
3. The cost of collecting the data on p chart is also less than the cost of collecting the data for $\overline{X}$and R chart for example, 10 or even more shafts might be inspected with go-no-go gauges in the time required to measure a single shaft diameter with a micrometer, Secondly P chart uses data already collected for other purposes.
4. P chart is best suited in cases as here inspection is carried out with a view to classfying an article as acceptable or rejectable.
   $\overline{X}$and R charts are best suited for critical examination.
5. P chart though discloses the presence of assignable cause of variation, it is not as sensitive as $\overline{X}$ and R chart.
6. The sample size is generally larger for P chart than for $\overline{X}$and R chart. The variations in the smaple size influences the control limits much more in $\overline{X}$and R charts than in P chart.

PROBLEMS AND SOLUTIONS

14.8. Control chatrs for x and R are maintained on the tensile strength for certa yarn. The subgroup size is 5. The values of $\bar{X}$ and R are computed for ea subgroups,after 25 sub groups.

Solution : $\Sigma \bar{X} = 514.8$ and $\Sigma R = 120$ compute the values of 3 sigmalimits for $\bar{X}$ and R char and estimate the value of on the assumption that the process is in statistical control.

Take, $d_2 = 2.326,\ D_2 = 4.92,\ D_1 = 0$

$$\text{Now, } \bar{\bar{X}} = \frac{\Sigma \bar{X}}{N} = \frac{514.8}{25} = 20.592$$

$$\bar{R} = \frac{\Sigma R}{N} = \frac{120}{25} = 4.80$$

$$\sigma' = \frac{\bar{R}}{d_2} = \frac{4.80}{2.326} = 2.0636$$

$$3\sigma'\bar{X} = 3\frac{\sigma'}{\sqrt{n}} = \frac{3 \times 2.0636}{\sqrt{5}} = 2.784$$

$$UCL\bar{X} = \bar{\bar{X}} + 3\sigma\bar{X}$$

$$= 20.592 + 2.748 = 23.376$$

$$LCL\bar{X} = \bar{\bar{X}} - 3\bar{\sigma}\bar{X}$$

$$= 20.592 - 2.748$$

$$= 17.808$$

For R chart

Central line $\bar{R} = 4.80$

$$ULLR = D_2\sigma'$$

$$= 4.92 \times 2.0636 = 10.128$$

$$LCLR = D_1\sigma'$$

$$= 0 \times 6$$

$$= 0 \text{ (Note that } D_1 = 0 \text{ upto } n = 5)$$

14.9. In an automatic filling, 175 gms of certain chemical is to be packed in certain container. The permissible variation is ± 5 gms. To investigate the capacity of a process, samples of 5 each were drawn from 10 successive batches, and data were recorded as given below.

Batch	1	2	3	4	5	6	7	8	9	10
Mean $\overline{X}$	177	177	176	176	174	177	175	176	176	174
Ranges R	3	5	3	8	2	8	5	7	3	2

Assuming the process to be within control,establish the capability of the process and compare it with the stipulated specifications.

Solution :

For a sample size of 5, $d_2 = \dfrac{\overline{R}}{\sigma'} = 2.326$

$$\overline{\overline{X}} = \frac{177 + 177 + 176 + 176 + 174 + 177 + 195 + 176 + 176 + 174}{10}$$

$$= 175.8$$

$$\overline{R} = \frac{\Sigma R}{N} = \frac{3 + 5 + 3 + 8 + 2 + 8 + 5 + 5 + 7 + 3 + 2}{10}$$

$$= 4.6$$

$$\sigma' = \frac{\overline{R}}{d_2} = \frac{4.6}{2.326} = 1.9776$$

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$$\sigma_{\overline{X}} = \frac{\sigma'}{\sqrt{n}} = \frac{1.9776}{\sqrt{5}} = 0.8844$$

$$UCL\overline{X} = \overline{\overline{X}} + 3\sigma\overline{X} = 175.8 + 3 \times 0.8844 = 178.4533$$

$$UCL\overline{X} = \overline{\overline{X}} - 3\sigma\overline{X} = 175.8 \times 3 \times 0.8844 = 173.1467$$

Process capability $= 6 = 6 \times 1.9776 = 11.8656$

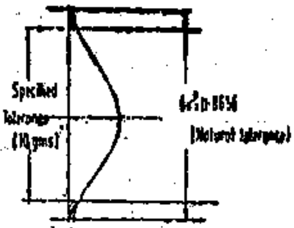


Fig. 14.15

Now specified tolerance
$= (X_{max} - X_{min}) = 10$
In this case $(X_{max} - X_{min}) < 6\sigma'$
Therefore,defective products will always be there.

14.10. The following are the $\overline{X}$ and R values of 4 subgroups of 5 readings $\overline{X}$ = 10, 12.1, 10.8 and 10.5 R = 1.1, 1.3, 0.9 and 0.8.

The specification limits for the components are 10.7 ± 0.2

Establish the control limits for $\overline{X}$ and R chart. will the products able to meet its specificatio

Given :

1. A_2 (factor for $\overline{X}$ Chart) = 0.58
2. D_4 (factor for R chart) = 2.11
3. D_3 (factor for R chart) = 0.00

Solution :

$$\overline{\overline{X}} = \frac{\Sigma \overline{X}}{N}$$

$$= \frac{10.2 + 12.1 + 10.8 + 10.5}{4}$$

$$\overline{\overline{X}} = 10.9$$

$$\overline{R} = \frac{\Sigma R}{N} = \frac{-1.1 + 1.3 + 0.9 + 0.8}{4}$$

$$= 1.025$$

$$UCL\overline{X} = \overline{\overline{X}} + A_2 \overline{R}$$

$$= 10.9 + 0.58 \times 1.025$$

$$= 11.4945$$

$$LCL\overline{X} = \overline{\overline{X}} - A_2 \overline{R}$$

$$= 10.9 - 0.58 \times 1.025$$

$$= 9.3055$$

The upper specification limit = 10.7 + 0.2 = 10.90

Lower specification limit = 10.7 - 0.2 = 10.50

Since the lower control limit is less than the lower specification limit some defective pa will be produced, the process is not able to meet the specifications.

14.11. A subgroup of 5 items each are taken from a manufacturing process at a regul interval. A certain quality characterstic is measured and $\overline{X}$ and R valu computed after 25 subgroups it is found that $\Sigma \overline{x}$ = 357.50 and ΣR = 8.8 If the specfication limits are 14.40 ± 0.40 and if the process is in statistic control what conclusion can you draw about the ability of the process to produ items within specification?

(for subgroup of 5 items d_2 = 2.326)

Solution :

$$\bar{\bar{X}} = \frac{\Sigma \bar{X}}{N} = \frac{357.50}{25} = 14.300$$

$$\bar{R} = \frac{\Sigma R}{N} = \frac{8.80}{25} = 0.352$$

$$= 1.025$$

$$\sigma' = \frac{\bar{R}}{d_2} = \frac{0.352}{2.326} = 0.15133$$

$$\sigma_{\bar{x}} = \frac{\sigma'}{\sqrt{5}} = \frac{0.15133}{\sqrt{5}} = 0.067678$$

$$UCL\bar{X} = \bar{\bar{X}} + 3\,\sigma_{\bar{x}} = 14.300 + 3 \times 0.67678 = 14.5030$$

$$LCL\bar{X} = \bar{\bar{X}} - 3\,\sigma_{\bar{x}} = 14.300 - 3 \times 0.067678 = 14.0970$$

Now, $X_{max} = 14.40 + 0.40 = 14.80$

$X_{min} = 14.40 - 0.40 = 14.00$

$\therefore X_{max} - X_{min} = 0.80$

Process capability $6\sigma' = 6 \times 0.15133$

$= 0.90758$

Conclusion : In this case $(X_{max} - X_{min}) < 6\sigma'$

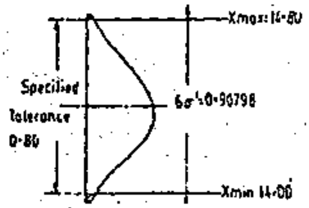


Fig. 14.16

Therefore defective parts will always be there,
Suggested remedy will be

1. Increase the tolerance if it does not affect the functioning of the product.
2. Reduce dispersion
3. Suffer and sort out the defectives.

14.12. Control charts for $\bar{X}$ is to be prepared for a certain dimension of component. The subgroup size is 4 After 20 subgroup it is found that $\Sigma \bar{X} = 825.60$ mm and $\Sigma R = 5.60$mm. Compute the central line and the control limits for $\bar{X}$ chart. Take $D_2 = 2.059$.

If the specifications are 41.0 $\pm$ 0.40mm and the process is in control and is normally distributed, can it meet the specfication requirement?

Solution :

$$\bar{\bar{X}} = \frac{\Sigma \bar{X}}{N} = \frac{825.60}{20} = 41.28$$

Central line = 41.28 mm

$\Sigma R \quad 5.60$

Central line = 41.28 mm

$$\overline{R} = \frac{\Sigma R}{20} = \frac{5.60}{20} = 0.28 \text{ mm}$$

$$= 1.025$$

$$\sigma' = \frac{\overline{R}}{d_2} = \frac{0.28}{2.059} = 0.1359$$

$$3\sigma\overline{x} = \frac{3\sigma'}{\sqrt{n}} = \frac{3 \times 0.1359}{\sqrt{4}}$$

$$= 0.2038$$

$$UCL\overline{X} = \overline{\overline{X}} + 3\,\sigma\overline{x}$$

$$= 14.28 + 0.2038 = 41.4838$$

$$LCL\overline{X} = 14.28 - 0.2038$$

$$= 41.0762$$

$$3\sigma' = 3 \times 0.1359$$

$$= 0.4077 \text{ mm}$$

Now, $X_{max} = 41 + 0.40 = 41.40$ mm

$X_{min} = 41.0.40 = 40.60$ mm

The centring of the process $\overline{\overline{X}}$ is 41.28. Therefore, for this process the dimensions ca vary form 41.28 - 0.4047 = 40.8723 mm to

40.28 + 0.4047 = 41.6877 mm.

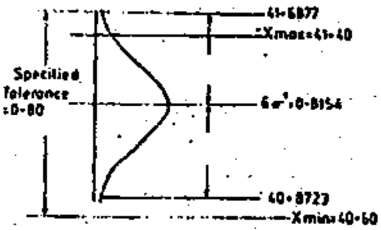


Fig.14.17

The process capability = $6\sigma' = 6 \times 0.1359 = 0.8154$
In this case, (Xmax - Xmin) < $6\sigma'$ Therefore, defectiv parts will always be there, morever centering is not properl done, if the centering is done properly the number of defectiv parts can be considerably reduced.

14.13. The design specifications for a component are 100 0.5 mm where the proces report shows that process average is 99.9 mm and standard deviation is 0.18 Do these figures call for any action by any one?

Solution : Upper specification limit, Xmax

= 100 + 0.5

= 100.5 mm

Lower specification limit Xmin = 100-0.5

= 99.5 mm.

$\overline{X}$ = 99.9 and σ' = 0.18 (given)

Now (Xmax - Xmin)

= 100.5 - 99.5

= 1 mm

$3\sigma'$ = 3 x 0.18

= 0.54 & $6\sigma'$ = 1.08

For this process the dimensions can vary from.

99.90 - 0.54 = 99.36 mm to,

99.90 + 0.54 = 100.44 mm

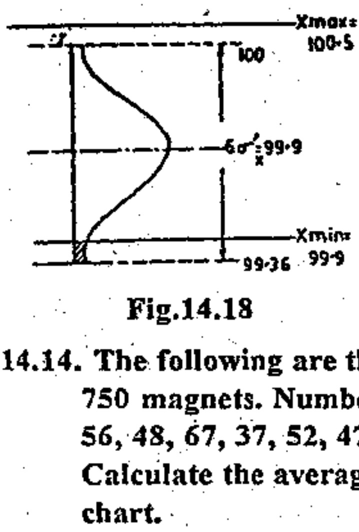


Fig.14.18

In this case (Xmax - Xmin) < σ'

Defective products will always be there. It is therfore, necessary to take action to reduce the number of defectives produced. There is a little difference between the specification limits and the process capability,hence it is suggested that the tolerance should be made slightly wider. The disign engineering is authorised to modify the especifications. At the same time from the above figure it is clear that the centring should be properly maintained by the process planner.

14.14. The following are the inspection results of 20 lots of magnets each lot having 750 magnets. Number of defective magnets in each lot are 48, 83, 70, 85, 45, 56, 48, 67, 37, 52, 47, 57, 71, 53, 34, 29 and 30.

Calculate the average fraction defective and three sigma control limits for p chart.

Solution :

Average fraction defective $\overline{p} = \dfrac{\text{Total number of defectives.}}{\text{Total number inspected.}}$

$$= \frac{48+83+70+85+45+56+48+67+37+52+47+50+47+57+51+71+53+34+29+30}{750 \times 20}$$

= 0.07067

$$\text{UCLP} = \overline{p} + 3\sqrt{\frac{\overline{p}(1-P)}{n}}$$

= 0.07067 + 0.000262

= 0.07083

UCLP = 0.07067 - 0.000262

= 0.07041

14.15.A manufacturer purchases small bolts in cartons that usually contain sev thousand bolts, Each shipment consists of number of cartons,as a part of acceptance prcedure for these bolts,400 bolts are selectd at random form e carton and are subjected to visual inspection for certain defects. In a shipm of 10 cartons the respective percentages of defectives in the samples fo each carton are 0, 0, 0, 5, 0.75, 0, 2, 0.25, 0, 0, 25, and 1.25. Does the shipm of bolts appear to exhibit statistical control with respect to the qua characterstic examined in this inspection.

$$\overline{p} = \frac{\text{Total number of defective articles}}{\text{Total number of articles inspected.}}$$

$$= \frac{(0+0+0.5+0.75+0+2+0.25+0+0.25+1.25)\ \frac{400}{100}}{400 \times 10}$$

$$= 0.005$$

$$\text{UCLP} = \overline{p} + 3\sqrt{\frac{\overline{p}\,(1 - P)}{n}}$$

$$= 0.005 + 3\sqrt{\frac{0.005\,(1 - 0.005)}{400}} = 0.015580$$

$$\text{UCLP} = \overline{p} - 3\sqrt{\frac{\overline{p}\,(1 - \overline{P})}{n}}$$

$$= 0.005 - 3\sqrt{\frac{0.005\,(1 - 0.005)}{400}}$$

= - 0.00558 0 (Since it is meaningless to have LCLP at - 0.00558)

Ater comparing the readings with UCLP and LCLP it is found that reading number 6 i. x 1/100 = 0.02 falls outside the upper control limit. Hence the shipment does not exh statistical control.

14.16.In a factory producing spark plugs the number of defectives found in inspect of 20 lots of 100 each, is given below :

Lot No	No.of defectives	Lot no	No.of defectives	Lot No defectives	No.of
1	5	8	3	15	3
2	10	9	3	16	4
3	12	10	5	17	5
4	8	11	4	18	8
5	6	12	7	19	6
6	4	13	8	20	10
7	6	14	2		

construct appropriate control chart and state whether the process is under control.

Solution :

$$\text{Average fraction defective } \overline{p} = \frac{\text{Total number of defective}}{\text{Total number of inspected.}}$$

$$= \frac{120}{20 \times 1.0} = 0.06$$

$$\text{UCLP} = \overline{p} + 3\sqrt{\frac{\overline{p}(1 - \overline{P})}{n}}$$

$$= 0.006 + 3\sqrt{\frac{30.06(1 - 0.06)}{100}}$$

$$= 0.06 + 3(0.037) = 0.1311$$

$$\text{UCLP} = 0.06 - 3(0.0237) = -0.011 \simeq O \text{ (say)}$$

Fig.14.19 p chart

(Since fraction defective can not be negative for constructing the chart the data may be tabulated as follows :

Lot No.	Fraction	Lot No	Fraction	Lot No	Fraction
1	0.05	8	0.03	16	0.04
2	0.10	9	0.03	17	0.05
3	0.12	10	0.05	18	0.08
4	0.08	11	0.04	19	0.06
5	0.06	12	0.07	20	0.10
6	0.04	134	0.08		
7	0.06	14	0.02		
		15	0.03		

14.17. The following table shows the number of defects observed in 25 similar castings.

Casting No	No.of defects	Casting No	No.of defects	Casing No	No.of defects
1	7	10	12	19	10
2	14	11	22	20	8
3	14	12	15	21	9
4	18	13	8	22	11
5	8	14	24	23	7
6	14	15	14	24	26
7	8	16	9	25	8
8	11	17	9		
9	20	18	11		

i. Find C¯
ii. Compute trial control limits.
iii. What value "C' can you suggest for subsequent period eliminating observations lying beyound control limits.

Solution :

$$\bar{C} = \frac{\text{Total numbar of defects}}{\text{Number of subgroups}}$$

$$= \frac{317}{25}$$

$$= 12.68$$

$$UCLC = \bar{C} + 3\sqrt{\bar{C}}$$

$$= 12.68 + 3\sqrt{12.68}$$

$$= 12.68 + 10.6827$$

$$= 23.3627$$

$$UCLC = \bar{C} - 3\sqrt{\bar{C}}$$

$$= 12.68 - 10.6827$$

$$= 1.9973$$

Reading for casting number 24 i.e. 26 goes above the upper control limit, eliminating the same we have.

$$\bar{C} = \frac{317 - 26}{24}$$

$$= 12.125$$

$$UCLP = \bar{C} + 3\sqrt{\bar{C}}$$

$$= 12.125 + 3\sqrt{12.125}$$

$$= 12.125 + 10.4463$$

$$= 22.57 \text{ say } 23$$

Now, all the readings are within the control limits Therefore suggested value of "C' for subsequent period

$$= \text{new } \bar{c} = 12.125$$

14.18. The cloth produced by the ABC manufacturer was inspected 100 square meters is taken as unit. The following defects per unit was recorded

	Unit						
100 Sq.m cloth length	1	2	3	4	5	6	7
No.of defects in each unit	0	3	2	1	4	5	3

State :

1. Whether data obtained during inspection is within control ?
2. What type of action is warranted by the management?

Solution : Since number of defects per unit is given, U chart should be used.

$$\bar{u} = \frac{\text{Total numbar of defects}}{\text{Number of Units}}$$

$$= \frac{0 + 3 + 2 + 1 + 4 + 5 + 3}{7} = \frac{18}{7}$$

$$= 2.5714$$

$$UCLu = \bar{u} + 3\sqrt{\frac{u}{n}}$$

$$= 2.5714 + 3\sqrt{\frac{2.5714}{7}}$$

$$= 2.5714 + 1.8182$$

$$= 4.3896$$

$$UCLu = \bar{u} - 3\sqrt{\frac{\bar{u}}{n}}$$

$$= 2.5714 - 1.8182$$

$$= 0.7532$$

i. It is clear from the observations that no point goes beyound the control limits.

ii. The management shold take care to maintain the average number of defects per unit i.e. $\bar{u}$.

Q.24. What do you mean by Acceptance Sampling? How does it help in Quality Control ?

Ans : Acceptance sampling is the process of evaluating a proportion of the products, materials in a lot for the purpose of accepting or rejecting the lot on the basis of conforming or non conforming to quality specifications.

Sampling is an act of drawing the samples from a lot on the random basis. Sampling depends upon statistical probability therefore,samples must be selected from all sides and different,depths of the container containing the lot of component parts, so that every part has an equal chance of being selected. Selecting a sample in such a way that each item in a lot has equal chance of being selected is called random sampling. Since a judgement about the lot is to be made on the basis of only a sample it is very important that a sample truely represents the universe from which it is drawn.

This requires that the sample size be large enough and the sampling procedure such as to avoid bias.

Acceptance sampling is more practical,quick and economical method to control the quality of the purchased as well as manufactured items. Since instead of inspecting all the items the decision for accetance or rejection is taken only on the bais of sample. Therefore, this method has got number of advantages as compared to 100% inspection (for advantages limitation of Acceptana sampling refer next question) The most important advantage of acceptance sampling is that it exerts more effective pressure on quality improvements, since, the rejection of entire lot on the basis of sample brings much stronger pressure on quality improvement than the rejection of individual articles.

Q.25. State the advantages & limitations of sampling inspection as compared to 100% inspection.

Sampling inspection is more practical, quick and economical method of taking decision regarding acceptance or rejection of the purchased or manufactured items. The advantages of sampling inspection are:

1. The items which are subjeced to destructive test must be inspected by sampling inspection only.
2. The cost and time required for sampling inspection is quite less as compared to 100% inspection.
3. Problem of inspection fatigue which occurs in 100% inspection is eliminated.
4. Less inspection staff is necassary.
5. Less damage to products because only few items are handled during inspection.
6. The problem of monotony and inspector error introduced by 100% inspection is minimized.
7. The lot is disposed off in shorter period, so that scheduling and delivary dates are inproved.
8. The most important advantage of sampling inspection is that it exerts more effective pressure on quality improvement. Since entire lot may be rejected only on the basis of sample.

Limitations :

1. In sampling inspection, since only a part is inspected the sample may not represent the exact picture obtaining in the lot, hence there is likely hood or risk of making wrong decisions about the lot.
2. The costs of rejected lots will be passed on by the producer on the consumer.

3. This method may not be suitable for taking decision on acceptance or rejection of very costly and important item.
4. It is necessary to use random sampling, select proper sample size and accepatance number for accurate results.

Q.26. Name the factors on which the success of acceptance sampling depends.

Ans : The sucess of a sampling scheme depends on the following factors.

a. Randomness of samples.
b. Sample size
c. Quality characterstic to be studied
d. Acceptance criteria
e. Lot size.

Q.27. What is meant by O.C.curve? Sketch neatly the ideal and actual O.C. curve. How O.C. curves are useful in selecting acceptance level?

The operating characteristic curve is a graph of fraction defective (or percent defective) in a lot against the probability of accepance. For any fraction defective P' in a submitted lot the O.C.curve shows the probability Pa that such a lot will be accepted by the sampling plan.

The shape of the O.C. curve depends upon the following parameters.

N = Lot size from which the samples are drawn.

n = Sample size

C = Acceptance number.

By changing the parameters N, n, and C different sampling plans are obtained, for different plans the O.C.curve will differ. Figure below shows the actual and ideal O.C. curves

When the acceptance plan is designed, it calls for designing a plan whose OC curve will pass through two stipulated points agreed upon by the consumer and producer. The first of these is the acceptable quality level (AQL) representing the maximum proporation of defectives which the consumer finds definately acceptable.

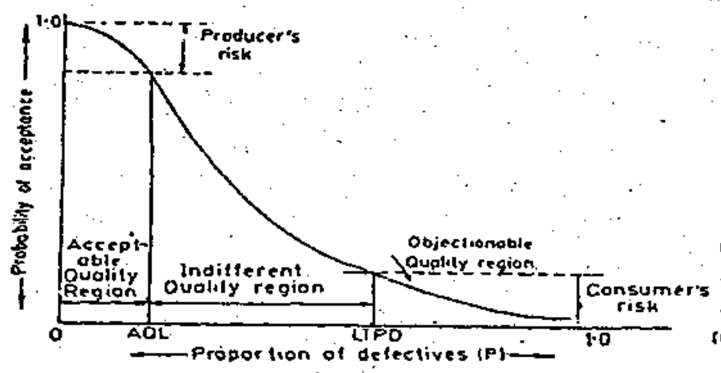


Fig.14.20

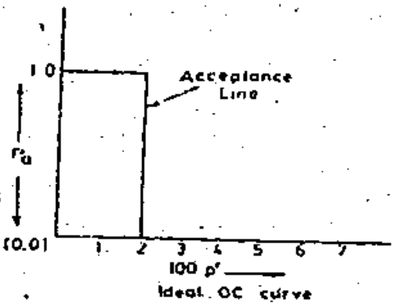


Fig.14.21

The second is the Lot Tolerance percent defective (LTPD) which represents the proportion of defectives which the consumer finds definitely unacceptable.

Accordingly, an OC curve can be divided into the regions as shown in figure.

1. Acceptable Quality Region.
2. Indiference Quality Region.
3. Objectionable Quality Region.

The first region represnts the lots which are acceptable to the coustomer (acceptance level)

Q.28. Draw a neat sketch of an OC curve. show the different regions and expalin the meaning of the terms :

1. A.Q.L
2. L.T.P.D.
3. I.Q.L.

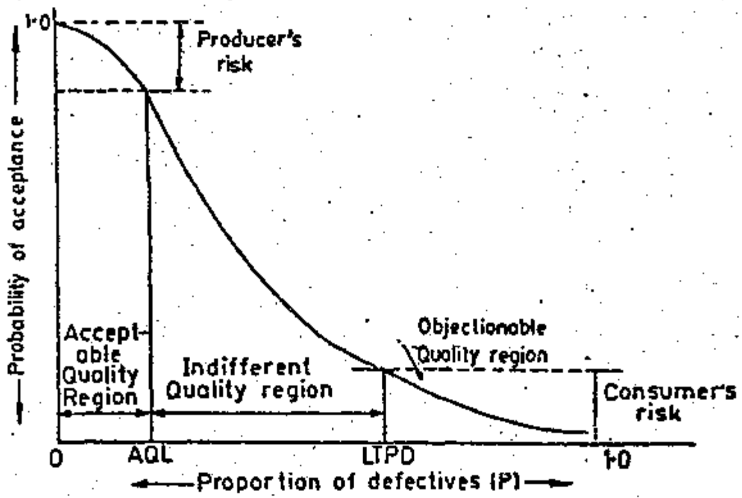


Fig. 14.22 Dc curve

1. A.Q.L. : AQL mean "Acceptable Quality Level" It represents the maximum proportion of defectives which the consumer finds definitely acceptable.

AQL can also be defined as the maximum percent defect that for the purpose of sampling inspection can be considered satisfactory as a process average.

It is the fraction defective that can be tolerated without any serious effect upon further processing or on customer relations As AQL is an acceptable quality level the probability of acceptance for an AQL lot should be high. In fact producers safe point is termed as AQL.

L.T.P.D. : LTPD means Lot Tolerance percent Defective. It is the definition of unsatisfactory quality. It represents the proportion of defectives which the consumer finds definitely unacceptable. As RQL is an unsatisfactory quality level, the probability of acceptance for an RQL lot should be low. The probability of accepting a lot at RQL represents consumers risk.

IQL : It means "Indifference Quality level". This is a quality level some what between the AQL and RQL. It is frequently defined as the quality level having a probability of acceptance of 0.50 for a given sampling plan.

Q.29) Explain the following terms :

i. Producers' Risk **ii. Consumers' Risk**

iii. A.O.Q. **iv. A.O.Q.L**

Ans :

i. Producer"s Risk : If the quality is good still from the sampling plan some lots are rejected, the producer has to suffer, The producer's risk is the probability of rejecting a good lot which otherwise would have been accepted. So the producer should be protected against the rejection of relatively better products.

The producer can decrease his risk by producing products at a better quality level than the specified AQL depending on other economical conditions.

ii. Consumer's risk : If the quality is bad still from the sampling plan some lots are to be accepted the consumer will suffer. Consumers risk is the probability of defective lots being accepted which otherwise would have been rejected. Saying that Pa 0.10 = 2.5 means that the consumer does not want a worse quality containing more than 2.5% defectives and he would at the most accept 10% of the lots containing 2.5% defectives.

iii. AOQ : AOQ means "Average Outgoint Quality" It represents the average percent defective in the outgoing products after inspection, including all accepted lot as a result of sampling inspection, and all rejected lots which are subjected to 100% inspection and rectification.

So for a given fraction defective, the lot accepted as a result of first sampling inspection vill have a fraction defective P', the rejected lots are 100% inspected and rectified (defective rticles replaced by non defectives) will contain all the nondefective products. Therefore the OQ will be less than "P'. It is represented by the equation.

$$AOQ = Pa.P'\left(\frac{N-n}{n}\right)$$

Where Pa = Probability of aceeptance,

N = Lot size

n = Sample size.

If the sample size is much less as compared to lot size then AOQ = Pap'

iv. AOQL : It means Average Outgoing Quality Limit" for any given sample size and :eptance number there is a maximum value of AOQ beyond which the average fraction 'ective passed forward will not rise, no matter how bad the quality of the lots when they 've at inspection.

Q.30. State the important characteristics of O.C. curve.

1. The operating characteristic curve of an acceptance sampling plan shows the ability of the plan to distinguish between good lots and bad lots.
2. With the fixed value of acceptance number and sample size the O.C.curves for different values of N are not appreciably different. It shows that it is the absolute size of the sample that is more important than its relative size compared to the size of the lot.

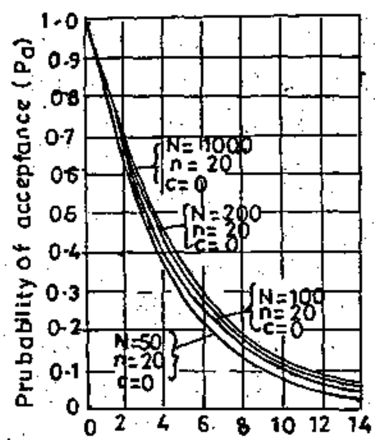


Fig.14.23 Comparison of O.c. curve for four sampling plan.

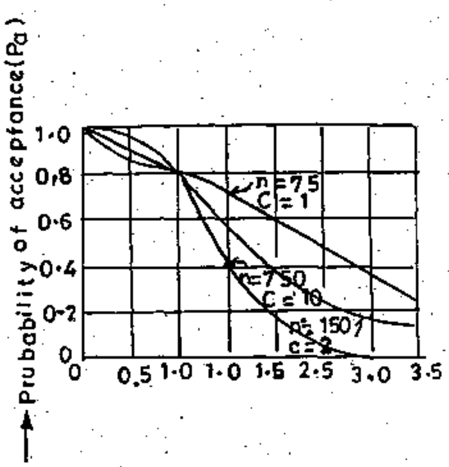


Fig.14.24 percent Defective (100p)

3. With a fixed value of N and C α n, larger the value of n, the better is the discrimination between good lots and bad lots.
4. With a fixed value of acceptance number and n α N the larger the n, the steeper the slope of O.C. curve and better ability to discriminate between good lots and bad lots.
5. The larger the sample size and acceptance number the steeper the slope of OC curve fig.14.24 shows that the larger sample size which protects the consumer against the acceptance of relatively bad lots also gives better protection to the producer against rejection of relatively good lots.

Q.31. Differentiate between Accceptance/Rejection and Acceptance/Rectitication scheme.

Ans : Acceptamce /Rejection scheme : In this scheme of acceptance sampling. The lots are subjected to sampling inspection. If the lot contains more than "C' defectives it is rejected otherwise it is accepted. The Average Outgoing Qulity will be equal to or more than the given fraction defectives. In acceptance rejection scheme O.C. curve is used to discriminate between good lots and bad lots.

Acceptance/Rectification schemes are specially appropriate where lots are produced in streams as in mass production. The lots are subjected to sampling inspection and if it contains "C' defectives are less then it is accepted. If the lot contains more than C defectives it is subjected to 100% inspection and defective articles are either replaced or corrected (rectified) before it is passed forward.

So, for a given fraction defectives, the lot accepted as a result of first sampling inspection will have a fraction defective P' the rejected lots are subjected to 100% inspection and defective articles are replaced or corrected therefore, the AOQ will be less than P'

$$AOQ = Pa.P'\left(\frac{N-n}{n}\right)$$

Where $\overline{p}$ = Probability of acceptance
P = fraction defective.
N = Lot size
n = Sample size

If the sample size is much less as compared to lot size then AOQ = pa.P'

For acceptance rectification scheme the curve of AOQ plotted against P' is used.

Q.32. Discuss the interests of the consumer and producer in the selection of sampling plans.

Ans : Since, the ideal sampling plan which will satisfy both the consumer and producer is not possible, some compromise has to be made and they have to tolerate certain risk.

At first imperession, it appears that the producer and consumer have completely opposite viewpoints towards the selection of sampling plans(i.e.their interests are conflicting). But more critical consideration will show that there is a continuing relationship between the producer and the consumer.

Substantial rejection of good products in the effort to exclude bad products is not necessarily in the interest of consumer. The consumer is interesed in quality, he is also interested in cost. In the long run the costs incident to the rejection of good products tend to be passed on by the producer to the consumer. Secondly, any good product that he rejects is not available for his immediate use.

Therefore, the producer and consumer should select acceptance plan which will satisfy both of them and they must be ready to tolerate certain risk.

Q.33. Explain single sampling plan and double sampling plan with respect to their respective acceptance criteria.

Ans . Single samling plan : When the decision on acceptance or rejection of the lot is made on the basis of only one sample. The sampling plan is called as single sampling plan.

In a single sampling plan there are three parameters:

N = Lot size from which the samples are drawn.

n = Sample size

C = acceptance number (i.e.maximum number of allowable defectives)

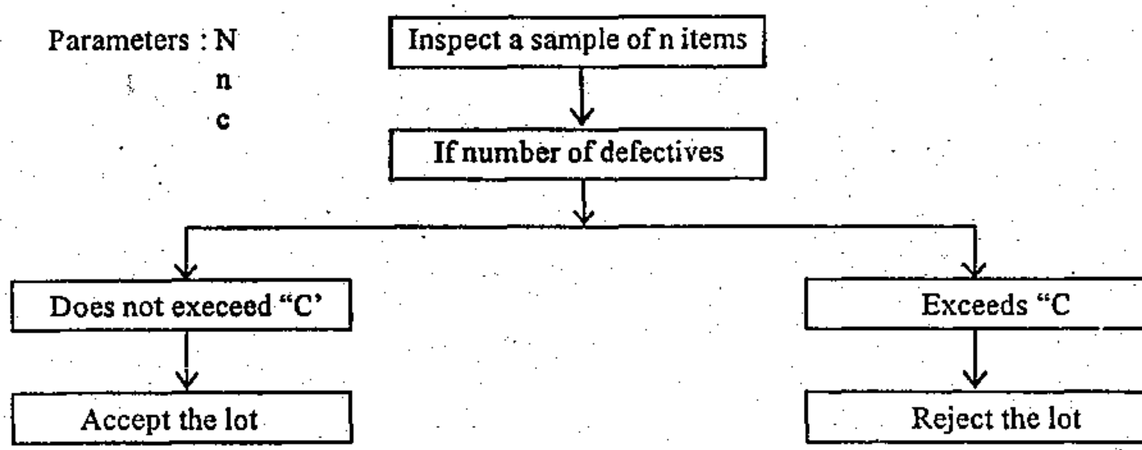
If the sampling plan is, N = 50

n = 6

C = 2

It means take a sample of 6 items from a lot of 50, if the sample contains more than 2 defectives rejcet the lot otherwise accept the lot.

The single sampling plan can be represented diagrametically as follows :



Single Sampling plan

Double sampling plan : In a double sampling plan the decision on acceptance or rejection of the lot is based on two samples. The lot may be accepted at once if the first sample is good enough or rejected at once if the first sample is bad enough. If the first sample is neither good enough nor bad enough, the decision on acceptance or rejection is based on the basis of first and second sample combined.

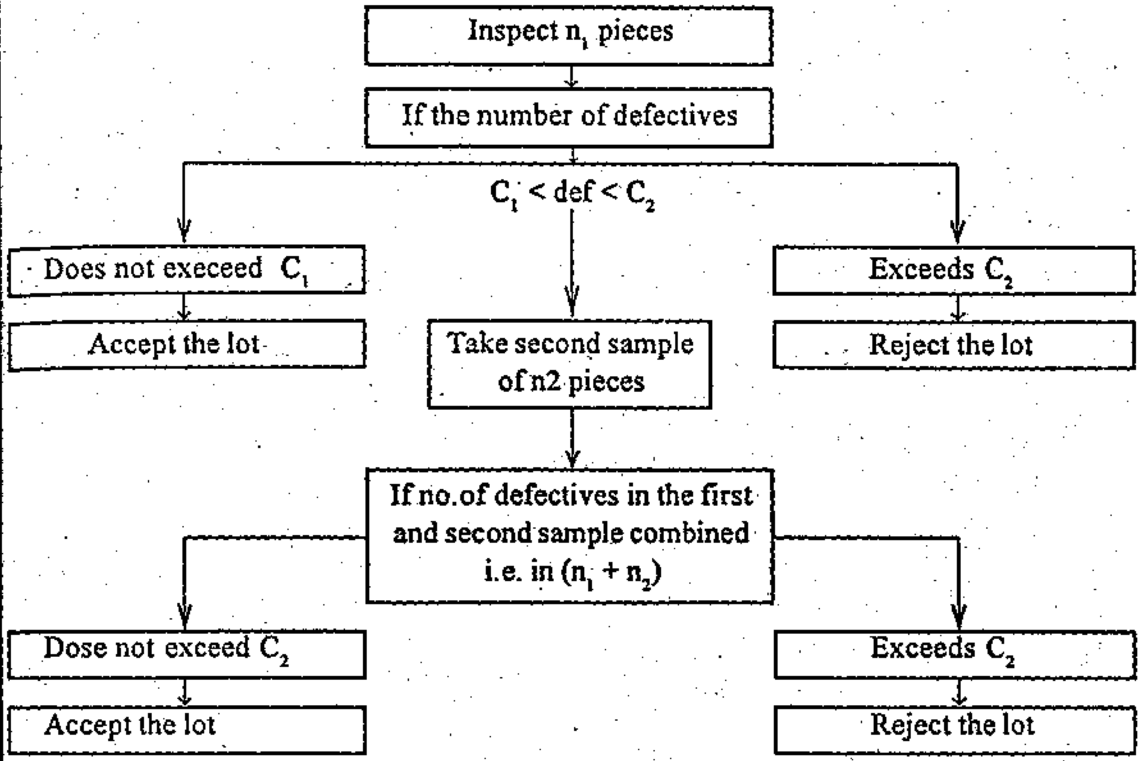
Parameters : n_1 = number articles in the sample.

c_1 = acceptnce number for the first sample i.e. maximum number of defectives that will permit the acceptance of the lot on the basis of the first sample.

n_2 = number of articles in the second sample.

$n_1 + n_2$ = number of articles in the two samples combined.

C_2 = acceptance number for the first and second sample combined.



Double Sampling plan

Q.34. Describe briefly Multiple Sampling plan.

Multiple sampling plan : The phrase multiple sampling is used when three or more samples of a stated size are permitted and when the decision on acceptnce or rejection must be reached after stated number of samples.

A multiple sampling procedure can be represented in a tabular form as follows :

Sample No.	Sample Size	combined samples		
		Size	Acceptance	Rejection
First	n_1	n_1	C_1	r_1
Second	n_2	$n_1 + n_2$	C_2	r_2
Third	n_3	$n_1 + n_2 + n_3$	C_3	r_3
Forth	n_4	$n_1 + n_2 + n_3 + n_4$	C_4	r_4
Fifth	n_5	$n_1 + n_2 + n_3 + n_4 + n_5$	C_5	r_5

A first sample of n_1 is drawn. The lot is accepted if there are no more than C_1 defectives, the lot is rejected if there are more than r_1 defectives otherwise a second sample of n_2 is drawn. The lot is accepted if there are no more than C_2 defectives in the combined sample of

$n_1 + n_2$. The lot is rejected if there are more than r_2 defectives in the combined sample of $n_1 + n_2$. The procedure is continued in accordance with the above table depending on the number of samples.

Multiple sampling plan gives better protection to doubtfull lots. But they usually require higher adminstrative costs and higher caliber inspection personnel may be necessary to guarantee proper use of the plans. secondly the indecision is continued for a longer period.

Q.35. Compare Single, Double and Multiple sampling plans.

Feature	Single sampling plan	Double samplig plan	Multiple sampling plan
1. Average number of pieces inspected per lot	Generally Largest	In between single and multiple plans	Lowest
2. Acceptability to producer	Psychologically poor, it gives only one chance of passing the lot (Risk of good lots being rejected)	Most acceptable (Gives a second) chance to doubtful lots	Less acceptable since indecision is continued for a longer period.
3. Cost of Administration	Lowest	In between single and multiple	Largest
4. Information available about prevailing quality level	Largest	In between single and multiple	Least

Compared with regards to all the four aspects double sampling plan is best. Where the cost of inspection is high, We choose multiple sampling plans. If the decision is taken on single sampling plan the lot has not to wait, but in multiple sample plan the indecision is continued for a long period and lot has to wait, therefore more storage space is necessary to store the items until the decision is taken.

Q.36 Explain the term product reliability ? How it is calculated ?

Ans. A product is an assembly of a number of parts or components. The components may be connected similar or dissimilar. The components may be connected in series or in parallel, or it may be a mixed system, where the components are connected in series as well as parallel.

1. Components connected in series : If the components of an assembly are connected in series the failure of any part causes the failure of the asembly or a system.

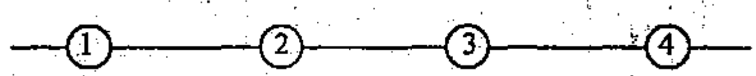
In this type of system the reliability of the assembly is given by the product of the reliabilities of the individual components.

Suppose a system (product) consists of three mechanical devices, A, B and C that operate in series in such a way that a failure in any one device casues a failure in the system.

Assume that, the prabibility that A will operate without failure for 100 hours is estimated to be 0.45 and that of B and C are 0.90 and 0.80, respectively. If the failures in A, B, and C are completely independent the probability that the system will operate without failure for 100 hours should be estimated to be

$$(0.95) \times (0.90) \times (0.80) = 0.684$$

Therfore, in general, if the system consists of n parts,

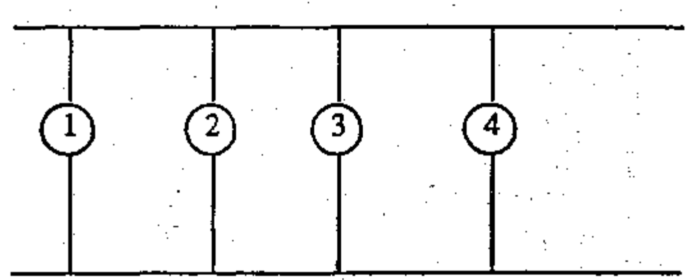


Components in series

Reliaibility of the system,

$$Rs(t) = R_1(t) \times R_2(t) \times R_3(t) \times \ldots\ldots \times R_n(t)$$

2. Components connected in parallel : When the components are connected in parallel, let



Components in parallel

q_i = probability of failure of the i^{th} component
$p_i = 1 - q_i$ = probability of successful operation

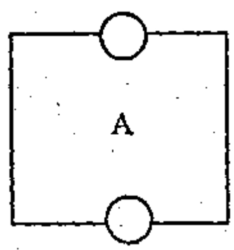
Then, probability of failure of the system is given by

$$F(t) = q_1 \times q_2 \times q_3 \times \ldots \times q_n$$

Reliability of the system,

$$R_{st} = 1 - f(t)$$
$$= 1 - (1 - P_1)\ (1 - P_2)\ (1 - P_3)\ \ldots\ (1 - P_n)$$

3. Mixed System : Figure shows two devices A and B connected in series. Device A consists of two parts 1 and 2 connected in parallel. Similarly, device Bconsists of two parts 3 and 4 connected in parallel.



The Reliability of the device A,

$$R_A(t) = 1 - (1 - P_1)\ (1 - P_2)$$

The reliability of the device B,

$$R_B(t) = 1 - (1 - P_3)\ (1 - P_4)$$

And the reliability of the system

$$R_s(t) = R_A(t) \times R_B(t)$$

i.e. System (Product) Reliability

$$[\, 1 - (1 - P_1)(1 - P_2)\,]\ [\, 1 - (1 - P_3)\ (1 - P_4)\,]$$

Q.37 Explain the terms :

i) MTBF ii) MTTR

in connected with reliability.

Ans. i) MTBF (Mean Time Between Failures) : MTBF is the mean (or average) time between successive failures of the product. This definition assumes that the product in question can be repaired and placed back in operation after each failure. An increase in an MTBF does not result in proportional increase in reliability (the probability of survival). If t =1 hour, the following table shows the mean time between failures required in order to obtain various reliabilities.

MTBF	R
5	0.82
10	0.90
20	0.95
100	0.99

MTBF is often used as the criterian for making important decisions affecting reliability.

ii) MTTR : Mean Time to Repair : It is the arithmetic mean of the time required to perform maintenance action.

$$\text{MTTR} = \frac{\text{Total maintenance time}}{\text{Number of maintenance action}}$$

Maintenance action rate (μ) : It is the numerical value representing the number of maintenance action that can be carried out on a particular equipment per hour.

$$\mu = \frac{1}{\text{MTTR}}$$

Mathematically, Mean time to repair

$$\text{MTTR} = \frac{\Sigma\, n_i\, \lambda_i\, tmi}{\Sigma\, ni\, \lambda i}$$

where, n_i = number of similar parts

λi = failure rate

tmi = predicted maintenance action time

EXERCISE

1. An industry produces springs of certain quality. The results of inspection of one of critical dimensions (length) is given in the following table. What interpretations can be derived regarding.
1. Its central tendency (process average)
2. Dispresion.
3. Suitability of the process

Dimension	Frequency
0.97	2
0.98	12
0.99	14
1.00	20
1.01	24
1.02	18
1.02	18
1.03	10
1.04	6
1.05	3

2. Following are the readings of 50 bars in a sample.

Cell intervals Class limits	Frequency
25.30-25.31	2
25.32-25.33	8
25.34-2535	18
25.36-2537	15
25.38-25.39	6
25.40-25.41	1

a. Draw the frequency polygon and frequency histogram.
b. Find the Arithmatic mean and standard deviation.

3. Compute the averge and the standard deviation of the followings distribution which shows the result of distribution of the resistnace of 500 units of certain electrical product.

Resistance	Frequency	Resistance	Frequency
2.7-2.9	2	4.2-4.4	113
3.0-3.2	16	4.5-4.7	71
3.3-3.5	48	4.8-5.0	22
3.9-4.1	188	5.15.3	4
3.9-4.1	138		

Calculate : A. Arithmetic mean
B. Standard diviation

4. You have collected the following data from micrometer measurements in millimeters of a sample selected from a large lot of machinery parts and have formed a frequency tally sheet of the data as follows.

Measurement	Tally	Measurement	Tally
25.70	|	25.10	|||| |
25.60	||	25.00	||||
25.50	||||	24.90	||||
25.40	|||| ||	24.80	|
25.30	|||| |||| |	24.70	|
25.20			

Compute the average and standard deviation of the samples Given a specification of 25 ± 0.5 mm interpreat the results on the basis of normal distribution.

5. Determine the control limits for $\overline{X}$ and R charts if $\sum \overline{X} = 375.50$, $\sum R = 9.90$ Number of subgroups = 20. If is given that $A_2 = 0.18$, $D_3 = 0.41$ and $D_4 = 1.59$, $d_2 = 3.735$. Also find process capability.

6. Control chart for $\overline{X}$ and R are maintained on a certain dimensions of a manufactured part, meausred in mm. the sub group size is 4. The value of $\overline{X}$ and R are computed for each subgroup. After 20 subgroups $\sum \overline{X} = 412.83$ and $\sum R = 3.39$ Compute the values of 3 sigma limits for the $\overline{X}$ and R charts and estimate the value of σ on the assumption that the process is in statistical control.

7. In a capability study of a lathe used in turning a shaft to a diameter of 23.75 ± 0.10 mm a sample of 5 consecutive pieces was taken each day for five days. The diameters of these shafts are as given below.

1st day	2nd day	3rd day	4th day	5th day
23.80	23.78	23.78	23.73	23.76
23.77	23.76	23.76	23.70	23.77
23.79	23.78	23.77	23.77	23.74
23.75	23.79	23.73	23.74	23.72
23.78	23.80	23.75	23.76	23.79

Construct $\overline{X}$ and R chart. State whether the machine is capable of meeting the tolerance or not.

8. Control charts for $\overline{X}$ and R are maintained on the outside diameter of a bearing. The subgroup size is 4. the values of $\overline{X}$ and R are computed for each subgroup. After 20 subgroups $\sum \overline{X} = 43.275$, $\sum R = 0.286$. The dimension specification of the produc is 2.150 + 0.020. If the dimension fall above the specification limit rework is required; if below the specification limit, the bearing must be rejected.

If the process is in statistical control and normally distributed, what can you conclude regarding the ability to meet the specifications? can you make any suggestions?

9. The following table shows the averages and ranges of the spindle diameters in mms. for 20 subgroups of 5 items each For the first 10 samples set up an $\overline{X}$ chart and R chart to see if the proces continues under control both as to average and range. Also find process capability.
($d2 = 2.326$)

X- X	R	X-	R	$\overline{X}$	R
45.020	0.375	45.660	0.475	45.26	0.150
45.950	0.450	45.680	0.275	45.650	0.200
45.480	0.450	45.600	0.275	45.620	0.400
45.320	0.150	45.020	0.175	45.480	0.225
45.280	0.200	45.320	0.200	45.380	0.125
45.580	0.250	45.560	0.425	45.660	0.350
45.400	0.475	45.140	0.250	—	—

10. The following data gives the number of missing rivets noted at aricraft final inspection.

Air Plane No	No.of missing rivets	Air plane No	No.of missing rivets	Air plane No	No.of missing rivets
1	8	10	12	19	11
2	16	11	13	20	9
3	14	12	16	21	10
4	19	13	9	22	22
5	11	14	25	23	7
6	15	15	15	24	28
7	8	16	9	25	9
8	11	17	9	—	—
9	21	18	14	—	—

I. Find $\overline{C}$
II. Compute control limits
III. Plot control chart.

11. The following are the inspection results fo 20 lots of magnets each lot being of 750 magnets Number of defective magnets in each lot are :

48	56	47	71
83	48	50	53
70	67	47	34
85	37	57	29
45	52	51	30

Calculate the average fraction defective and three sigma control limits for P chart and state whether the process is in control.

12. An inspection results of 10 typical samples, for establishing P chart are :

Sample No	1	2	3	4	5	6	7	8	9	10
No.of defective	10	12	8	9	11	8	10	11	9	12
No.inspected	90	110	90	100	130	100	80	110	110	80

Computer trial control limits, plot P chart and establish the value of p and control limits for future production.

13. **Following table refers to the average number of outlet leaks per radiator for 10 lots of 100 radiators each.**

Lot No.	No. of leaks (c)	Leaks per radiator $U = \frac{C}{n}$	Lot No	No.of leaks (c)	Leaks per radiator $U = \frac{C}{n}$
1	15	0.15	6	5	0.05
2	17	0.17	7	14	0.14
3	12	0.12	8	11	0.11
4	16	0.16	9	9	0.09
5	14	0.14	10	10	0.10

I. **Compute control limits for U chart.**

II. **Establish $\overline{U}$, for future production.**

Appendix

APPENDIX

TABLES

Table A

Areas Under the Normal Curve

Proportion of total area under

Curve from -to X_1-X/σ` where is the standard deviation of the universe.

$\frac{X_i - x'}{\sigma'}$	0.09	0.08	0.07	0.06	0.05	0.04	0.03	0.02	0.01	0.00
-3.5	0.00017	0.00017	0.00018	0.00019	0.00019	0.00020	0.00021	0.00022	0.00022	0.00023
-3.4	0.00024	0.00025	0.00026	0.00027	0.00028	0.00029	0.00030	30.00031	0.00033	0.00034
-3.3	0.00035	0.00036	0.00038	0.00039	0.00040	0.00042	0.00043	0.00045	0.00047	0.00048
-3.2	0.00050	0.00052	0.00054	0.00056	0.00058	0.00060	0.00062	0.00064	0.00066	0.00069
-3.1	0.00071	0.00074	0.00076	0.00079	0.00082	0.00085	0.00087	0.00090	0.00094	0.00097
-3.0	0.00100	0.00104	0.00107	0.00111	0.00114	0.00118	0.00122	0.00126	0.00131	0.00135
-2.9	0.0014	0.0014	0.0015	0.0015	0.0016	0.0016	0.017	0.0017	0.0018	0.0019
-2.8	0.0019	0.0020	0.0021	0.0022	0.0023	0.0023	0.0023	0.0024	0.0025	0.0026
-.2.7	0.0026	0.0027	0.0028	0.0029	0.0030	0.0031	0.0032	0.0033	0.0034	0.0035
-2.6	0.0036	0.0037	0.0038	0.0039	0.0040	0.0041	0.0043	0.0044	0.0045	0.0047
-2.5	0.0048	0.0049	0.0051	0.0052	0.0054	0.0055	0.0057	0.0059	0.0060	0.0062
-2.4	0.0064	0.0066	0.0068	0.0069	0.0071	0.0073	0.0075	0.0078	0.0080	0.0082
-2.3	0.0084	0.0087	0.0089	0.0091	0.0094	0.0096	0.0099	0.0102	0.00104	0.0107
-2.2	0.0110	0.0113	0.0116	0.0119	0.0122	0.0125	0.0129	0.0132	0.0136	0.0139
-2.1	0.0143	0.0146	0.0150	0.0154	0.0158	0.0162	0.0166	0.0170	0.0174	0.0179
-2.0	0.0183	0.0188	0.0192	0.0197	0.0202	0.0207	0.0212	0.0217	0.0222	0.0228
-1.9	0.0233	0.0239	0.0244	0.0250	0.0256	0.0262	0.0268	0.0274	0.0281	0.0287
-1.8	0.0294	0.0301	0.0307	0.0314	0.322	0.0329	0.0336	0.344	0.0351	0.0359
-1.7	0.0367	0.0375	0.0384	0.0392	0.401	0.00409	0.0418	0.0427	0.0436	0.0446
-1.6	0.0455	0.0465	0.0475	0.0485	0.0495	0.505	0.0516	0.0526	0.0537	0.0548
-1.5	0.0559	0.0571	0.0582	0.0594	0.0606	0.0618	0.0630	0.0643	0.0655	0.0668
-1.4	0.0681	0.0694	0.0708	0.0721	0.0735	0.0749	00764	0.0778	0.093	0.0808
-1.3	0.0823	0.0838	0.0853	0.0869	0.0885	0.0901	0.0918	0.0934	0.0951	0.0968
-1.2	0.0985	0.1003	0.1020	0.1038	0.1057	0.1075	0.1093	0.1112	0.1131	0.1151
-1.1	0.1170	0.1190	0.1210	0.1230	0.1251	0.1271	0.1292	0.1314	0.1335	0.1357
-1.0	0.1379	0.1401	0.1423	0.1446	0.1469	0.1492	0.1515	0.1539	0.1562	0.1587
-0.9	0.1611	0.1635	0.1660	0.1685	0.1711	0.1736	0.1762	0.1788	0.1814	0.1841
-0.8	0.1867	0.1894	0.1822	0.1949	0.1977	0.2005	0.2033	0.2061	0.2090	0.2119
-0.7	0.2148	0.2177	0.2207	0.2236	0.2266	0.2297	0.2327	0.2358	0.2389	0.2420
-0.6	0.2451	0.2483	0.2514	0.2578	0.2546	0.2611	0.2643	0.2676	0.2709	0.2743
-0.5	0.2776	0.2810	0.2843	0.2877	0.2912	0.2946	0.2981	0.3015	0.3050	0.3085
-0.4	0.3121	0.3156	0.3292	0.3228	0.3264	0.3300	0.3336	0.3372	0.3409	0.3446
-0.3	0.3483	0.3520	0.3557	0.3594	0.3632	0.3669	0.3707	0.3745	0.3783	0.3821
-0.2	0.3859	-0.3857	0.3557	0.3594	0.3632	0.3669	0.3707	0.3745	0.3783	0.3821
-0.1	0.4247	0.4286	0.4325	0.4364	0.4404	0.4443	0.4483	0.4522	0.4562	0.4602
-0.0	0.4641	0.4681	0.4721	0.4761	0.4801	0.4840	0.4880	0.4920	0.4960	0.5000

TABLE A

Areas Under the Normal Curve- (Continued)

X_n -X'	0.0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
+0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5358
+0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	05675	0.5714	0.5753
+0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6130	0.6141
+0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6358	0.6406	0.6443	0.6480	0.6517
+0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
+0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
+0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7480	0.7517	0.7540
+0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
+0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	8079	0.8106	0.8133
+0.9	0.8159	0.8156	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8355	0.8389
+1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8654	0.8577	0.8599	0.8621
+1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
+1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.8830
+1.3	0.9032	0.9049	0.9066	0.9082	0.9090	0.9115	0.9131	0.9147	0.9162	0.8177
+1.4	0.9192	0.92.7	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9310
+1.5	9332	0.9345	0.9357	0.9370	0.9382	0.9384	0.9406	0.9418	0.9429	0.9441
+1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0 9545
+1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
+1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9705
+1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
+2.0	0.9773	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
+2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
+2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
+2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
+2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
+2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
+2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
+2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
+2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
+2.9	0.9981	0.9982	0.9983	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
+3.0	0.99865	0.99800	0.99874	0.99878	0.99882	0.99889	0.99889	0.99893	0.99896	0.99900
+3.1	0.99903	0.99906	0.99910	0.99913	0.99915	0.99918	0.99921	0.99924	0.99926	0.99929
+3.2	0.99931	0.99934	0.99936	0.99938	0.99940	0.99942	0.99944	0.99946	0.99948	0.99950
+3.3	0.99952	0.99953	0.99955	0.99957	0.99958	0.99960	0.99961	0.99962	0.99964	0.99965
+3.4	0.99966	0.99967	0.99969	0.99970	0.99971	0.99972	0.99973	0.99974	0.99975	0.99976
[illegible]	[illegible]	[illegible]	[illegible]	0.99739	0.99980	0.99981	0.99981	0.99982	0.99983	0.99983

0.08	0.09
0.5319	0.5358
0.5714	0.5753
0.6130	0.6141
0.6480	0.6517
0.6844	0.6879
0.7190	0.7224
0.7517	0.7540
0.7823	0.7852
0.8106	0.8133
0.8355	0.8389
0.8599	0.8621
0.8810	0.8830
0.8997	0.8830
0.9162	0.8177
0.9306	0.9310
0.9429	0.9441
0.9535	0 9545
0.9625	0.9633
0.9699	0.9705
0.9761	0.9767
0.9812	0.9817
0.9854	0.9857
0.9887	0.9890
0.9913	0.9916
0.9934	0.9936
0.9951	0.9952
0.9963	0.9964
0.9973	0.9974
0.9980	0.9981
0.9986	0.9986
0.99896	0.99900
0.99926	0.99929
0.99948	0.99950
0.99964	0.99965
0.99975	0.99976
0.99983	0.99983

TABLE B

Factors Estimating σ` from RÓor σ`

Number of observations in sub-group n	Factor for Estimate d_2=R/σ`	Factor for estimate from c_2= σ`/σ`
2	1.128	0.5642
3	1.693	0.7236
4	0.059	0.7979
5	2.326	0.8407
6	2.534	0.8686
7	2.704	0.8882
8	2.847	0.9027
9	2.970	0.9139
10	3.078	0.9227
11	3.173	0.9300
12	3.258	0.9359
13	3.326	0.9410
14	3.407	0.9453
15	3.472	0.9490
16	3.532	0.9523
17	3.588	0.9551
18	3.640	0.9576
19	3.689	0.9599
20	3.735	0.9619
21	3.778	0.9638
22	3.819	0.9655
23	3.858	0.9670
24	0.895	0.9684
25	3.931	0.9696
30	4.086	0.9748
35	4.213	0.9784
40	4.322	0.9811
45	4.415	0.9832
50	4.498	0.9849
55	4.573	0.9863
60	4.639	0.9874
65	4.699	0.9884
70	4.755	0.9892
75	4.806	0.9900
80	4.854	0.9906
85	4.498	0.9912
90	4.939	0.9916
95	4.978	0.9921
100	0.015	0.9925

Estimate of σ` = R/$d_2$ or σ`/C_2

These factors assume sampling from a normal universe

Table C

Factors for Determining from $\overline{R}$ the 3- Sigms control.

Limits for $\overline{\overline{X}}$ and $\overline{R}$ Charts from $\overline{R}$

Number of observations	Factor for X Chart	Factor for R chart	
		Lower control limit	upper control limit
n	A_2	D_2	D_4
2	1.88	0	03.27
3	1.02	0	2.57
4	0.73	0	2.28
5	0.58	0	2.11
6	0.48	0	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.34	0.187	1.82
10	0.31	0.22	1.78
11	0.29	0.22	1.74
12	0.27	0.28	1.72
13	0.25	0.31	1.69
14	0.24	0.33	1.67
15	0.22	0.35	1.65
16	0.21	0.36	1.64
17	0.20	0.38	1.62
18	0.19	0.39	1.61
19	0.19	0.40	1.60
20	0.18	0.41	1.59

Upper Control limit for $\overline{X}$ = $UCL_{\overline{X}} = \overline{\overline{X}} + A_2\overline{R}$

Lower control limit for $\overline{X}$ = $LCL_{\overline{X}} = \overline{\overline{X}} - A_2\overline{R}$

(If aimed or standard value $\overline{X}$ is used rather than $\overline{\overline{X}}$ as the central line on the control chart, $\overline{X}$ should be substiuted for $\overline{\overline{X}}$ in the preceding formulas.)

Upper Control Limit for R = UCL_R = $D_4\overline{R}$

Lower Control Limit for R = LCL_R = $D_3\overline{R}$

All factors in Table C are based on the normal distribution.

TABLE D

Factors for Determining from the 3 sigma Control Limits for X and σ Charts

Number of observations	Factor for X Chart	Factor for R chart	
		Lower control limit	upper control limit
n	A_1	B_3	B_4
2	3.76	0	0.27
3	2.39	0	0.57
4	1.88	0	2.57
5	1.60	0	2.09
6	1.41	0.03	1.97
7	.28	0.12	1.88
8	1.17	0.19	1.88
9	1.09	0.24	1.76
10	1.03	0.28	1.72
11	0.97	0.32	1.68
12	0.93	0.35	1.65
13	0.88	0.38	1.62
14	1.85	0.41	1.59
15	0.82	0.43	1.57
16	1.79	0.45	1.55
17	0.76	0.47	1.53
18	0.74	0.48	1.52
19	0.72	0.50	1.50
20	0.70	0.51	1.49
21	0.68	0.52	1.48
22	0.66	0.53	1.47
23	0.65	0.54	1.46
24	0.63	0.55	1.45
25	0.62	0.56	1.44
30	0.56	0.60	1.40
35	0.52	0.63	1.37
40	0.48	0.66	1.34
45	0.45	0.68	1.32
50	0.43	0.70	1.30
55	0.41	0.71	1.29
60	0.39	0.72	1.28
65	0.38	0.73	1.27
70	0.37	0.74	1.26
75	0.35	0.76	1.25
80	0.34	0.75	1.24
85	0.33	0.77	1.23
90	0.32	0.77	1.23
95	0.31	0.78	1.22
100	0.30	0.79	1.21

Upper control limit for $\bar{X}$ = $UCL_{\bar{X}} = X + A_1\bar{\sigma}$

Lower control limit for $\bar{X}$ = $LCL\,X = S - A_1\sigma$

(If aimed or standard value $\bar{x}$ is used rather than as $\bar{x}$ the central line on the chart, $\bar{x}$ should be subsitued for $\bar{x}$ in the preeding formulas.)

Upper Control limit for σ = $UCL = B_4\bar{\sigma}$

Lower Control Limit for σ = $LCL = B_2\bar{\sigma}$

All factos in Table D are based on the norma distribution.

TABLE - E

Factors for Determining from the 3 sigma Control Limits for $\bar{X}$/R and σ Charts

Number of observations	Factor for X Chart	Factor for R chart		Factor for R chart	
		Lower control limit	upper control limit	Lower control limit	upper control limit
n	A	D_1	D_2	B_1	B_2
2	2.12	0	3.69	0	1.84
3	1.73	0	4.36	0	1.86
4	1.50	0	4.70	0	1.81
5	1.94	0	4.92	0	1.76
6	1.22	0	5.08	0.03	1.71
7	1.16	0.20	5.20	0.10	1.37
8	1.06	0.39	5.31	0.17	1.64
9	1.00	0.55	5.39	0.22	1.61
10	0.95	1.70	5.47	0.26	1.58
11	.90	0.81	0.53	0.30	1.56
12	87	0.92	5.59	0.33	1.54
13	0.83	1.03	5.65	0.36	1.52
14	0.80	1.12	5.69	0.38	1.51
15	0.77	1.21	5.74	0.41	1.49
16	0.75	1.28	5.78	0.43	1.48
17	0.73	1.36	5.82	0.42	1.47
18	0.71	1.43	5.85	0.46	1.45
19	0.69	1.49	5.89	0.48	1.44
20	0.67	1.55	5.92	0.49	1.43
25	0.60			0.55	1.39
30	0.55			0.69	1.36
35	0.51			0.62	1.33
40	0.47			0.65	1.31
45	0.42			0.67	1.30
50	0.39			0.68	1.28
60	0.36			3.71	1.26
70	0.34			0.74	1.24
80	0.32			0.75	1.23
90	0.30			0.77	1.22
100				0.78	1.20

$UCL_{\bar{X}} = \bar{X} + A \qquad LCL = \bar{X} - A\sigma$

(If actual average is to be used rather than standard or aimed at a average, $\bar{X}$ should be substitued for $\bar{X}$ in the preceding formula)

$UCL_R = D_2\sigma$

Central lime$_R$ = $d_R\sigma$

$LCL_R = D_R\sigma$

$UCL_{\sigma} = B_1\sigma$

Central line$_{\sigma}$ = $c_2\sigma$

$LCL_{\sigma} = B_1\sigma$