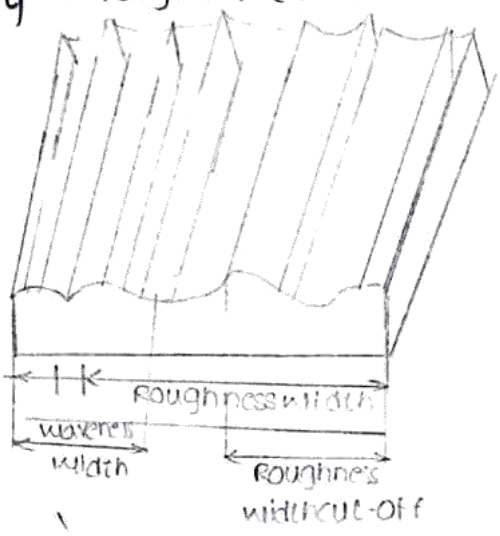
Elements of surface roughness:

The various elements of surface roughness can be defined & explained with the help of figure (1) which shows a highly maginified surface:



surface is confined as the portion that limits the body & separates it from the surronding surface

Actual surface:

It is defined as the newly obtained or actually obtained surface after a manufacturing process. Normal surface is the geomentrically perfect surface which does not exists but is an average of the irregularities measured on the surface.

Profile:

Through a surface the counter part obtained from any section is to be a profile

Roughness Height:

It is rated as newly as the arithmetical mean divi's deviation expressed in micro inches or micrometer

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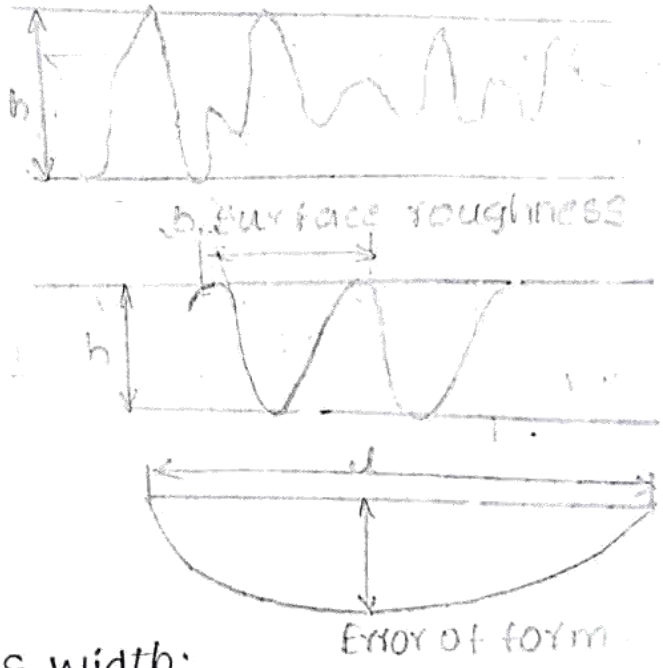
normal to an imaginary centre line passing through the surface roughness profile.



Roughness width:

It is the distance measured parallel to the normal surface between the successive peaks or ridges that constitute the predominant pattern of roughness

Roughness with cutoff (sampling length)

This is the maximum length of surface irregularities induced in the measurement of roughness of length & is always greather than roughness width.

various elements of surface roughness can be explained with the help of figure.

Surface roughness:

* It refers to relatively finely spaced micro & geometrical irregularities
* Roughness is reffred as primary texture
* It is genarally produced by the action of cutting tool.

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* These are characterized by the low ratio of their pitch 's' to heights 'h' [peak to valley distance] since

$$\frac{s}{h} < 50$$

Surface waveness:

* It refers to the surface irregularities greater spacings than roughness
* waviness is reffred as a secondary texture
* It is genarally produced due to vibrations, machine or work deflection.
* These are characterized by a high ratio of their pitch 's' to height 'h' since

$$50 \leq \frac{s}{h} \leq 1000$$

waviness:

waviness refers to those surface irregularities, which have greater spacing than roughness that occurs in the form of waves. It may be caused by vibration machine, or work deflections, warping etc.., It is also reffered as 'secondary texture' waviness is characterized by the ratio of their pitch to the peak to the valley distance, s/h being equal to 50 to 100. The wavelength is greather than about 1mm

flaws:

flaws are surface irregularities or imperfections occur at random intervals. some of the imperfections are scratches, holes, cracks, pits, checks, porosity etc.., These may be observed directly or with the aid of a penetrating dye or other materials. that make them

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visible for examination & evaluation.

Flaws may also termed as micro-geometrical irregularities. These are random but not regularly repeated deviations on the theoretical surface. These are characterized by the large ratio of the length 'l' over which the deviation extends to the amount of deviation d/h ≥ 1000 example, out of roundness taper etc..,

Lay:

Lay is defined as the direction of the predominant surface pattern, produced by tool marks. The symbol is used to indicate the direction of lay are given below.

Parallel:

Lay parallel to the boundary line of nominal surface i.e, lay is parallel to the line representing, surface to which the symbol is applied Ex: O.D grinding.

Perpendicular:

Lay perpendicular to the boundary line of the nominal surface i.e, lay perpendicular to the line representing surface to the boundary line of the nominal surface. or lay + to the line representing surface to which the symbol is applied Ex: end view of shaping, I.D grinding.

X: lay angular in both directions to line representing the surface to which symbol is applied Ex: Side wheel grinding

M: Lay multi directional Ex: lapping, super finishing

C: Lay approximately circular relative to the centre of the surface. the which the symbol is applied Ex: facing on a lathe.

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genarally the cutting process such as lapping & honning produces an irregular & multi directional texture, where as the finishing process such as grinding have an irregular unidirectional texture The other cutting process are boring, shaping etc.., produce a unidirectional texture

Examples:

* The heat is transferred perfectly when the heat exchanger slightly rough surfaces instead of having finished surfaces
* The brake drums & clutch plates with slight roughner works efficiently than smooth surface finish.

controlling the surface finish:

following are the improtant reasons for controlling the surface finish.

* To minimize the frictional wear.
* For improving the service life of components
* minimising corrosion through reduction in depth of irregularities
* for improve a fatigue resistance
* To have a pleasing apperance
* For having a close dimensional tolerance.
* Due to excessive roughness, the movable components get heated up, bind & then freezes
* The electrical house hold appliances need more power supply, when the surface of the shafts and bearings positions

Affecting a surface roughness.

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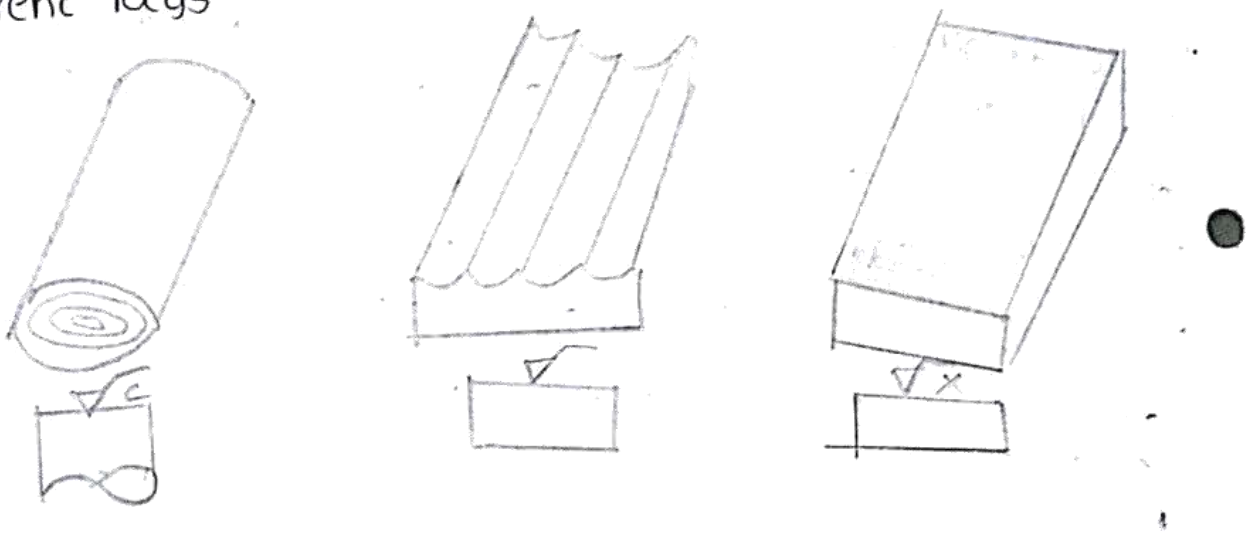
R: Lay approx mately radial relative to the centre of the surface to which the symbol Ex: surface grounded on a turn table.

The various types of lays in fig(3) It should be noticed that the surfacess is measured at 90° to direction of lay.

Different lays



Different applications demand different surface texture. The surfaces which are manufactured by using different process will have irregularities & imperfections on it. The irregularities are in the form of succession of hills & valleys, which varies in their heights & spacing. These irregularities are known as surface roughness, surface finish or surface texture.

The operations performed on the work part surfaces such as casting, hot working, powder metallurgy will produce the component or product with irregularities, which are associated with manufacturing of dies. These irregularities also exists after the completion of machining process on the work part surfaces such as turning, boring, laping, shaping etc..,

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Factors for affecting surface roughness

* Type of coolant used
* Type of machining
* vibrations
* Material of the work piece.
* cutting conditions like speed etc..,
* cutting tool material, from type & sharpness.
* Rigidity of machining

Reasons for controlling the surface roughness.

* for good look of the material
* To reduce wear due to friction.
* To improve the life of the component
* To reduce initial wear of parts
* To achieve close dimensional tolerance on the parts.
* To reduce pitting corrosion
* To improve the waviness resistance.

Direct instrument methods for measure ment of surface finish:

This method enables to determine the numerical value of the surface by using instrument stylus probe type, operating on electrical principles. In these instruments the out put to be implified, which is used to operate reading or recording or indicating instruments. stylus is a fine point made of diamond or any such hard material drawn over the surface to be tested. The movements of the stylus are used to modulate a high frequency carrier current or to genarate a voltage signal. The out put is then amplified by sutiable means are used to operate a recording or indicating instrument.

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The stylus probe instruments currenty in use for surface finish measurement are

* profilometer
* The Tomlinson surface meter
* The taylor hobson Talysurf
* The sigma micrOtest
* The Rubbur mecrin roughness indicator.

primary texture	secondary texture
1, primary texture or roughness is a type of error	* secondary texture is also type of error resulting due to the geomentrical irregularities of surface.
* Irregularities of small wave length	* Irregularities are of considerable wave length of periodic character.
* It is caused by the action of cutting element on the material or disturbances such as wear, friction & corrosion	* It is caused by the mechanical disturbances in the genarating setup.
* It is termed as micro-geomentrical error	* It is termed as micro geomentrical error.
* Irregularities are due to mis-alignment of centres lack of straightness of guide ways & non linear feed motion	* IRregularities due to tool feed rate & tool chatter.
* Irregularities are of 3rd & 4th order	* irregularites are of 1st & 2nd order

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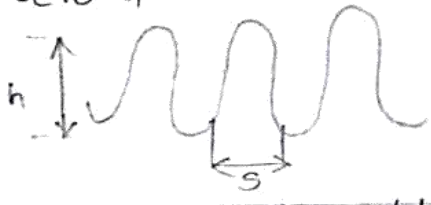
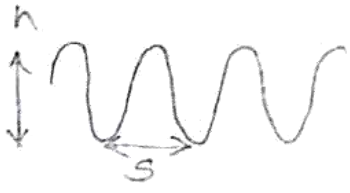
Direct method of measurment of roughness	Indirect method of measurement of roughness
* This method enable to determine a numerical	* In this method the surface texture is assesed by observatio of the surface by comparsion methods
* Nearly all instruments used as stylus probe	* Examples are touch inspection, visual inspection etc..,
* This method operates on electrical principle	* this method operates on comparsion principles
* Reliable method	* Not reliable.

Surface roughness	Surface waviness
* Roughness is also known as primary texture	* waviness is also known as secondary texture.
* It refers to irregulaties of small wave length	* It refers to the surface irregularities of greater spacing than roughness
* It consists of finely spaced micro-geomentrical irregularities or errors as shown in below	* It consists of macro-geomentrical errors as shown below





* AISO includes 3rd & 4th order irregularities	* AISO includes 1st & 2nd order irregularities
* These are characterised by a low ratio of their length & surface's to surface deviation 'h' which is less than 50 $\therefore S/h < 50$	* These are characterised by a high ratio of their long surfaces to the surface deviation 'h' which is greather than 50 $S/h > 50$
* genarally produced by the action of cutting tools	* genarally produced due to vibrations.

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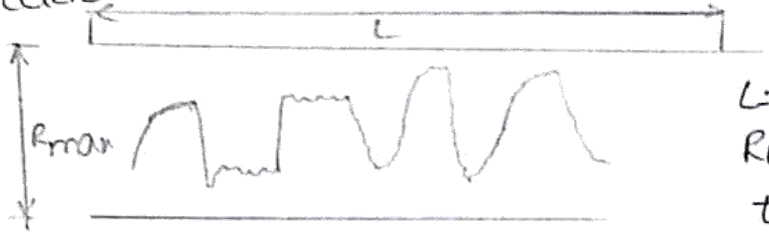
Maximum peak to valley height of roughness:

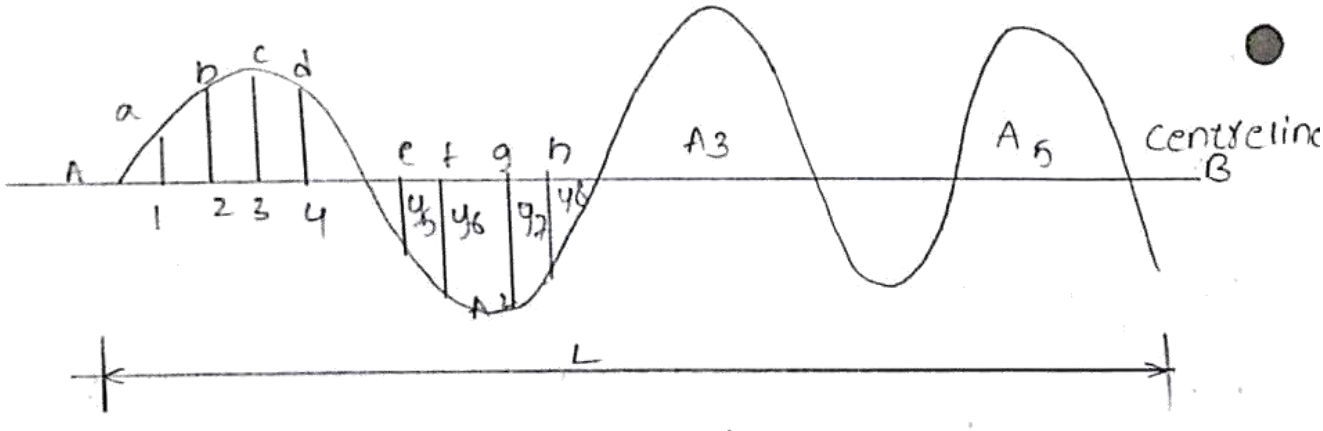
Generally peak to valley height is the separation of highest peak of the irregularity & its lowest valley maximum peak to valley Rmax is defined as the largest single peak to valley height in the five adjoining sampl length. This is used to measure the depth of surface roughness. The disadvantage of this method is that, its reads the same value



L-sampling length
Rmax: maximum peak to valley height-

RMS:

It is the most accepted method of assesing the surface roughness as the average deviation froma nominal surface value of surface roughness it is expressed in micrometers (μ-m)



In these figure (2) the centre line AB is located such tha the sum of the areas above the lines is equal to the area below the line. If 'n' measurements are made from the centre line vertically to points on the profile are closed y, then root mean square value is positive squa

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of the arthimatic mean of the value of the squares of the value in the set the distances above the centre line taken as positive as below as negative.

$$R.M.S \text{ average} = \frac{\sqrt{y_1^2 + y_2^2 + y_3^2 \cdots y_n^2}}{n}$$

$$= \left[\frac{(\Sigma y_i)^2}{n}\right]^{1/2}$$

centre line average method:

Now a days Rms is superseded in this method the surface roughness is measured as the average deviation of the nominal surface C.L.A of Arthimetic mean deviation may be defined as the average height from the mean line neglecting the arthimetic signs ordinates

$$C.L.A \text{ value} = \frac{h_1 + h_2 + h_3 + h_4 \cdots h_p}{p}$$

But to find C.L.A value like this lengthy process

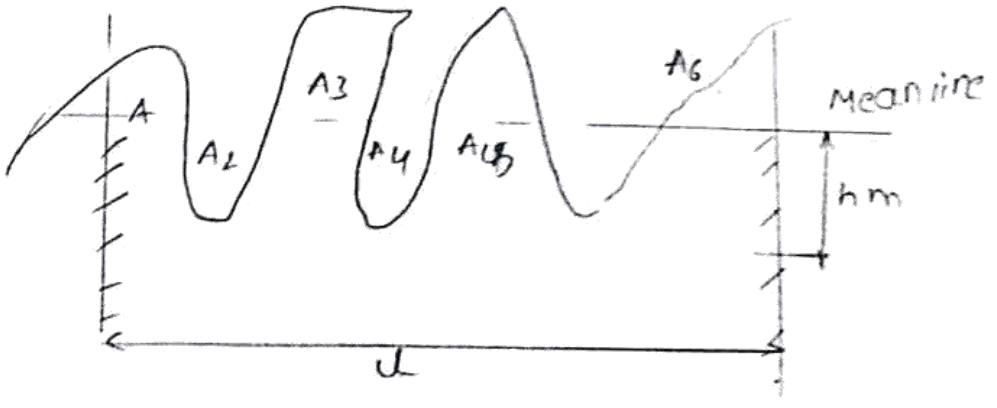
∴ By using planimeter we can find out are a of any curve things can be much samplified let us assume that some how the mean line is exactly known then

$$C.L.A \text{ value} = R_a = \frac{A_1 + A_2 + A_3 \cdots A_p}{L}$$

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

CLA value is determines in microns

1 micron $= 10^{-6}$ m



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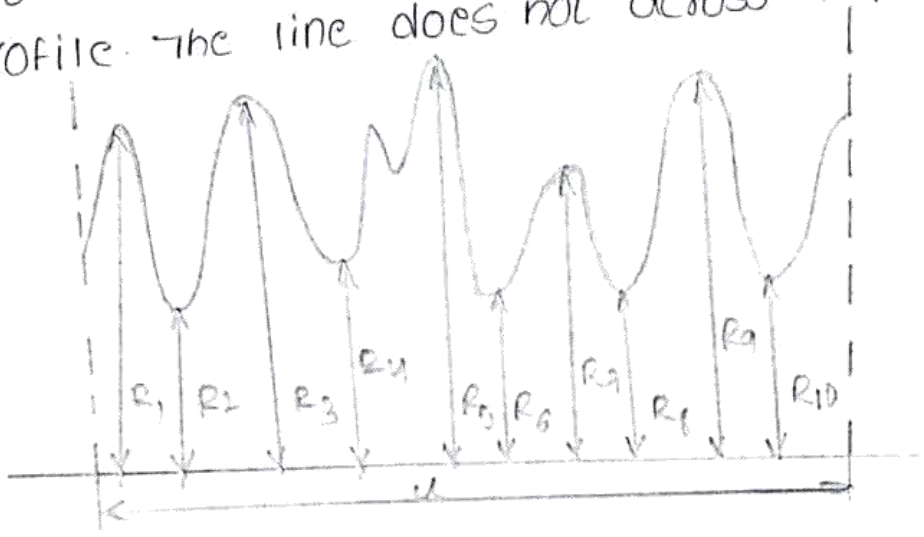
Ten point height method:

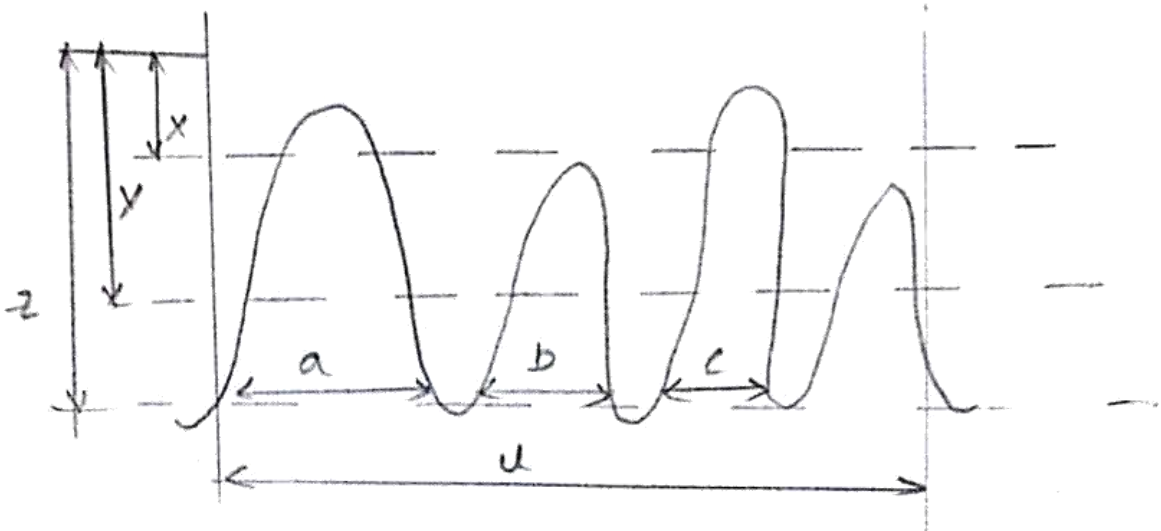
It is the simplest method used to measure the total depth of the surface roughness. This is the average difference b/w the 5 highest peaks & the 5 deepest valleys within sampling length, measured from a line drawn ∥-to the general direction of the profile. The line does not across the profile.



Form factor or Bearing curve method

This method was developed by abbot & hence the bearing area curve is commonly known as abbot curve. It was developed from a stylus trace or the surface texture & represents the length of the material intercepts a, b, c etc.., as a percentage the true length as a function of depth of irregularities as shown in

fig



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centre line average method (Ra)

In the measurement of roughness the heights of 16 successive peaks and troughs were measured from the datum are 18, 42, 25, 35, 22, 36, 18, 42, 22, 32, 24, 36, 16, 38, 23, 40 microns if these measure ments were obtained over length of 30mm determine the following values

i, Ra ii, R_z iii, RMS

i, centre line average method (Ra)

The approxmiate value $= \int_{i=1}^{n} h_i$

$$= \frac{18+42+25+35+22+36+18+42+22+32+24+36+16+38+23+40}{30}$$

$$= 15.63 \text{ microns}$$

Average peak to valley height (R_z)

$$R_z = \frac{R_1+R_3+R_5+R_7+R_9-[R_2+R_4+R_6+R_8+R_{10}}{5}$$

$$= \frac{\{42+40+38+36+35\}-\{16+18+22+24+25\}}{5}$$

$$= 17.2 \text{ microns}$$

iii, R.M.S value

$$\left[\frac{1}{2}\int_0^L y^2 \cdot dL\right]^{1/2} = \sqrt{\frac{y_1^2+y_2^2+y_3^2+y_4^2 \cdots y_p^2}{p}}$$

$$= \sqrt{\frac{18^2+42^2+25^2+35^2+22^2+36^2+18^2+42^2+22^2+32^2+24^2+36^2+16^2+38^2+23^2+40^2}{16}}$$

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= 30.634 microns

The heights of peak & valleys of 20 successive points on a surface are 45, 25, 23, 22, 24, 53, 15, 22, 64, 32, 12, 23, 34, 55, 23, 11, 12, 17, 15 microns respectively measured over a length.

Different methods of measure surface finish

The methods used to measure the surface finish are classified into two types.

* Inspection method
* Direct instrument method

* Inspection method:

In this measurement method of surface finish, the surface is assessed by observation, tested & compared with a known roughness surface value. The required surface finish is obtained by similar machining process, performed on specimen.

The different methods of surface finish measurement with refrence to inspection by comparsion are.

1, visual inspection:

The method in which the inspection of surface is done by a naked eye is called as visual inspection. This method is generally used to inspect rough surfaces. more accurate results can be obtained with the help of illuminated magnifiers.

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Touch inspection:

This method can simply tell which surface is more rough. It is a simple touch inspection method, in which a finger tip is moved along the surface with 25mm per second speed. By this we can inspect certain small irregularities of 0.01mm. A modification of it is possible using a table tennis ball, which is subjected over the surface to be detected. The main defect of this method is that, the degree of surface roughness cannot be assessed and also minute flaws cannot be inspected or detected.

Microscopic inspection:

In this method a microscope is used to inspect the surface roughness (or) texture. initially, the finished surface, is placed under microscope & compared with the surface under inspection. This method is considered to the best method for examining the surface roughness. But only a small portion of surface is detected at a time

Scratch inspection:

In this method, a softer material such as lead or plastic is used to detect the surface finish. The material is rubber over the surface to be inspected. By doing so it carries the impression of scratches on the surfaces which can easily visualized.

Micro interferometer:

In this method, a mono chromotic source of light is used to detect the surface texture. The light ray is passed through the optical flat, which is placed on

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Parameters like Ra, Rz, Rmax etc.., indicate the present system of specifying the surface finish. This system specify the geometry only in the vertical direction. The parameters are sufficient for control purposes in production. Yet they are insufficient for analysing the functional behaviour of surfaces.

Ex: profile having same 'Ra' value can have different profile shapes varying in functional behaviour. They do not specify the openness or closeness of the surface, no of peaks contained in the surface etc. This needs specification & measurement of new parameters of surface geometry that have a direct influence of function parameters like Rmax, Ra etc. These parameters given an indication of the surface in frequency domain as well as in amplitude.

Working principle of profilograph

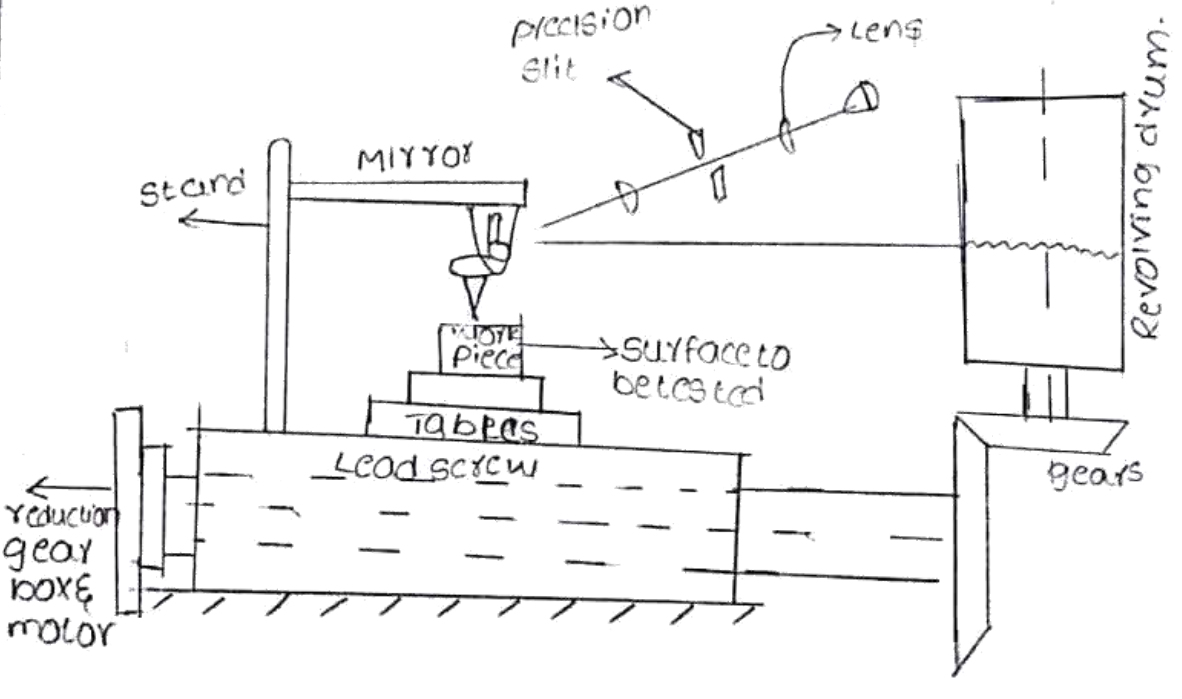

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figure shows the schematic diagram & working principle of photilograph. The surface to be tested is placed on the table and can be moved to & fro along the axis of the lead screw through the nut & bolt mechanism with the aid of the vector

The stylus or tracer point which is at rest on the testing surface is pivoted with mirror as shown in figure. Initially the pivot point is changed to a desired position & then fixed in space with the help of a stand. When the surface to be tested moves the oscillations of the tracer or transmitted to the mirror when the beam of light from the light source through lens & the precision slit strikes the oscillating mirror, it gets reflected on the revolving drum upon which a sensitive film is arranged. Thus the photilograph is used to determine the surface finish.

Measurement of surface roughness by electronic means:

Taylor - Hobson Talysurf is a stylus and skid type of instrument used to measure surface roughness on carrier modulating principle or by electronic principle. This electronic means is more rapid and accurate as compared to Tomlinson surface meter Taylor Hobson Talysurf consists a sharply pointed diamond stylus in measuring head

In this type of instrument, the stylus trace the profile of the surface irregularities & the oscillatory movement of the stylus is converted into change

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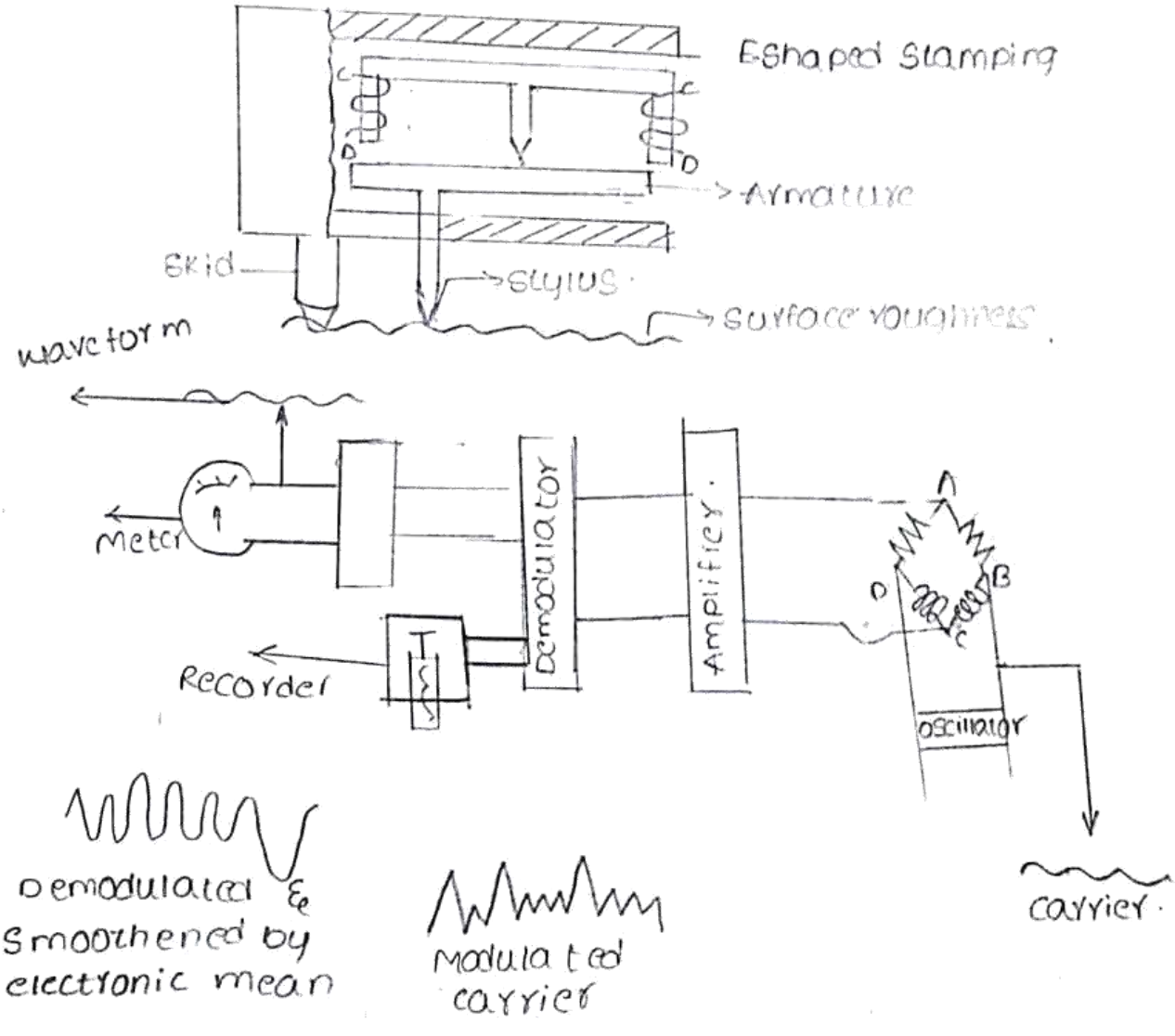
in electri current by the arrangement of electronic means. The arm carrying the stylus forms an armature which pivots about the centre piece of E shaped stamping has two coils or two legs of it. carrying current (A.C) these two coils with other two resistance forms an oscillator, which is purely a electronic mean. As the armature is pivoted about the centre leg. any movement of the stylus causes the air gap to vary & thus the amplitude of original Ac current flow in the coil is modulated. Hence surface roughness is effectively measured by this electronic mean.



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Roughness graphing using talysurf:

Roughness graphing is described as a electrical recorder a graph of the surface roughness variation as shown when the diamond stylus is moved over the surface. The instrument Taylor hobson talysurf actually records the static displacement of the stylus, whose tip radius is of about 0·02mm.

When the pen recording is switched on, the movements of the stylus which is automatically drawn slowly over the surface being amplified electrically and feed to the pen recorder which traces on a moving strip of paper that shows a roughness graphing on the surface

It is necessary to keep the meter reading & pen record with in their limits between 1000 & 50,000 electrical magnifications The record is also strictly rectilinear, instead of distortion of the pen swinging in arc.

working of profilometer:

It is also called as abbot profilometer The instrument is used for indicating & recording the measured roughness values of surfaces, in microns. It is used to check comparsion standards for accuracy & to measure work directly as means of controlling surface finish.

During this movement, the tracer point is displaced the minute ridges & valleys on the surface & its displacement is magnified and registered on a meter or a chart for reading & analysis.

The tracer is conically shaped diamond pointed & it is used to explore the surfaces which are to be

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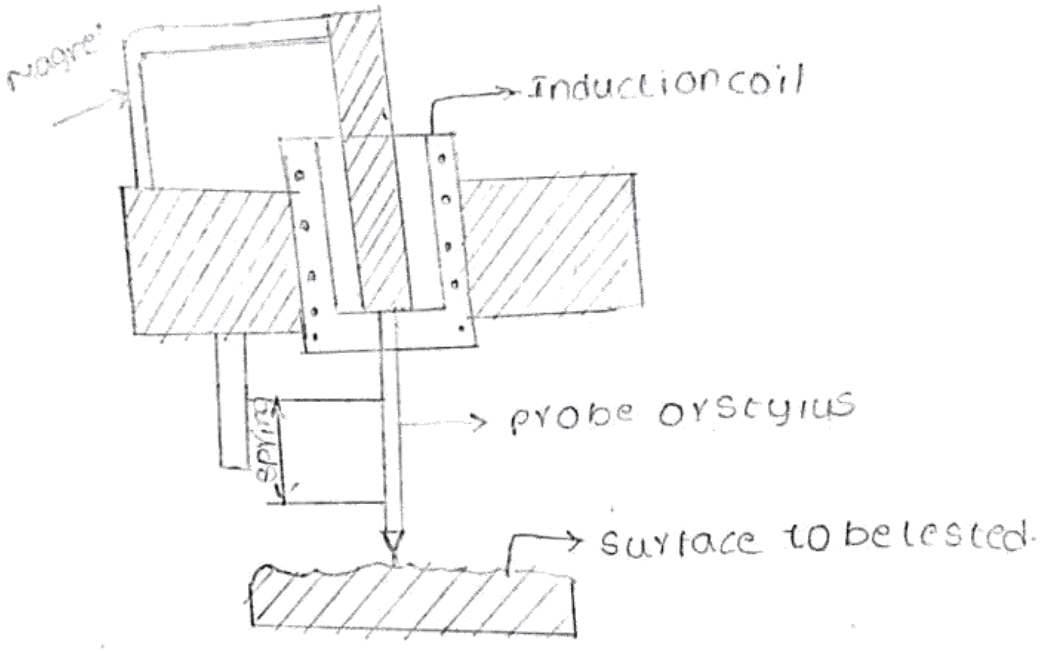
inspected. The stylus or tracer point has a diamond tip with point radius of 12 microns is suspended on flat spring

The vibration is transmitted to the coil in the magnetic field and the induced current is amplified & measured with a galavonometer

It is the surface a steady reading will be obtained but if it is not average variations may be estimated from the meter fluctuations.



Roughness measurement using Tomlinson Talysurf:

As the name implies, this instrument was designed by Dr Tomlinson. In this instrument be used mechanical cum optical means for maginification. The working principle is shown in figure.

This instrument consists of stylus with a diamond probe on the surface finish recorder & is held by spring pressure against the surface of a lapped steel cylinder This stylus also is attached to the body of the

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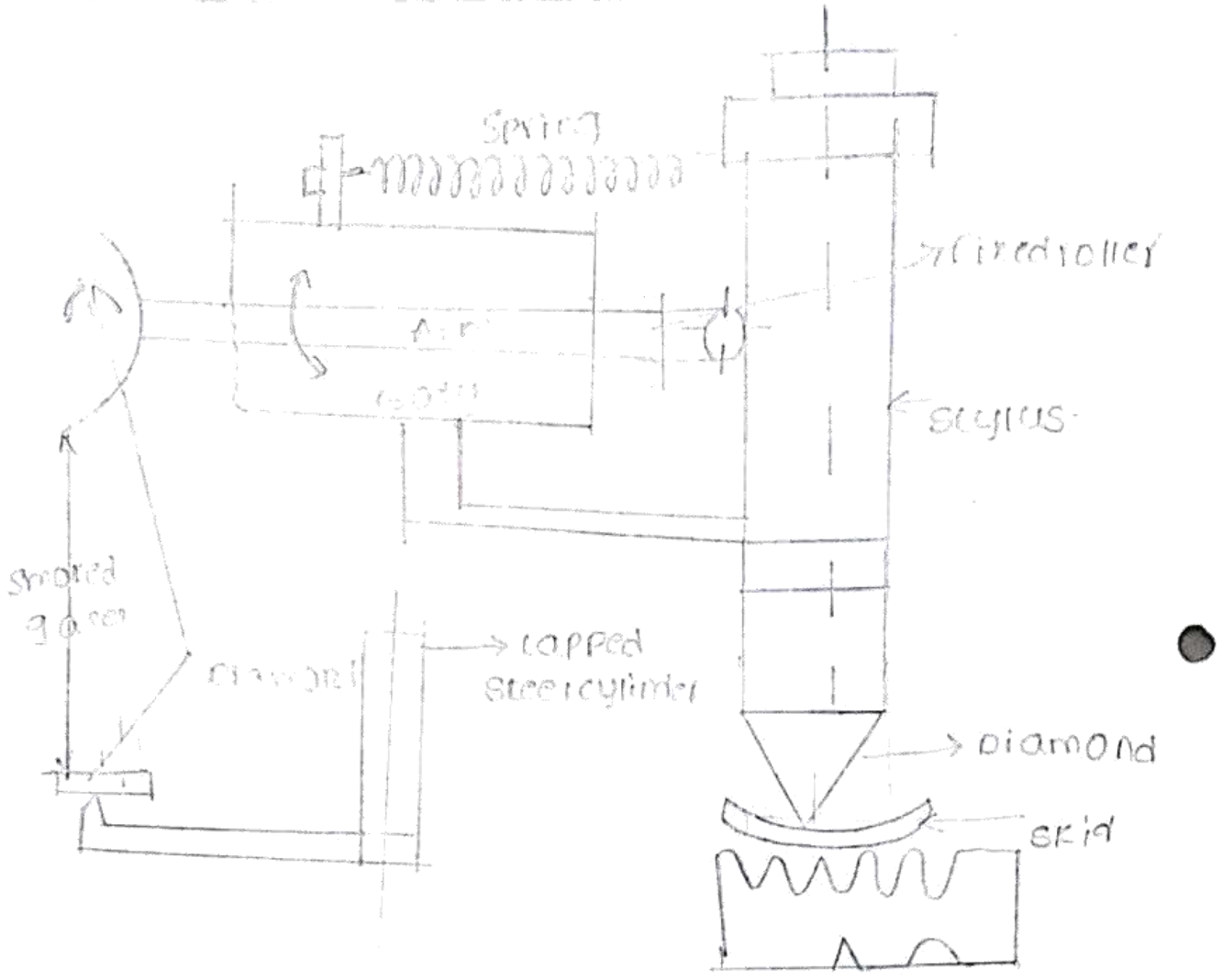

body of the instrument by a leaf spring There is a lapped steel cylinder in b/w the stylus & the two fixed rollers

As it used to measure surface finish, the body of the instrument is moved across the surface with the help of synchronous motor. The vertical motion of the stylus cause the horizontal lapped steel cylinder to roll, as one of its end is attached to the stylus. Due to rolling, the light arm attached to its end also provides a magnified movement & produce a trace on the smoked glass plate as shown in figure finally the smoked glass trace is further projected at x50 or x100 magnification for examination with the help of optical projector.

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Advantages of stylus probe type instruments:

- for measuring surface finish of deepbores
- profilometer is used for direct measurement of surface quality.
- profilometer is a dynamic instrument.
- profilometer records the average height of surface roughness.
- The tomlinson surface meter an economical instrument
- The Taylor-Hobson Talysurf gives information much rapidly & accurately

* Disadvantages of stylus probe type instrument:

- Initial cost of the stylus probe is high.
- This instrument is massive.
- The instrument is relatively undurable.
- Measurement of surface waviness is confined.
- In order to operate the stylus probe instrument, skilled operators are required.

Tomlinson surface recorder:

Merits:

- The tomilson recorder is economical
- simple & rapid reproduction.
- The results of this instrument give accuracy.
- copies can be made on to graph paper, the computation of the areas which are needed for the determination of index members.

Merits of Talysurf machine:

- The response of Taylor-Hobson Talysurf machine is more rapid & more accurate.

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* From the talysurf trace, waviness of surface texture, quantitative estimates of maximum roughness can be easily evaluated.

ISI symbols for indication of surface finish.

The surface roughness is represented in figure. If the matching method is milling, sampling length is 2.5mm direction of lay ⊥ to the surface, machining allowance in 3mm representative will be shown in figure.

Represen tation of surface roughness

$Ra^{8.0}_{16.0}$ $Ra^{8.0-16.0}$

The surface roughness & sample length is represented as

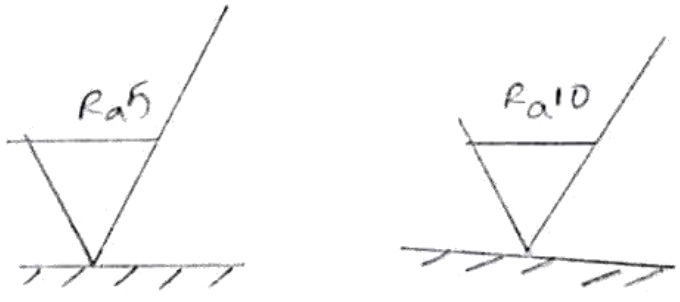
Ra 8.0 (2.5)

Sampling length = 25mm

The surface roughness & lay can be stated as

Ra 1.6 Lay circular.

In most cases, one single piece of information is sufficient which is indicated as follows



The I.S.O has recommended as series of preffered roughness values & corresponding roughness grade numbers be used when specifying surface roughness on drawings.

The roughness symbol indicated followed in the industry.

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Comparators

Comparator :

It is used to compare dimensions of parts with working standards. it does not measure the actual dimension but indicates how much the size of the part differs from the working standards. The readings are magnified by suitable arrangement. measurements can be done rapidly and accurately, so it is suitable in mass production. Comparators are used to check dimensions as well as geometric forms. There are no chances of errors due to incorrect contact pressure or deformation of workpiece.

Classification of Comparators :-

Comparator is a device which works on relative measurement. it compares the unknown dimensions of a part with standard setting. which gives basic size and dimensional variations. The Comparators are classified as follows :

1. Mechanical Comparators
2. mechanical - optical Comparators
3. Electrical and electronic Comparators
4. Pneumatic Comparators
5. fluid displacement comparators
6. projection Comparators
7. multi- check Comparators
8. Automatic gauging Comparators

Uses of comparators :-

Comparators are used in the following ways,

1. When selective assembly of production parts is required, Comparators are used as final inspection gauges.
2. They are used in mass production which involves Quick check-ing of the components at very high speed.
3. The gauges which are newly purchased are inspected by the use of the Comparators.
4. They are used as labaratory standards and with the aid of these standards the inspection and operation of the gauges are specified.

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5. when the comparators are attached to different machines, they can be used as working gauges which can prevent the work damage and can maintain the requirement of tolerances in every significant stage in manufacturing.
6. They are used in selective assembly of parts which involves grading of parts into three or more groups based on their tolerances.

Essential Characteristics of Good Comparator:

i. The instrument must be of robust design and constructed so as to withstand the effect of ordinary usage without impairing its measuring accuracy.
ii. The indicating devices, must be such that readings are obtained in least possible time and for this, magnification system used should be such that the readings are accurate. The system should be free from backlash, wear effects and the inertial should be minimum possible.
iii. provision must be made for maximum compensation for temperature effects.
iv. The scale must be linear and must have straight line characteristic.
v. Indicator should be constant in its return to zero
vi. Instrument must have the maximum versatility, i.e., the design must be such that it can be used for a wide range of operations.
vii. measuring pressure should be low and constant.

In general, mechanical comparators are limited to the lower magnification, pneumatic comparators are the most accurate type in their operation

Types of mechanical comparators :-

The various types of mechanical comparators are listed below.

1. Dial indicator
2. Read type mechanical Comparator
3. Johasson mikrolcator
4. Sigma comparator

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Types of optical comparators:

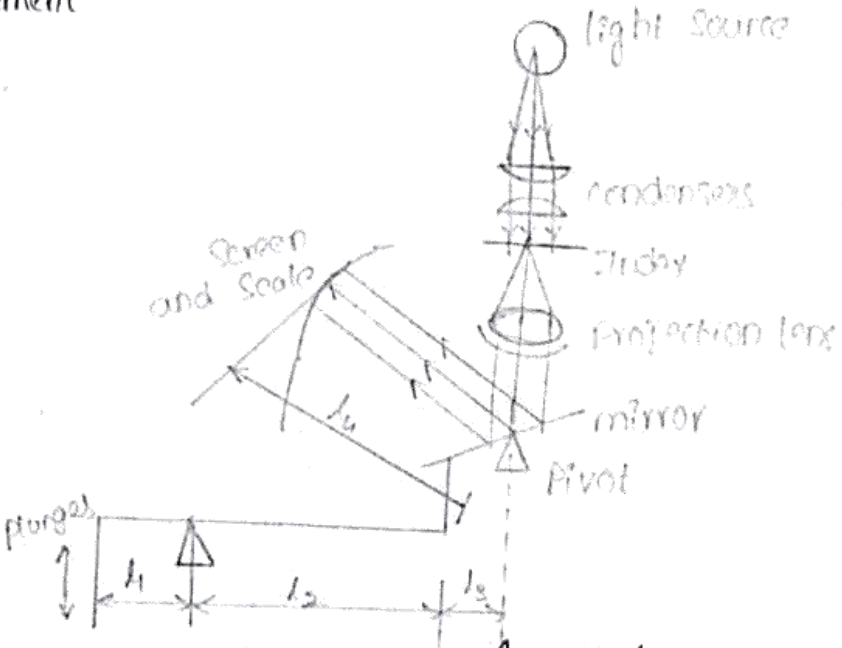
The various types of optical comparators are listed below:

i. Zeiss ultra-optimeter
ii. Zeiss optotest comparator
iii. Newall OMS horizontal optimeter
iv. Eden-Rolt millionth comparator.

Mechanical optical comparator:

In these instruments, small displacements of the measuring plunger are amplified initially by a mechanical system consisting of pivoted levers, followed by a further amplification by a sample optical system involving the projection of an image.

The mechanical system causes a plane reflector (mirror) to tilt about an axis and the image of an index is then projected to a position relative on a scale, and on the inner face of a ground-glass screen. This arrangement is shown in figure:



Principle of optical Comparator

At first the light source passes through the condenser and falls on the index and then through the projection lens it falls on the mirror or plane reflector. Due to the presence of mechanical system, the axis is tilted and the image of the index is projected on the scale of

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a Screen.

Therefore, in such system,

mechanical amplification $= \frac{l_2}{l_1}$

optical amplification $= 2\alpha \times \frac{l_4}{l_3}$

[$\because$ Image is tilted by 2α]

Total magnification is the product of mechanical amplification to the optical amplification

$$= 2 \times \frac{l_2}{l_1} \times \frac{l_4}{l_3}$$

Sigma Comparator :-

Another mechanical comparator of a ingenious yet simple design is that produced in a range of magnification by the "Sigma instrument Company".

The movement is shown in diagrammatic from in the following figure. it most be emphasized that this is a diagram explaining the principles and that the actual movement is much more compact than this.

The plunger is mounted on a pair of slit diagphragms to give a friction less linear moment. a knife edge is mounted on it and bears upon the face of the moving member of a cross-strip-hing. this consists of the moving component and a fixed member, connected by thin flexible strips alternately at right angles to each other. If an external force is applied to the moving member, it will pivot, has wood a hing, about the line of intersection of the strips.

To the moving member, an arm which divides into a "Y". from is attached. If the effective length of this arm is 'L' and the distance from the hing pivot. to the knife edge is x. then the first stage of the magnification is $\frac{l}{x}$.

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To the extremities of the Y arm a phosphor-bronze strip which is passed through around a drum of radius 'r' attached to the pointer or spindle. if the length of the pointer is R then the second stage of magnification is $\frac{R}{r}$ and the total magnification is,

$$= \frac{L}{x} \times \frac{R}{r}$$

The magnification can be adjusted if the distance x is changed by slackening and tightening to the screws attaching the knife edge to the plunger.

The important features of this instrument are as follows

1. Safety:

Since, the knife edge moves away from the moving member of the hinge and is followed by it. therefore, if a robust plunger moment is made, the knife edge moves away from the hinge member and shocks are not transmitted through the movement.

2. Dead beat readings:

The pointer is caused to come to rest, with little or no oscillation by mounting a non-ferrous disc on the pointer spindle and making it to move in the field of a permanent magnet. Thus dead beat readings are obtained. Rotational movement of pointer and disc in the magnetic field causes eddy currents to be set up in the disc, which have a turning effect in opposition to the direction of motion and proportional to the rotational velocity. Thus oscillations are damped out by a damping force which increases with the amplitude and velocity of the oscillation

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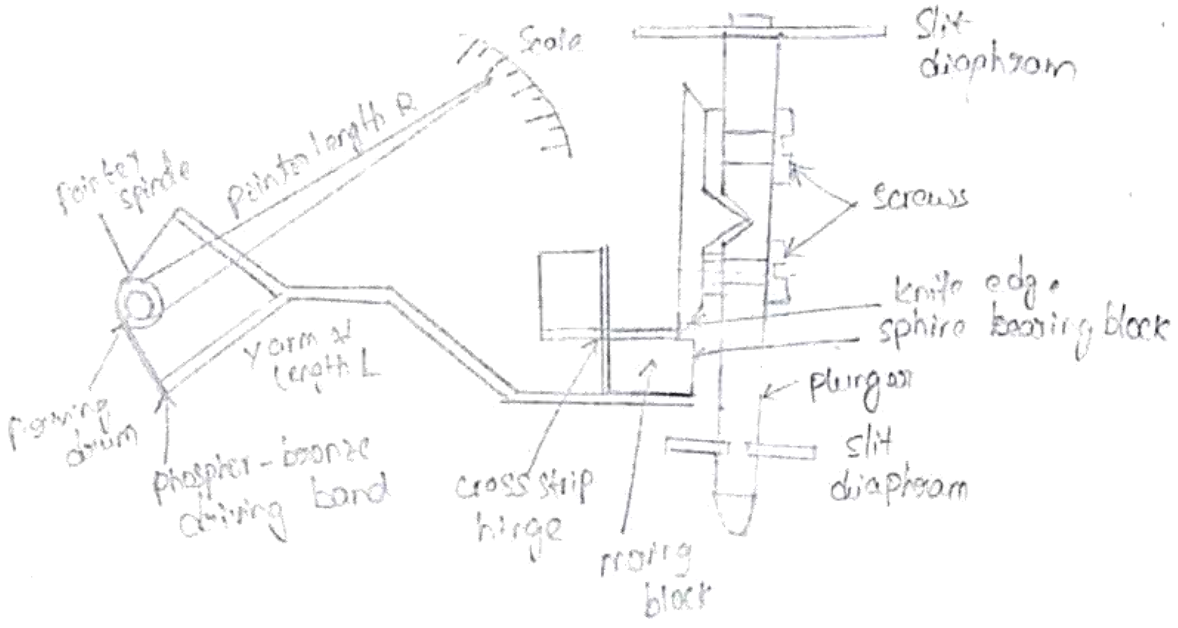

3. Fine Adjustment :

The normal height adjustment of the work stage to put the pointer to zero, is too coarse for a high magnification of an instrument, and is unsuitable for this purpose. To overcome this, the dial of the sigma instrument is mounted so that it rotates about the spindle axis. Thus, final setting of the pointer is achieved by moving the scale, rather than the work, and in this case the instrument magnification helps rather than hinders.

4. Parallax :

This common cause of erroneously reading dial type instruments is overcome by having a reflective strip on the scale. The ~~constant~~ line between the eye and pointer is only normal to the scale when the pointer obscures its own image in the silvered part of the dial.

5. Constant measuring pressure :

A feature not shown in the simplified diagram is the use of a magnet to enable the plunger contact pressure to constant over the range of the instrument. In any instrument of this type, the greater the deflection of the movement, the greater will be the displacement fore required, and thus the measuring pressure. The adverse effect is compensated mounting a horse shoe magnet on the frame and a keeper bar on the top of the plunger.

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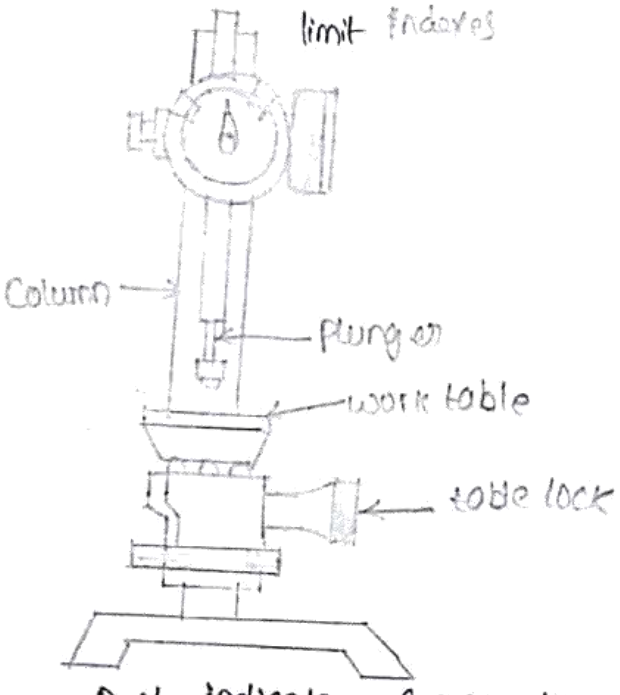
Dial gauge as a comparator: (94)

It consists of a rigid column with provision for vertical adjustment and a small accurate reference plane or work table with provision for fine adjustment. it is simple and is idel for checking components within a tolerance of ±0.05 mm. Each division on the dial of the dial indicator represents 0.02 mm movement of the plunger. with the advantage of adjustable limit indexes, it can be used as a visual gauging device. with the limit indexes set to the maximum and minimum tolerance limits, if the pointer records outside the limit indexes, the component is rejected. Else, the component is well within the limits. The inspection can be done effectively even by unskilled operators.



Dail indicator Comparator

Working principle of Eden - Rolt Millionth Comparator:-

The eden - Rolt Millionth comparator is a mechanical cum optical comparator. it is suitable for high magnification and calibration of gauges.

The working principle is considered to be two separate magnification systems. They are.

1. Mechanical System
2. optical System.

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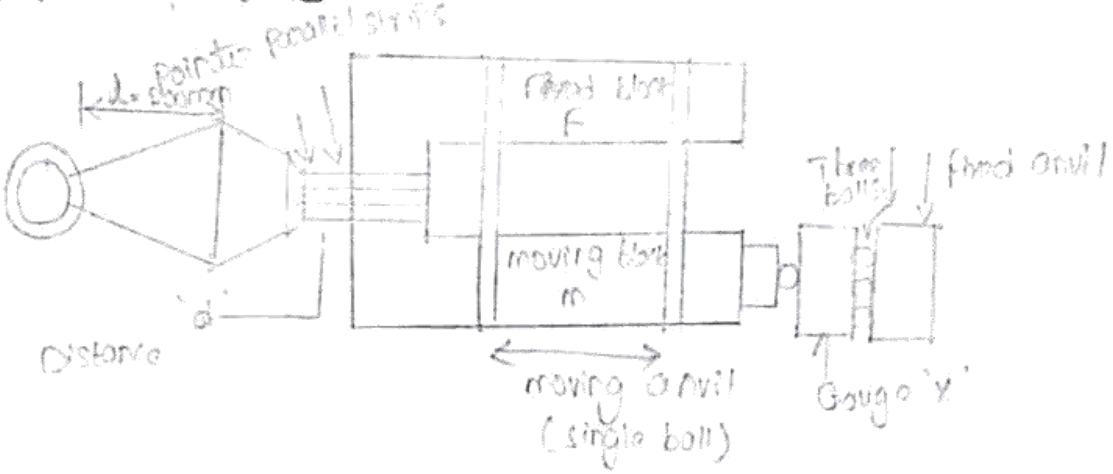
1. mechanical System :-

The reference gauge "x" is kept between the fixed anvil and the moving anvil of the moving block "m". This block "m" moves little relative to the block 'F' o/ parallel strip support. The blocks are connected by thin steel strips and to a pointer carrying at its other end, a ring across which it streches a spider web. The moving block 'm' causes a deflection of the pointer, whose length is about 20cm. The pointer movement is magnified about 400 times at the web.



2. optical System :

The spider web at the end of the pointer is not viewed directly, but as an image moving relative to a scale in the optical system, which is a projection system, which is a projection system, in which a light beam terminates in a ring a/c, a thin stand mounted. The optical magnification is generally, x50

Hence, the total magnification at scale = 400 x 50 = 20,000

magnification Calculations :-

Let δ = Linear displacement of moving block "m".

$\therefore$ Angular displacement = $\frac{\delta}{d}$ radians

where : d = distance between parallel strips

Linear displacement of web = $\frac{\delta}{d} \times L$

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bench. The work can be brought to the instrument, or vice versa.
7. multiple dameters may be checked at the same time.
8. pneumatic gauges are easier to use than mechanical gages
9. Holes may be inspected for out-of-roundness, parallelism, Concentricity, and other Surface irregularities.
10. Gauging heads and pads are self-cleaning.

Disadvantages of pneumatic comparator:

1. it requires elaborate auxiliary equipment such as accurate Pressure regulator.
2. The scale is generally not uniform
3. when indicating device is the glass tube, then high magnification is necessary in order to avoid the meniscus errors.
4. The apparatus is not easily portable and is rather elaborate for many industrial applications.
5. Different gauging heads are required for different dimensions.

1. A level comparator has axial radius of 200 m, divisions 2.5 mm apart and contact feet at 10 mm center distance. Calculate the difference in length of two gauges under comparison if the total bubble displacement is 5 divisions.

Answer:

Given that

Radius $R = 200m$, $R = 200 \times 1000$, $R = 200,000 mm$

$d = 5$ divisions, $d = 5 \times 10 mm$, $d = 50 mm$

In a level comparator, one-half of the difference between the readings or the displacement is equal to the difference in the length between the gauges.

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$\frac{1}{2}d = \frac{1}{2} \times 50 = 25mm$

If 'h' is the difference between the gauge lengths. Then

$$\frac{h}{2.5} = \frac{25}{200,000}$$

$$h \times 200000 = 25 \times 2.5 \Rightarrow h \times 200000 = 62.5$$

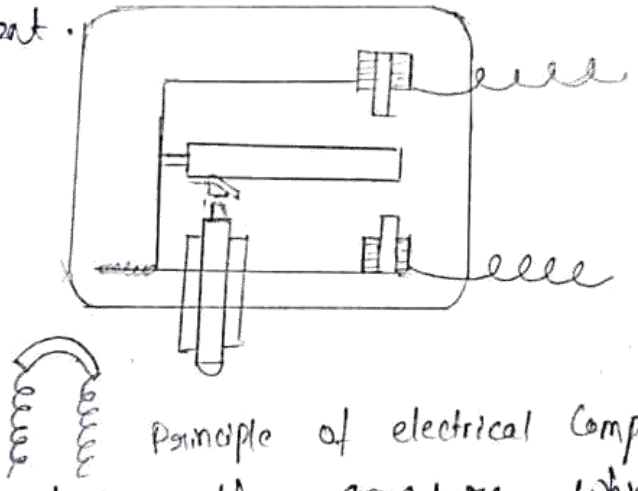
$$h = \frac{62.5}{200000}$$

$$h = 0.000312 5 mm$$

Electrical and electronic comparator :-

Electrical Comparator :.

The principle of operation of electrical comparators depends upon the operation on an ac. wheatstone bridge circuit with an galavanometer. In this type of comparator, electrical signals are generated due to moment of the measuring contact. the generated electrical signals are recorded in calibrated in types of plunger moved by the instrument.



Principle of electrical Comparator

coil A and B holes the armature which is supported on thin steel strips. The gap between the coils and armature is equal when the gap maintained between the armature and coils are equall the wheatstone bridge is balanced and current does not flow through its galvanometer. Any moment in the plunger, to the right or left unbalances the bridge which results in the flow of current through the galvanometer. The scale of the galvanometer is calibrated, which

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gives moments to the plunger. High degree of reliability is possible in electrical comparators, because of less moving parts. High order of magnification is possible with this type of comparator

Mechanical comparator	Electrical comparator
1. It consists of high no. of movable parts therefore the rate of wear and friction is high	1. It consists of very less no. of movable parts, so the friction, wear is low
2. Accuracy of these comparators is low	2. Accuracy of these comparators is high
3. These comparators are independent of external power supply	3. These comparators are dependent on the external power supply
4. Variations in the power supply does not effect the accuracy of the readings	4. Fluctuations in the frequency of the electric power supply effects the accuracy of measurement
5. These comparators are movable and are in cheap	5. These comparators cannot be carried easily. as they require electric supply and are very expensive
6. Sensitivity of instrument the vibrations is caused by the inertia of the movable parts	6. These are not sensitive to vibrations as the mechanism which carries the pointers are very light
7. Range of these instrument is very low	7. These comparators passes very high range of magnification.

Comparator :-

Industrially, pneumatic comparators, in which small variations are made in the dimension being measured with respect to a reference dimensions and which are shown by a variation in either air pressure or velocity of air flow, are becoming of increasing importance

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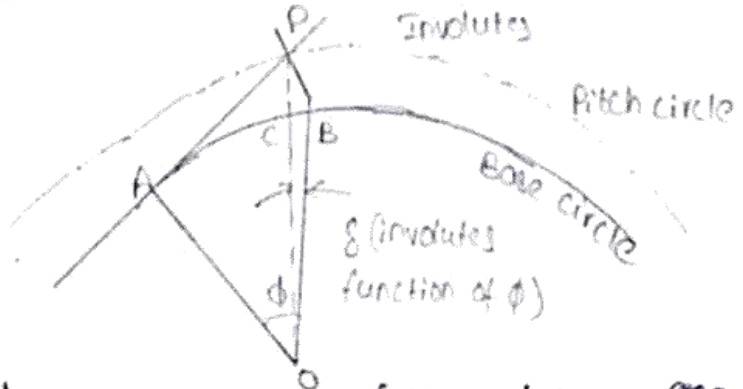
The reasons for this are that very high amplifications are possible, no physical contact is made either with the setting gauge or the part being measured and the internal dimensions may be radially measured, not only with respect to tolerance boundaries, but also geometric form. Further, the system lends to the inspection of a single or a number of dimensions simultaneously, either during the operating cycle of a machine tool. Therefore, the pneumatic magnification is proportional to the area, or the square of the diameter of the control orifice.

The air from its normal source of supply, say the factory air line, is filtered, and passes through a flow value. its pressure is then reduced and maintained at a constant value by a dip tube into a water chamber, the pressure value being determined by the head of the water. the air at reduced pressure then passes through the control orifice, and escapes from the measuring orifice. The tube is graduated linearly to show changes of pressure resulting from changes in dimension d. figure (1) amplifications of upto 50,000 are obtainable with this system



Another back-pressure comparators are made by Produced by mercer Air Gauges Ltd., but this operates at the much higher pressure of 27.5 N/cm² gauge. The constant pressure input is produced from the line pressure by a diaphram type regulator and passed to control orifice and then-

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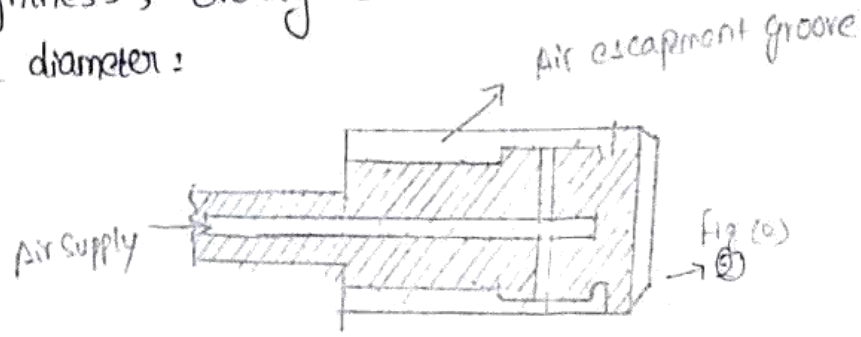
b. For either internal or external limit gauging :-

The pneumatic comparators are widely being employed for the internal and external limit gauging. They are used for measurement of diameters, lobing, taper, straightness, ovality etc...

Single diameter :



Two equal and opposite jets are incorporated as shown in figure (a). The cylindrical plug gauge form is adopted which ensures constant air flow inside regardless of the gauge position inside the bore. A reduction of flow in one jet is compensated by increased flow in the other. usage of twin nozzles reduces the magnification and in order to restore magnification, average Separation is halved.

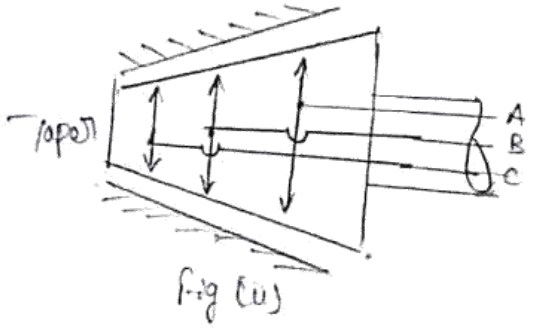
Lobing :-

The varying positions of the plug and the bore are shown in fig (3). will result in high and low scale readings



Taper :-

Three pairs of jet incorporated to ensure straightness of the taper and its diameter as shown in fig (4)



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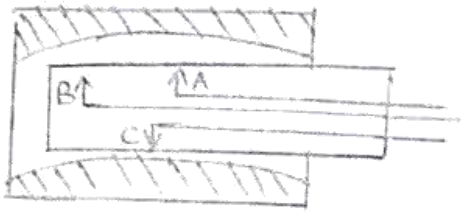
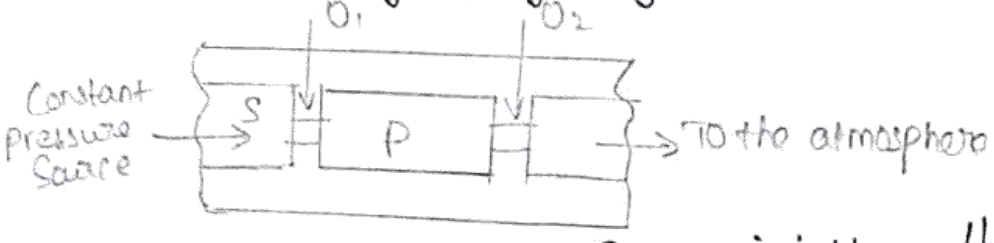
Straightness:

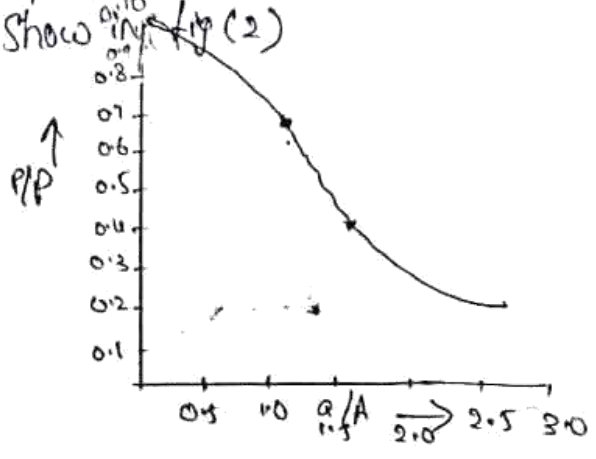
Three jets are arranged in parallel such that flow in two pipes remains equal and flow in third jet is sum of the flow in first two pipes as shown in fig (5). This results in high and low readings which result from relative plug and bore rotation.



Principle of pneumatic gauging by back pressure system:



Air from Constant pressure Source 'S' flows through the two orifice O_1 and O_2 to the atmosphere. Let p be upstream pressure of orifice O_1 and p' is the pressure between two orifices both measured with reference to atmospheric pressure as datum. The relationship between p and p' will depend on relative sizes of the two orifices as shown in fig (1). When O_2 is blocked, the p' will be equal to p and it tends to zero when size of O_2 is increased indefinitely. Let A be the geometric area of O_1 and a of O_2. If p and A are kept Constant, while a is varied, the relationship between dimensionless Quantities (p'/p) and (a/A) as shown in fig (2)



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The relation ship between the above dimensionless quantities is given by $\frac{p}{P} = R - b\left(\frac{a}{A}\right)$ (99)

where $R = 1.10$

b = Slope of straight portion

The characteristics of p/P and a/A are determined experimentally for pressures P varying from 0.13 to 0.5 kg/cm² and inspection of any one of these p's shows that within the range of 0.6p/P to 0.8p/P, the curve approximates to a straight line.

Working principle of Solex pneumatic gauges:

Industrially. Pneumatic comparators, in which small variations are made in the dimensions begin measured wrt to reference dimension and which are shown by variation.

The reasons for this are that very high amplifications are possible, no physical contact is made either with the setting gauge or the part being measured and the internal dimensions may be readily measured, not only with respect to tolerance boundaries, but also geometric form. further, the system leads to the inspection of a single or a number of dimensions simultaneously, either during or immediately after the operating cycle of a machine tool.

Solex pneumatic comparator is used for the inspection of bores. Vertical metal cylinder contains water to a prescribed level, a tube, attaching to an upper chamber, reaches nearly to the bottom of the cylinder, and air from the air line at about 140 KN/m² pressure is fed to the upper chamber. A restricting jet leads from this chamber to a second which also has an outlet to a glass manometer tube placed outside the cylinder. The second chamber is fixed to the flexible tube. The

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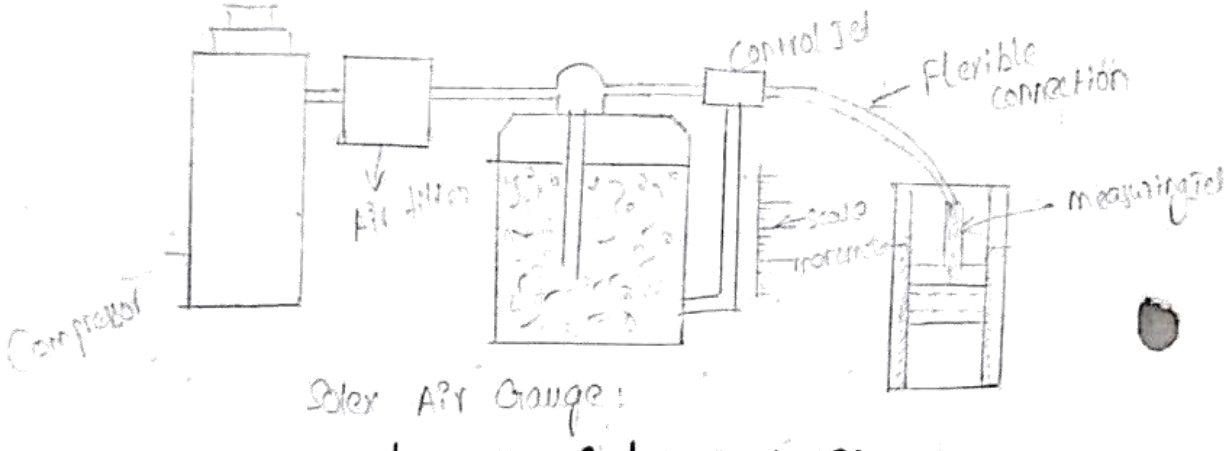
Pressure in the first chamber behind the control jet is kept constant and equal to the head of water forced down the vertical tube, excess air bubbling out from the bottom of the tube and escaping freely. The jets on the gauging plug are so proportioned, relative to the control jet, that partial closures of these jets cause various pressures in the second chamber. This causes to vary the height of water in the manometer tube, a calibrated scale being set beside the tube. In other words, the pressure in the second chamber changes with the relative rates of escape of air through the first jet and plug jets. The scale set by the side of manometer is calibrated in such a way that clearance between the plug (a) and the bore can directly be read on the scale simply by noting the water level in the manometer tube



Solex Air Gauge:

Measuring heads are basically categorized as,

1. Direct head and
2. Indirect head

Tapered nose type direct head is quite popular as it permits easy access in constricted measuring conditions. The ratio of land diameter compared to jet diameter is twice in size, bigger ratio would effect the escapement of air and the characteristics of the system.

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