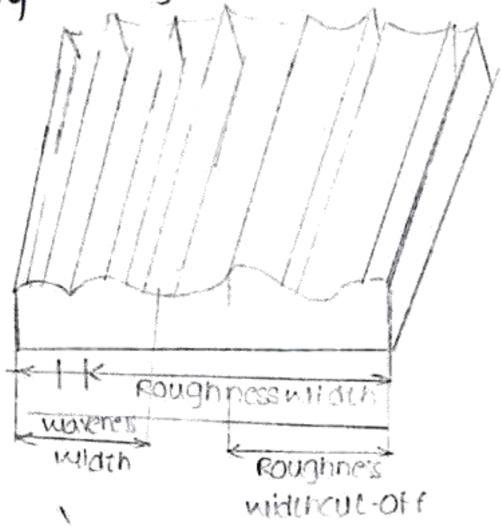
Unit-IV Surface Roughness Measurement (1)

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:

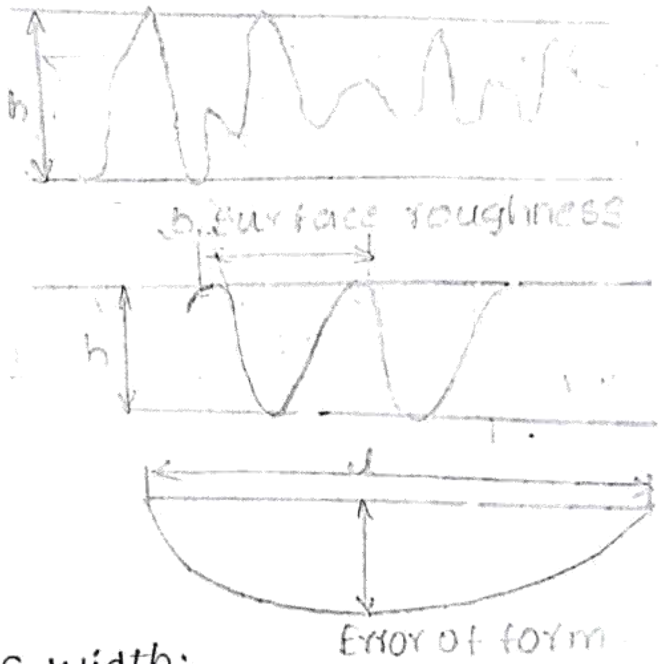
It is defined as the newly obtained or actually obtained surface after a manufacturing process. Normal surface is the geomentrically perfect surface which does not exists but is an average of the irregularities measured on the surface.

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 divis deviation expressed in micro inches or micrometer normal to an imaginary centre line. passing through the 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 cutt off (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-geomentrical irregularities
* Roughness is reffred as primary texture
* It is genarally produced by the action of cutting tool.

* 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 n 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

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 l/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.

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 roughness works efficiently than smooth surface finish.

controlling the surface finish:

following are the impotant reasons for controlling the surface finish.

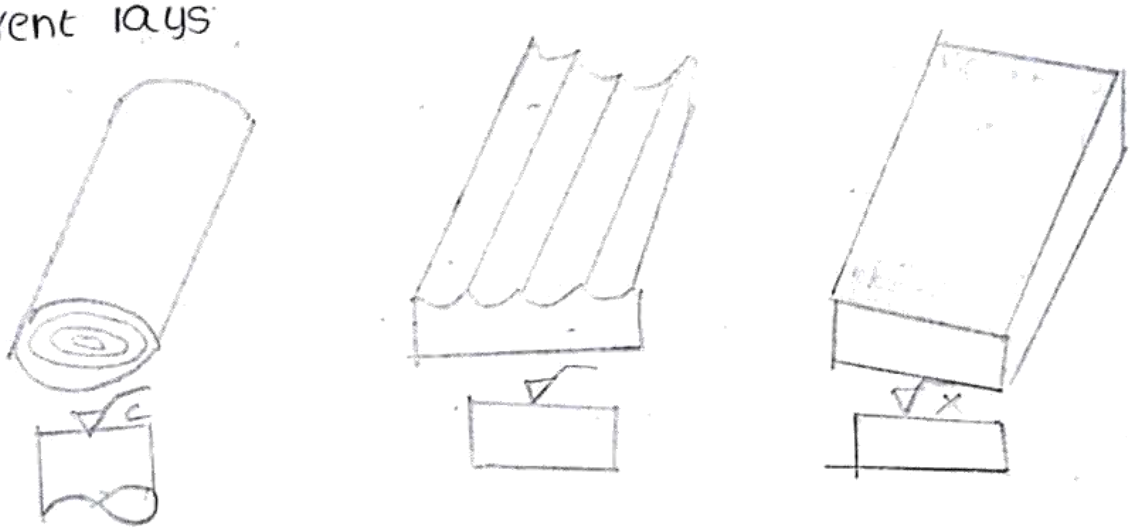
* To minimize the frictional wear.
* For improving the service life of components
* minimising corrosion through reduction in depth of irregularities
* for improve a fatigue resistance
* To have a pleasing apperance
* For having a close dimensional tolerance.
* Due to excessive roughness, the movable 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 surface roughness.

R: Lay approximately radial relative to the centre of the surface to which the symbol Ex: surface ground 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 workpart surfaces such as casting, hot working, powder metallurgy will produce the component or product with irregularities, which are associated with manfacturing of dies. These irregularities also exists after the completion of machining process on the work part surfaces such as turning, boring, laping, shaping etc...

Factors for affecting surface roughness

- * Type of coolant used
- * Type of machining
- * vibrations
- * Material of the workpiece.
- * 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 measurement of surface finish:

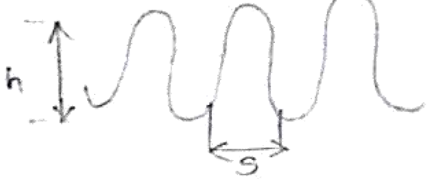
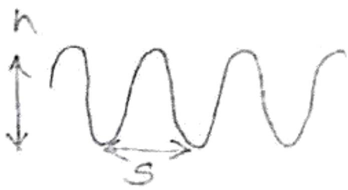
This method enables to determine the numerical value of the surface by using instrument stylus probe type, operating on electrical principles. In these instruments the out put to be implified, which is used to operate reading or recording or indicating instruments. stylus is a fine point made of diamond 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 generate a voltage signal. The out put is then amplified by sutiable means are used to operate a recording or indicating instrument.

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.

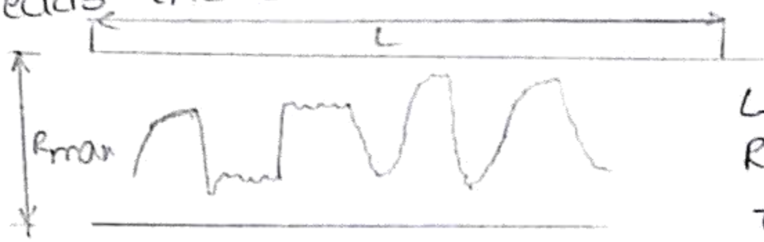
primary texture	secondary texture
1, primary texture or roughness is a type of error	* secondary texture is also type of error resulting due to the geomentrical irregularities of surface.
* Irregularities of small wave length	* Irregularities are of considerable wave length of periodic character.
* It 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-allignment 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

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 observation 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 irregularities 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 
* Also includes 3rd & 4th order irregularities	* Also includes st & 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.

Maximum peak to valley height of roughness:

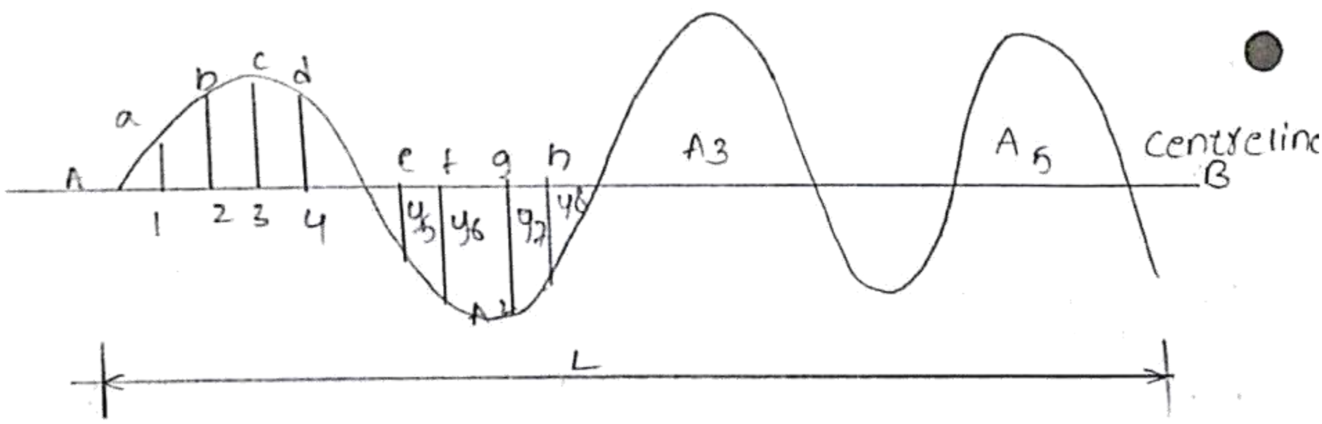
Generally peak to valley height is the separation of highest peak of the irregularity & its lowest valley maximum peak to valley Rmax is defined as the largest single peak to valley height in the five adjoining sample length. This is used to measure the depth of surface roughness. The disadvantage of 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 from a nominal surface value of surface roughness it is expressed in micrometers (μ-m)



In these figure (2) the centre line AB is located such that the sum of the areas above the lines is equal to the areas 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 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.

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

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

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 cordinates

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

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

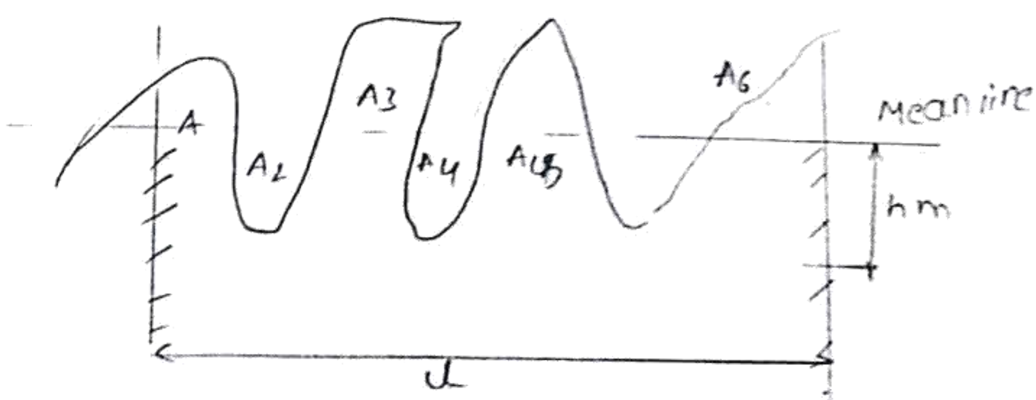
∴ By using planimeter we can find out area of any curve things can be much samplified let us assume that some how the mean line is exactly known then

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

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

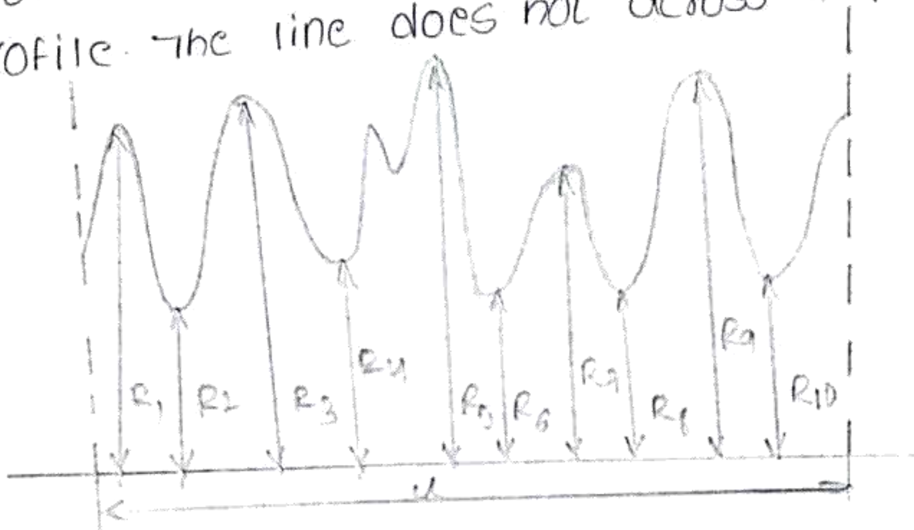
CLA value is determines in microns

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



Ten point height method:

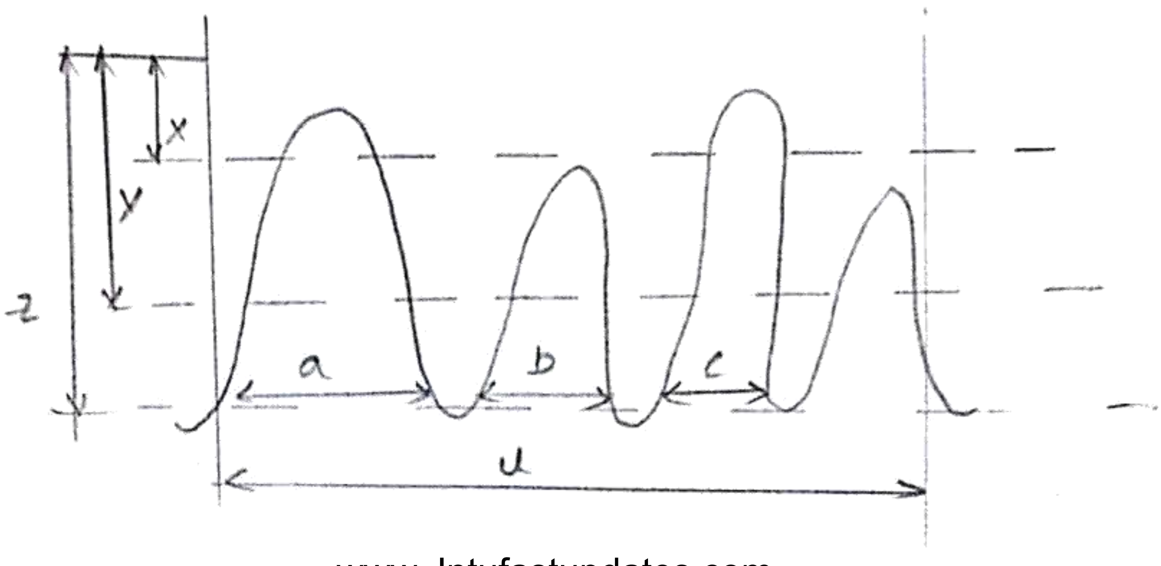
It is the simplest method used to measure the total depth of the surface roughness. This is the average difference b/w the 5 highest peaks & the 5 deepest valleys within sampling length, measured from a line drawn ‖ to the genaral direction of the profile. The line does not across the profile



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



centre line averagemethod (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 measurements wer 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 $= \dfrac{\int_{i=1} h_i}{n}$

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

$= 15.63$ microns

Average peak to valley height (R_z)

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

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

$= 17.2$ microns

iii, R.M.S value

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

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

= 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 overa 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.

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

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 donot specify the openness or closeness of the surface noof 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

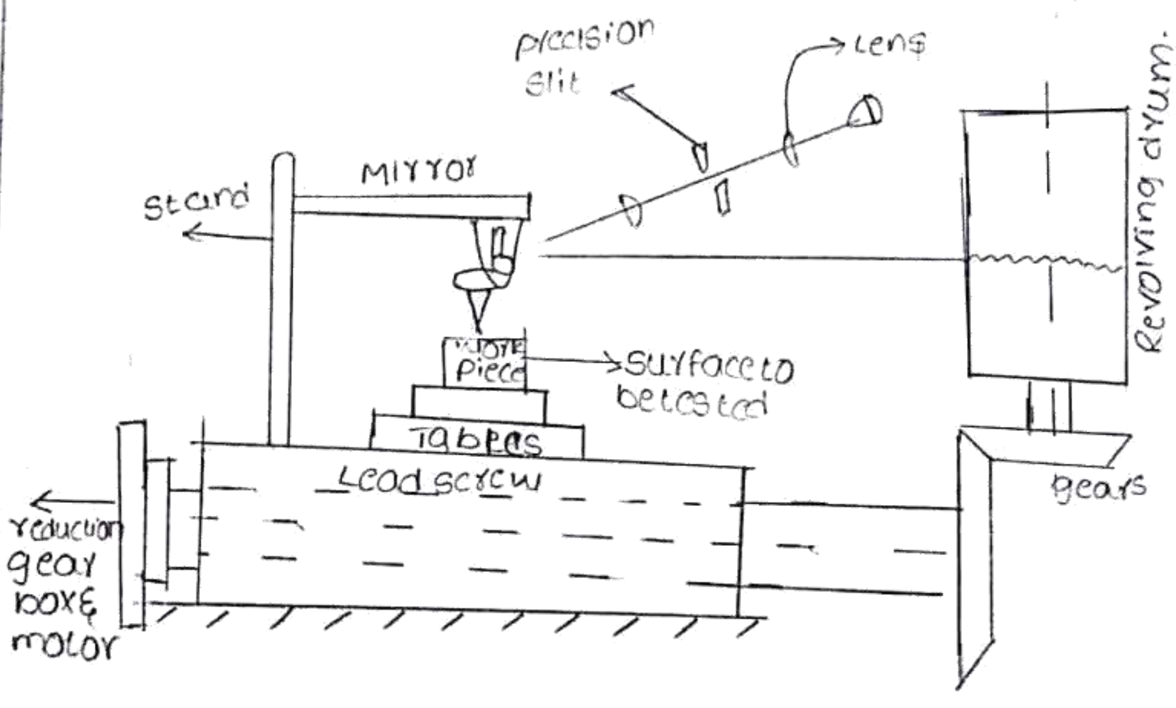


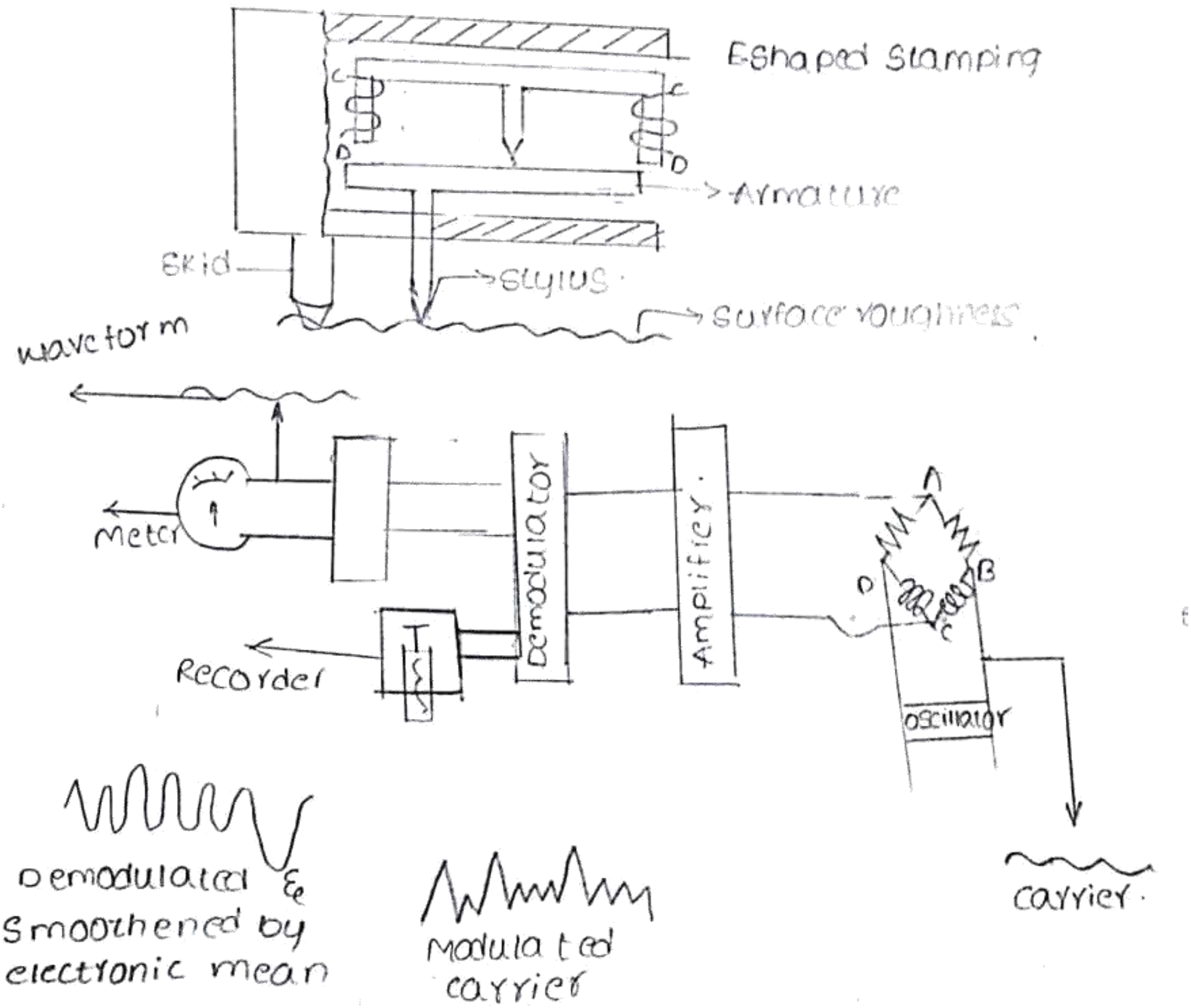
figure shows the schematic diagram & working principle of profilograph. The surface to be tested is placed on the table and can be moved to & from along the axis of the lead screw through the nut & bolt mechanism with the aid of the vector

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 with a sensitive film is arranged. Thus the profilograph 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 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 on 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.



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 maginifications. The record is also strictly rectilinear, instead of distortion of the pen swinging in arc.

Working of profilometer:

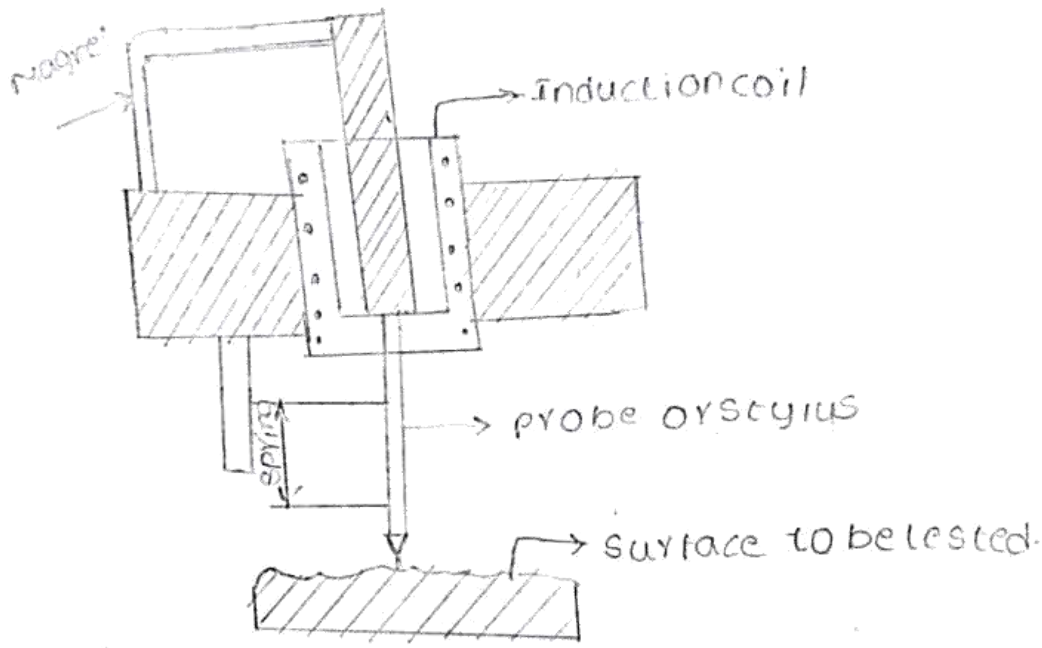
It is also called as abbot profilometer. The instrument is used for indicating & recording the measured roughness values of surfaces, in microns. It is used to check comparsion standards for accuracy & to measure work directly as means of controlling surface finish.

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 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

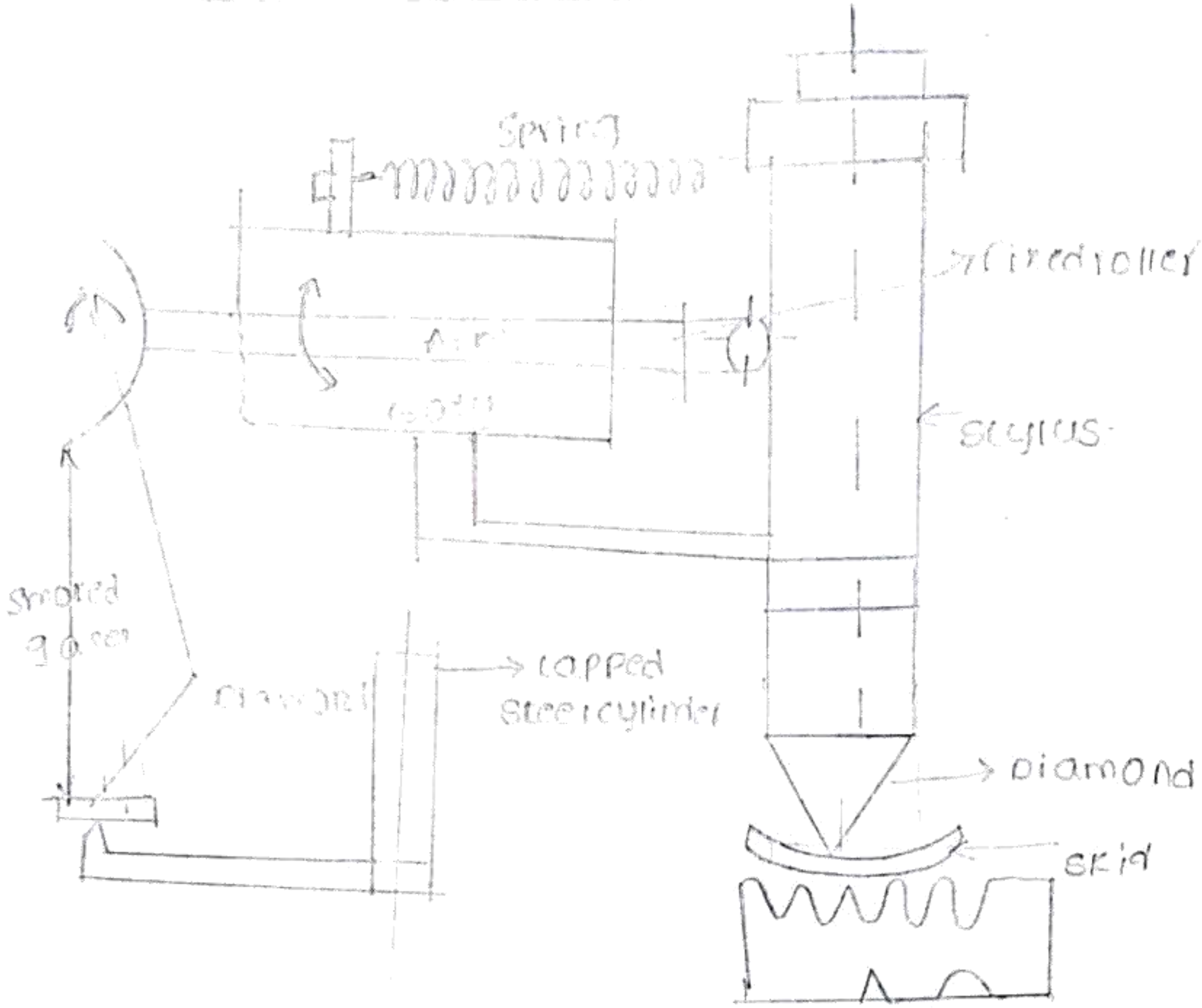
It is the surface a steady reading will be obtained but if it is not average variations may be estimated from the meter fluctuations.



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



body of the instrument by a leaf spring There is 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.

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 - Habson 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.

* From the talysurf trace, wairness 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 2.5m direction of lay ∥ to the surface, machining allowance in 3mm representative will be shown in figure.

Representation of surface roughness

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

The surface roughness & sample length is represented as

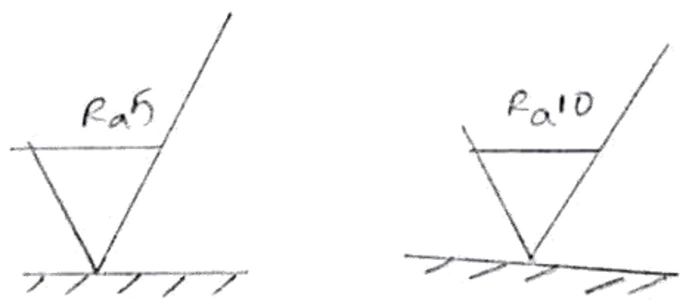
Ra 8.0(2.5)

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



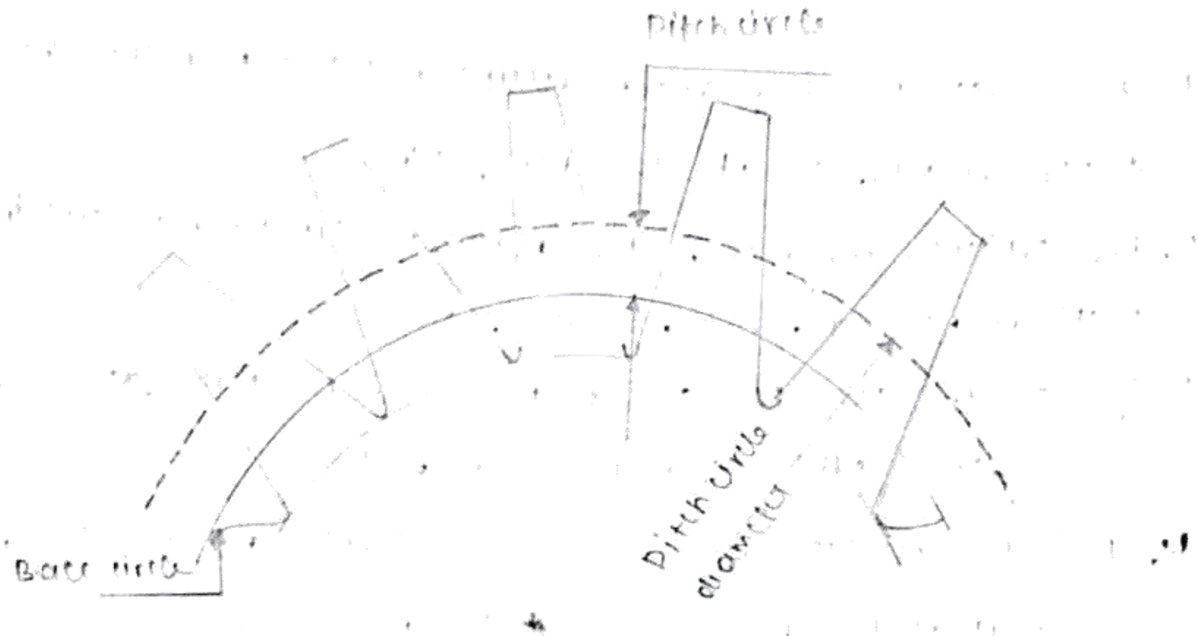
The I.S.O has recommended as series of preferred roughness values & corresponding roughness grade numbers be used when specifying surface roughness on drawings.

The roughness symbol indicated followed in the industry.

Gear Measurement

Base Circle:-

It is the circle, which produced the involute curve of the tooth profile. Generally, base circles are exist only in involute gears of tooth profiles. Base circle is fixed and rigid to the gear compared to other terms related to the gear terminology.



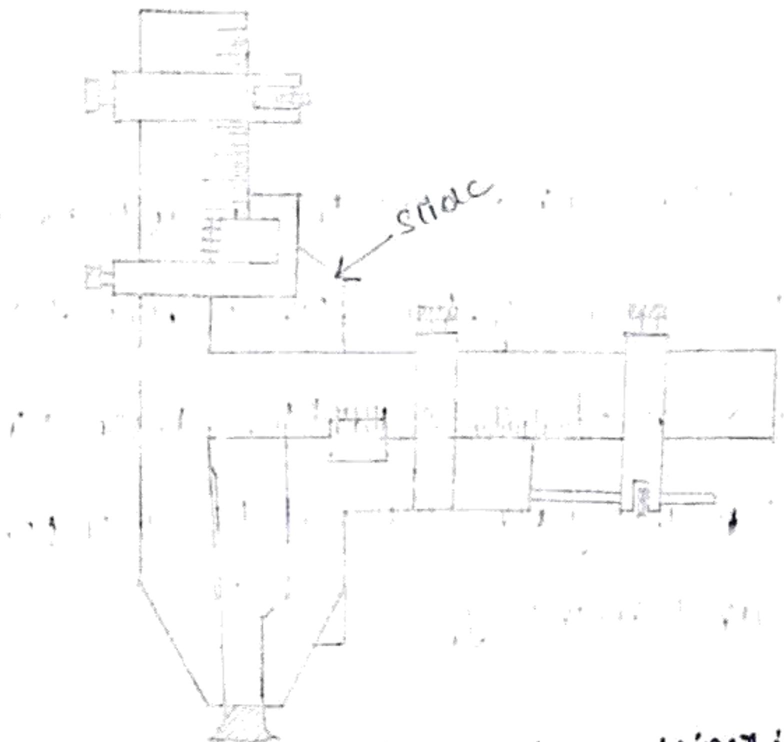
Pitch circle:-

It is the non-existent circle represented by dotted line as shown in figure. It is possible to select unlimited number of pitch circles, each one is related to its own pressure angle

Pitch circle Diameter:-

It is the diameter of circle which is generated by performing pure rolling action and it acts as a toothed gear wheel.

Gear tooth vernier calliper:—



1. A gear tooth vernier calliper is used to measure the tooth thickness at the pitch circle
2. The calliper consists of two perpendicular vernier calliper with a vernier scale on each arm
3. One of the arm is used to measure the thickness of gear teeth and other for measuring depth.
4. Till the calliper touches and slides on the top of the tooth and the lower ends of the caliper jaws touches the slides of the tooth at the pitch circle. the calliper is adjusted..
5. Thus the horizontal vernier scales gives the measurement of chordal thickness 'T' and the vertical gives the chordal addendum of the respective tooth. Finally the measured values are compared with analysis values

Reasons for inspection gear tooth elements:— (101)

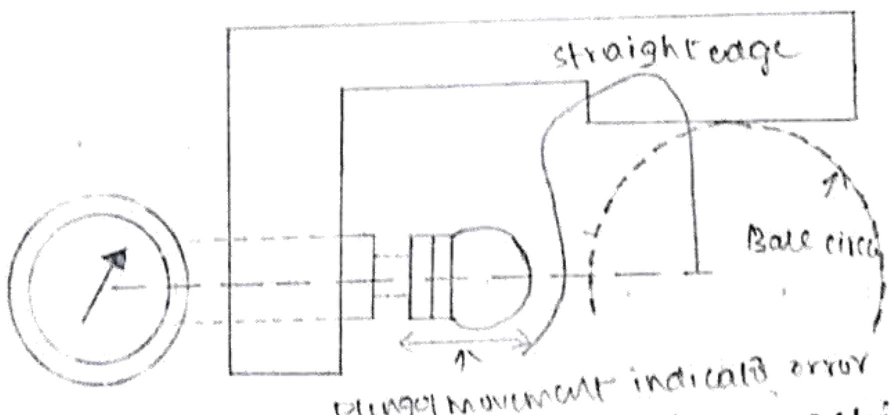
The gear tooth elements are inspected for the purpose of obtaining higher efficiency and better accuracy of gears. Therefore, it is essential to inspect the arrangement of shafts, gears and bearings before use. Better accuracy can be obtained by the precision with which gears are manufactured. Precision has a great effect on smoothness of operation, freedom from noise and life span. Hence, it is necessary to inspect and measure the gears accurately before use

Methods

(i) Optical Projection Method.

This is a very quick method in which the profile of a gear tooth may be checked and projected on a screen by optical means then the magnified profile of the gear is compared against a master diagram or template may be used on thin gears with sharp edges

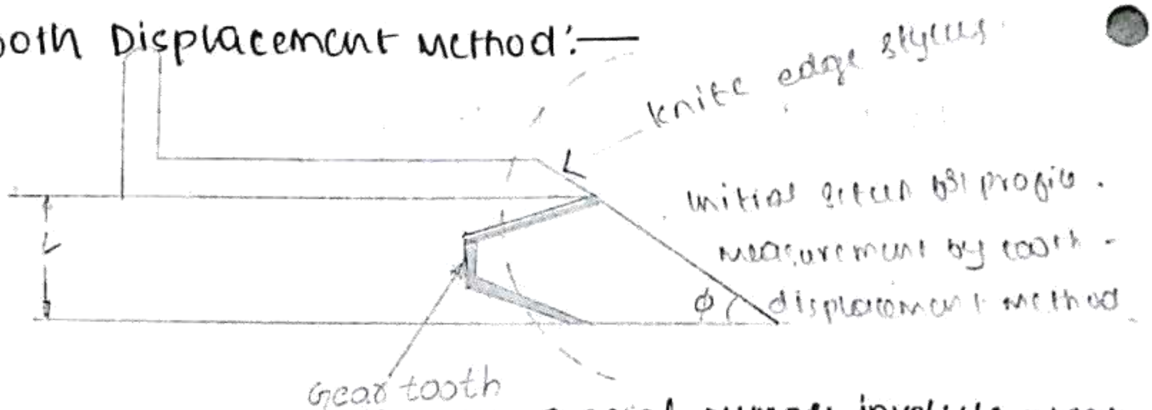
(ii) Using involute measuring machine:—



The principle of involute testing machine is that, if an edge is rolled around a base circle without slipping the stylus of a dial gauge attached to the straight edge would traverse a true involute

In this method, the gear to be tested is held in 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 the tooth profile. When the gear and disc are rotated, the stylus moves over the tooth profile and the deviation from true involute profile are indicated on dial gauge. It's accuracy is up to 0.002 mm.

(iii) Tooth Displacement method:—



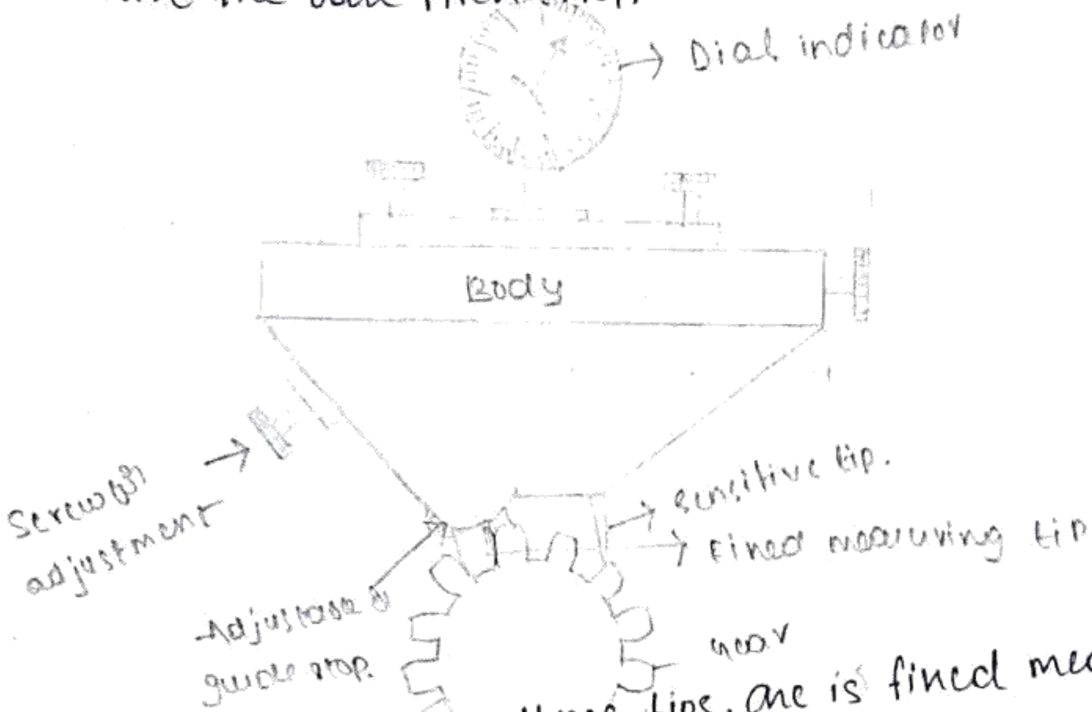
For larger gears and when special purpose involute measuring instrument or equipment is not available, the accuracy of the profile may be determined by using a dividing involved is the knife-edge of the vertical measuring machine stylus should be normal to the axis of measurement. In practice the gear is rotated through small angle increments and the readings of the vertical measurement machine are compared with the theoretically calculated ones.

Base pitch measurement of Gear:—

(i) Step by step Method.

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 arbitrarily chosen datum position.

The portable hand-held instrument is shown below which measure the base pitch error. (102)



This 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 meant to adjust or for guide stop. It is meant for the adjusted by a screw.

The space between the fixed and sensitive tip is 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 contact the tooth profile. The reading on the dial indicator is the error in the base pitch.

-Another method is to be 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 pitch error are present.

(iii) Direct Angular Measurement:-

This is the simplest method for detecting pitch error. In this method dial gauge is set against a tooth and the reading is noted. If gear is not indexed through the angular pitch the reading differs from the original readings. The difference between these, is the cumulative pitch error.

Merits of Parkinson's gear tester:-

1. It detects poor tooth form caused due to worn or inaccurate cutting tool
2. It detects pitch circle eccentricity which results due to inaccurate centering of the gear blank prior to tooth cutting

Demerits Parkinson's gear tester:-

1. In actual practice, both tooth flanks rarely come in contact
2. It does not provide a clear indication of true cumulative pitch error.
3. It tells whether a gear is to be accepted or rejected, but does not help to find detailed causes for rejection.
4. Measurement are directly dependent upon the master gear or reference gear.

- Tooth thickness measurement with gear tooth vernier flange micrometer pitch measurement.

- Reasons for inspecting gear:-

For answer refer unit - VI, Q3, Topic : Reasons for Inspection gear tooth elements.

Gear tooth vernier calliper:-

The tooth thickness of a gear can be measured by using gear tooth vernier calliper. The tooth thickness is generally measured at pitch circle and therefore it is referred to as pitch line thickness of the tooth. This instrument consists of horizontal

(8) This comparator comprise of a fixed anvil. On the side of a moving anvil, there is a micrometer which has a very short movement (10^5) on both sides of the zero setting. With the help of distance pieces or gauges blocks, with the aid of locking ring and setting tube, the distance of fixed anvil is adjusted at a required place.

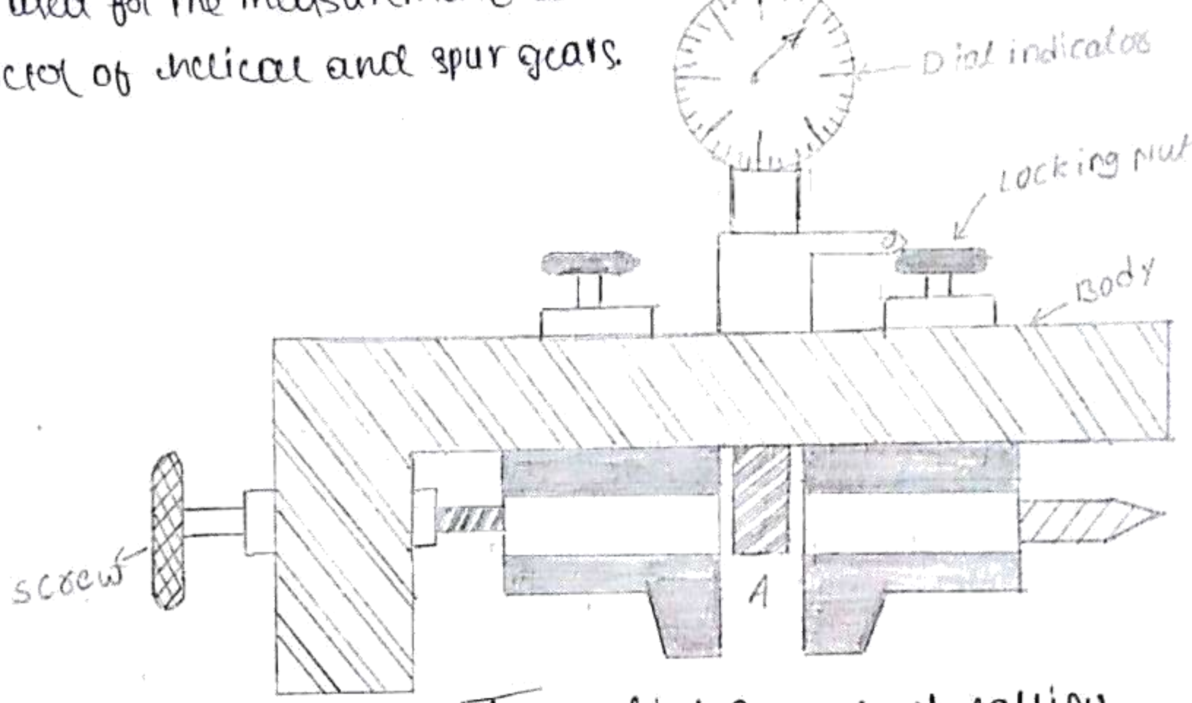
Measure of span of convenient :—

For answer refer unit VI, Topic Base Tangent Method.

Tangential Gear tooth calliper :—

- A tangential gear tooth calliper comprise of a body, measuring tips, locking nuts, screw and dial indicator as shown in fig.

It is used for the measurement can be obtained from the external diameter of helical and spur gears.

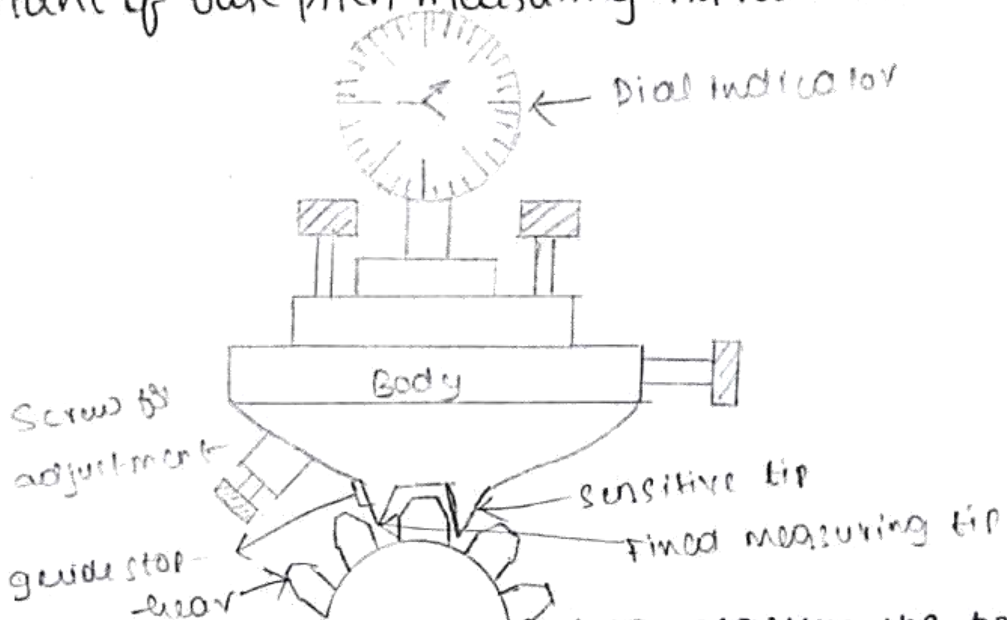


Tangential Gear teeth calliper

The body of the instrument has slides, which consists of two measuring tips. The measuring contacts or tips are generally flat and arranged at an inclination of 14.5° or 20° with the central vertical axis. The extended portion of the dial indicator spindle with point 'A' can passes symmentrically through the two measuring contacts in vertical direction. A screw with right and left handed thread helps to bring the measuring contacts together and vice versa with reference to the central vertical

The setup of calliper is carried out based upon the cylindrical master gauge, with accurate diameter. The diameter of cylindrical master gauge, depends upon the module of the gear to be measured. Once the measuring tips are adjusted, the position of tips are locked by using locking by using nuts so that they cannot move further. This arrangement of calliper is applied on gear tooth to measure the variation of the tooth profile. Hence, the variation recorded on the dial indicator from the external diameter of gear.

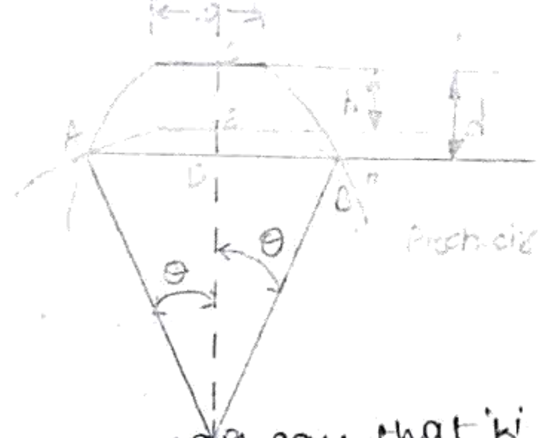
Important of base pitch measuring instrument:



1. It is a portable instrument, used to measure the base pitch errors
2. It is a hand held instrument that measures the base pitch error
3. It is a properly set-up instrument which is applied to the gear such that all the 3 tips contact the tooth profile. The dial indicator reading gives the error in the base pitch.
4. The base pitch measuring instrument is most commonly used for measuring base pitch errors.
5. With the help of this instrument tooth to tooth pitch measurement can be successfully carried out
6. It is used for the measuring of variations in pitch between successive teeth of the gears

vernier calliper for making the measurement of chordal thickness (w) and vertical vernier depth gauge for measuring the value of chordal addendum finally, the measured values are compared with analytical values. (103)

consider a gear tooth on which measured values of chordal thickness (w) and chordal addendum are shown in figure



From the figure, we can say that 'w' is equal to the length of the chordal ADB and tooth thickness is equal to the arc distance AEB. the distance 'd' is slightly greater than addendum CE i.e, 'h' and therefore 'w' is called a chordal thickness and 'd' is called as chordal addendum.

$$\therefore w = AB = 2AD.$$

$$\text{and } \angle AOD = \theta = \frac{360^\circ}{4T}$$

where T = number of teeth

$$w = 2AD = 2 \times AO \sin\theta$$

we know that

AO = Radius of the pitch circles

$$\text{and } \theta = \frac{360^\circ}{4T}$$

$$\therefore w = 2R\sin\left(\frac{360^\circ}{4T}\right)$$

$$\text{Also, module 'm'} = \frac{\text{Pitch circle diameter}}{\text{Number of teeth}} = \frac{2R}{T}$$

$$\therefore R = \frac{Tm}{2}$$

By substituting the value of 'R' in eq (1), we get

$$w = 2 \cdot \frac{Tm}{2} \cdot \sin\left(\frac{360^\circ}{4T}\right)$$

$= T \cdot M \cdot \sin\left(\frac{90^\circ}{T}\right)$

From fig $d = OC - OD$

But, $OC = OE + \text{Addendum}$

$= R + m$

and $OD = R\cos\theta$

Then $d = R + M - R\cos\theta$

(or) $h = \frac{TM}{2} + M - \frac{TM}{2}\cos\left(\frac{90^\circ}{T}\right)$

$\therefore h = \frac{TM}{2}\left[1 + \frac{2}{T} - \cos\left(\frac{90^\circ}{T}\right)\right]$

Various methods of checking gear tooth thickness

The various methods of checking gear tooth thickness.

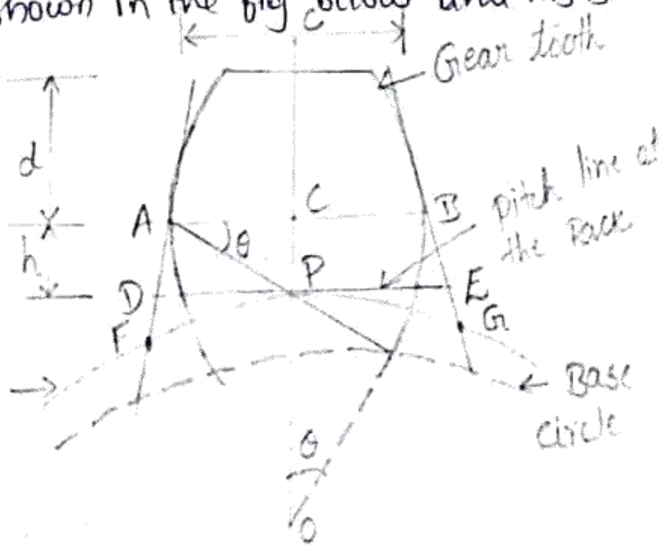
1. Gear Tooth Vernier:—

For answer refer unit-VI, Q5.

2. constant chord method.

It is very difficult to measure a large number of gears in involute separate sets each having number of teeth, because calculations and becomes laborious and timeconsuming. Hence, to overcome such difficulties, a constant chord method is used.

In this method, the constant chord is the chord between the points at which the tooth becomes touches the basic rack of the system, where the tangents to the flank lie at the pressure angle to the launch and AB is central line. The geometry is shown in the fig below shown as constant chord.



Then the value of constant chord AB and its depth can be mathematically, calculated as follows (104)

From the fig $PD = PF = \text{arc } PF$

$= \frac{1}{4} \times \text{circular pitch}$

$= \frac{1}{4} \times \frac{\pi \times PCD}{N}$

$= \frac{\pi}{4} \times m.$

Since AP is the line tangential to base circle, $CAP = \theta$,

∴ In right angled ΔAPD,

$AP = PD \cos\theta$

$AP = \left(\frac{\pi}{4}\right) m \cos\theta \left[\because PD = \frac{\pi}{4} \times m\right]$

In ΔPAC

$AC = AP \cos\theta$

$= \frac{\pi}{4} m \cos\theta \times \cos\theta$

$= \frac{\pi}{4} m \cos^2\theta$

$\therefore 2AC = 2 \times \frac{\pi}{4} m \cos^2\theta$

$= \frac{\pi}{4} m \cos^2\theta$

But, $2AC = C$ (constant chord)

For helical gear, $C = \frac{\pi}{2} M_n \cos^2\theta_n$

where M_n = Normal module

θ_n = Normal pressure angle

Now, $PC = AP \sin\theta = \frac{\pi}{4} \times m \cos\theta \cdot \sin\theta$

$\therefore d = \text{Addendum} - PC$

$= m - \frac{\pi}{4} \times m \cos\theta \cdot \sin\theta.$

$= m\left(1 - \frac{\pi}{4} \cos\theta \cdot \sin\theta\right)$

Similarly, for helical gear,

$$d = mn\left(1 - \frac{\pi}{4}\cos\theta_n \sin\theta_n\right)$$

Also, height of the constant chord AB,

$$h = pc = \frac{\pi}{4} \times M \sin\theta \cos\theta$$

$$= \frac{\pi}{4} \times M \times \frac{2}{2} \sin\theta \cos\theta$$

$$= \frac{\pi}{8} \times M \sin\theta \left[\because \sin 2\theta = 2\sin\theta\cos\theta\right]$$

3. Addendum comparator Method.

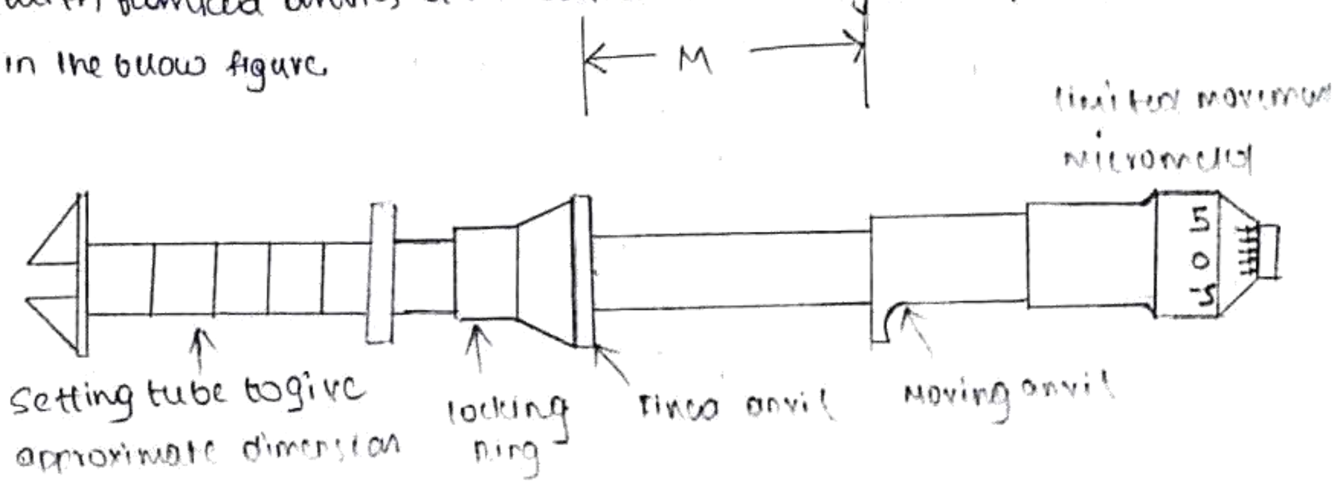
The addendum comparator method is used to measure the tooth thickness of a gear. The tooth thickness of a gear in this of a comparator and the normal pressure angle of the tooth should be same. The jaws of the comparator are set to a proper width by using a steel block which is equivalent to a rack tooth of the proper diametral pitch. For standard addendum, the dial indicator is set to zero simultan

A thin tooth projects into the comparator when the gear is to be checked the dial gauge reads a value when the it is placed is same position or in reverse position. The change in tooth thickness may be determined by the relation.

At = 2 × Readings of comparator × Range of normal pressure angle

4. Base tangent Method:—

Base tangent method measure, the gear tooth thickness with higher accuracy. Base tangent method uses either a micrometer with flanked anvils or the David Brown tangent comparator a shown in the below figure.



7. It is stable for measurement due to its third tip (106)

8. Using this instrument the base pitch can be measured directly

Enumerate various gear parameter:—

The various gear parameter measured in metrology lab and the corresponding instruments required for measurement are shown in table below.

S.NO	Gear Parameter	Corresponding Instrument
1.	Runout	Gear essentricity testor
2.	Pitch	Portable hand-held instrument
3.	Profile	Involute measuring machine.
4.	Lead	Lead checking instrument.
5.	Back lash	comparator
6.	Tooth thickness	Gear tooth vernier callipy
7.	concentricity	Dail gauge
8.	Allignment	Parallel bar.
9.	composite errors	Master gear.

Methods of inspection gear:—

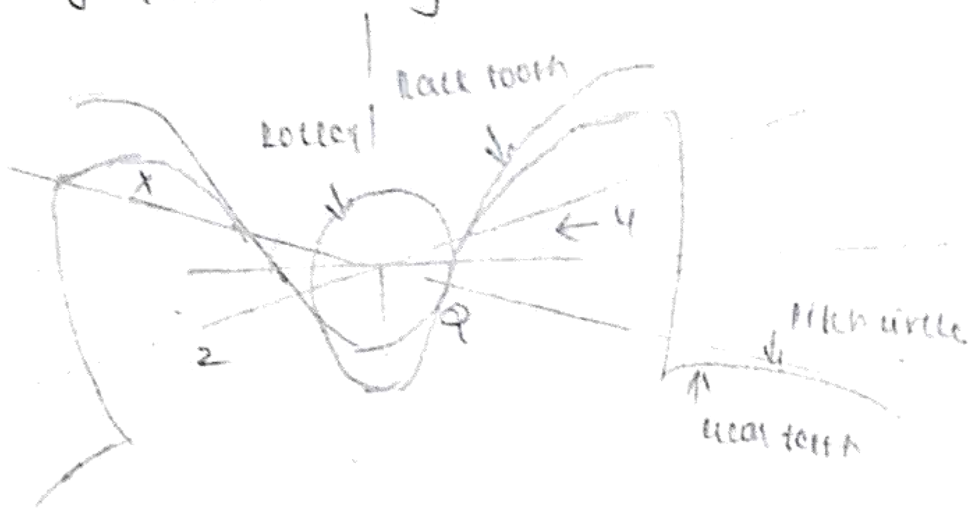
(A) Runout:—

It is the eccentricity in the referance or pitch circle. Gears with eccentricity which tends to posses vibration per revolution. Service eccentricity may even cause gear failure without any prior indication.

Gear eccentricity tester are used to measure the runout in gears. The gear whose runout is to be measured is held on a mandrel in the centres. The dial indicator of the testy possesses a special type of tip which depends on the module of the gear under checking. The tip of the dial indicator is inserted between the tooth spaces and the gears is rotated tooth by tooth. The maximum variation is noted from the dial indicator reading and it gives the runout of the gear. The runout is twice the eccentricity.

Perpendicular to the rack side. Hence the roller will rest towards the gear teeth x and y and its centre will lies on pitch circle

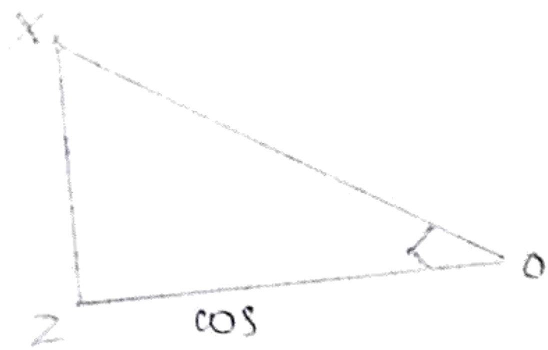
(10)



- consider Triangle OX2 i.e. $\triangle OXY$

$$OZ = \frac{\text{circular Pitch}}{4}$$

$$OZ = \frac{\pi}{4m}$$



$$OX = OZ \cos\psi$$

$$= \frac{\pi}{4m} \cos\psi$$

- OZ = Diameter of roller & plug = $2OX$.

$$OZ = 2\frac{\pi}{4m} \cos\psi$$

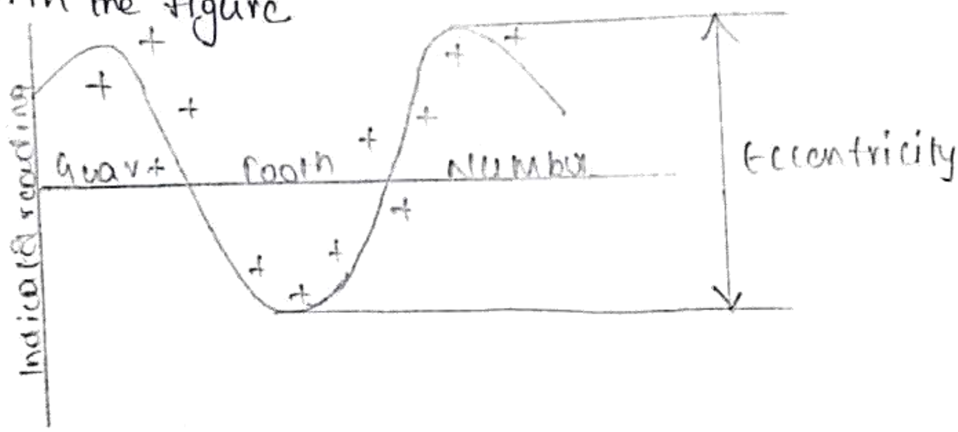
$$\text{Diameter of roller} = \frac{\pi}{2} m\cos\psi$$

The diameter of plug will remain same for all gears having the same pitch and pressure angle.

The accuracy of spacing over a number of teeth can be determined by calculating the angle subtended to the centre and relating this value with the obtained value (of chordal check the plug).

(8) teeth generated, otherwise, the situation may arise in which the gear will not function properly because of the eccentricity of the mounting.

Therefore, the concentricity of the gear tooth can be checked by mounted the gear between the bench centres, placed a standard roller in each tooth space and then using a dial indicator. Generally the variation in reading and tooth thickness is the function of eccentricity present. The error thickness due to eccentricity may be established if the results of the measurement are plotted graphically as shown in the figure



Hence the presence of eccentricity will be indicated by a smooth sinusoidal curve with the tooth thickness variation indicated by the spread of the measurement above this line.

Cylindricity of Method of Inspector Gear:—

Cylindricity of a gear refers to the measurement of the surface of the gear for its cylindrical nature. It is the net effected of several circular planes which are equally placed. A good inspection method rotates the part around an axis and measures variations in the radius of the part. It is inspected with gear testing machines, CMM.

Test plug method:—

From the figure, it can be seen that the sides of the rack meet with the gear teeth at point x and y. Let 'O' be the space encloses with its outline. Then, the radius 'ox' and 'oy' will fit and coincide the rack spaces at point x and y as they travel in a direction

(7) Total composite error and Tooth to Tooth composite errors. (108)

Various sources of errors in gears:—

The gear teeth are generally produced by one of the following two methods of manufacturing. They are

1. Reproducing method in which involute cutter is the cutting tool. It forms the profile of gear teeth by reproducing the shape of cutter itself. In this method each tooth space is cut independent of the other tooth spaces.
2. Generating method in which the cutting tool forms the profiles of several teeth simultaneously during constant relative motion of tool and blank.

Therefore, the sources of errors produced from reproducing method are,

(i) Due to possesion of incorrect profile on cutting tool.
(ii) Due to incorrect positioning of tool in relation to work
(iii) Due to incorrect indexing of blank.

The sources of errors produced by generating method are

(i) Errors in manufacturing of cutting tool.
(ii) Error in positioning the tool in relation to work.
(iii) Error in relative motion of tool and blank in relation to work.

Various errors in gears:—

The various errors in gears are as follows:—

1. Runout:—

It is the total range of reading of a fixed indicator with the contact point applied to a surface rotated, without axial movement, about a fixed axis

2. Axial Runout:—

It is the runout measured parallel to the axis of rotation at a specified distance from the axis

3. Tooth alignment error:—

The distance of any point on a tooth trace from the design tooth trace passing through a selected reference point on that tooth is called tooth alignment cylinder.

4. Tooth thickness error:—

It is the value obtained by subtracting the design tooth thickness from the actual tooth thickness measured along the surface of the reference cylinder.

5. Cyclic Error:—

It is the error occurring during each revolution of the element under considerations.

6. Periodic Error:—

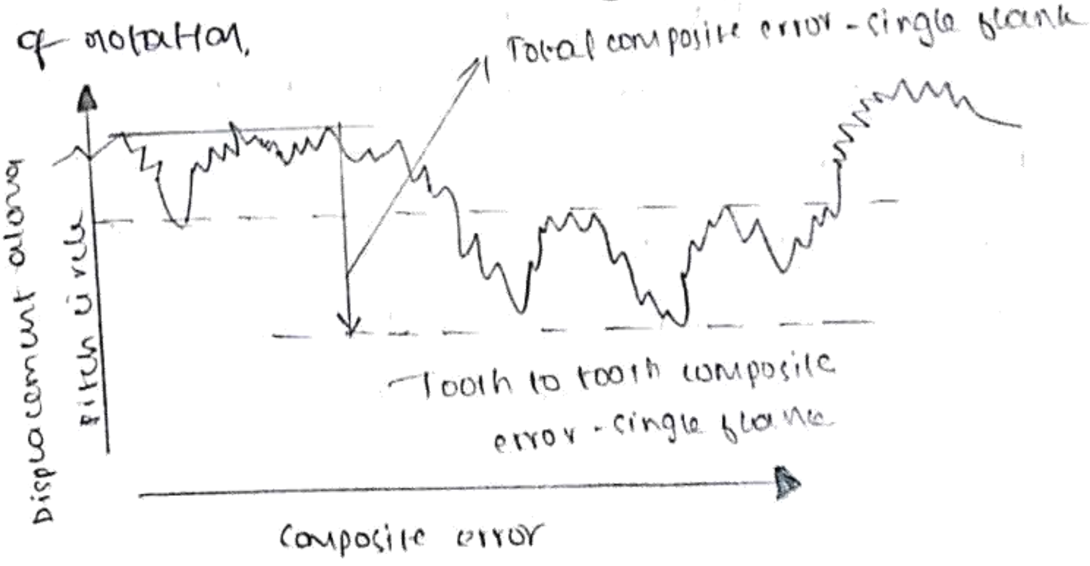
An error occurring at regular intervals not necessarily corresponding to one revolution of the component.

7. Eccentricity:—

It is the half the radial runout.

8. Radial Runout:—

It is the runout measured along a perpendicular to the axis of rotation.



Adjacent Pitch error:—

It is given by the difference between actual pitch and design pitch.

Tooth to tooth composite error - single flank.

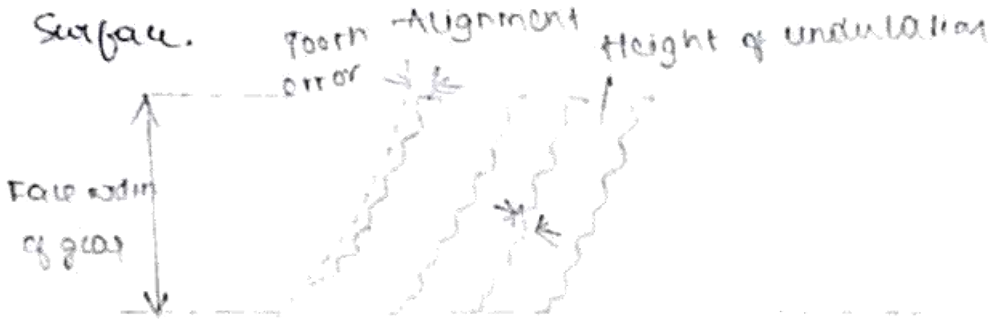
It is the range of difference between displacement at pitch circle of a gear and that of a master gear meshed with it at fixed centre when moved through 1 pitch distance.

Total composite error - single flank:—

It is the range of difference between displacement at pitch circle of a gear and that of a master gear meshed with it at fixed centre when moved through one complete revolution.

Undulation:—

→ A periodic departure of the actual tooth surface from the design surface.



Undulation Height:—

The distance between the crest and trough of the tooth undulation.

Determine the setting for a straight spur gear having 50 teeth of module 3MM.

Given that,

$m = 3MM$

$T = 50$

$w = mT\sin\left(\frac{90°}{T}\right)$

$= 3 \times 50\sin\left(\frac{90°}{50}\right)$

$= 4.711 MM.$

$$h = \frac{Tm}{2}\left[1+\frac{2}{T} - \cos\left(\frac{90^\circ}{T}\right)\right]$$

$$= \frac{50\times 3}{2}\left[1+\frac{2}{50} - \cos\left(\frac{90^\circ}{50}\right)\right]$$

$$= 75\left[1+\frac{2}{50} - \cos\left(\frac{90^\circ}{50}\right)\right]$$

$$= 3.037\text{mm}.$$

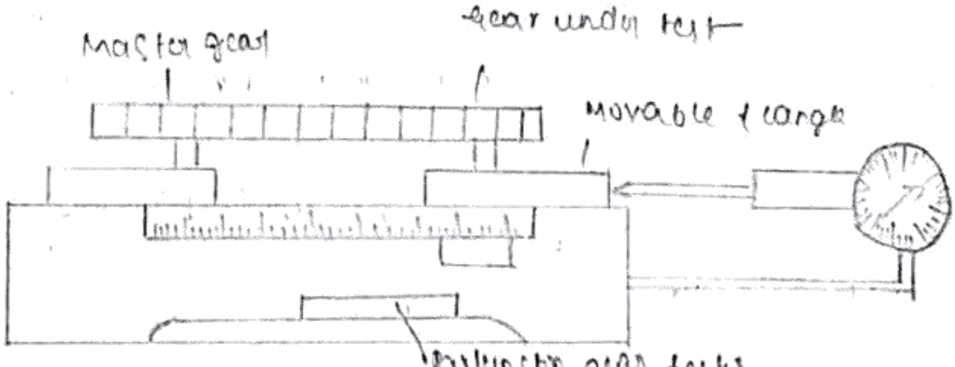
Parkinson's gear tester:—

This device is used for composite checking of gears like,

(i) total composite variation

(ii) tooth to tooth composite variation.

The principle is too mount standard gear on a fixed vertical spindle and the gear to be tested on another similar spindle mounted on a sliding carriage, maintaining the gear in mesh by spring pressure. Movement of the sliding carriage as the gears are rotated are shown by dial indicator, and variation are measured. Fig(1) shows a gear tester spur gear.



The gears are mounted on the two mandrels, so that they are free to rotate without mandrels clearance. The left side spindle can move along table and clamped in any desired position. The right side mandrel slide is free to move, running on steel balls, against spring pressure. The mandrel's can be adjusted so that their axial distance is equal to the specified gear centre distance. A scale is attached to one carriage and a vernier

What is gear pitch? Describe any two methods of measuring gear pitch.

It is the distance measured around the base circle from the origin of the involute on the tooth to the origin of a similar involute on the next tooth.

$$\text{Base pitch} = \frac{\text{Base circumference}}{\text{Number of teeth}}$$

$$= \frac{\pi \times \text{Diameter of base circle}}{N}$$

$$= \frac{\pi \times D \cos\phi}{N}$$

$$= \pi . M \cos\phi$$

where M = Module

ϕ = Pressure angle.

Pitch Errors:—

Errors in pitch of gear or tooth spacing may be measured by,

(a) step by step method or measuring the position of a suitable point on a suitable point on a tooth after the gear has been indexed through a suitable angle.

Gear metrology of spur gears:—

In gears backlash is the play between the mating tooth surface. Backlash may be defined as the amount by which a tooth exceeds the thickness on an engaging tooth. In gear teeth backlash result due to error in profile, pitch thickness of gear teeth etc. Backlash is measured at the tightest point of the mesh. The variation of backlash in precision gear not exceed to 20 to 30 microns. Backlash may be of two, one is circumferential backlash and the other is normal backlash.

Backlash is measured by mounting the gear in a specified position. It should be measured at the measured at the tightest the pinion is held firmly against rotation and a rigid mounted dial indicator is placed against the tooth at the extreme heel perpendicular to the surface. The backlash is then determined by back and fro movement of gear. The variation in backlash is measured by locating the points of maximum and minimum backlash in the pair

(11)

The involute wave is traced by the end 'A' of the straight edge that rolls in a base circle diameter cylinder. Any point 'C' on the curve would correspond to the position 'CE' of the straight edge that always remain tangential to the base circle. conversely if the base circle cylinder was to roll on a straight edge, any fixed point example 'C' will move in an involute path, such as 'CA' as the cylinder rolls along the fixed straight edge 'CE'.

Equivalent to this arrangement is a straight edge rolled on the edge of a disc, it provides the principle on which involute testers works.

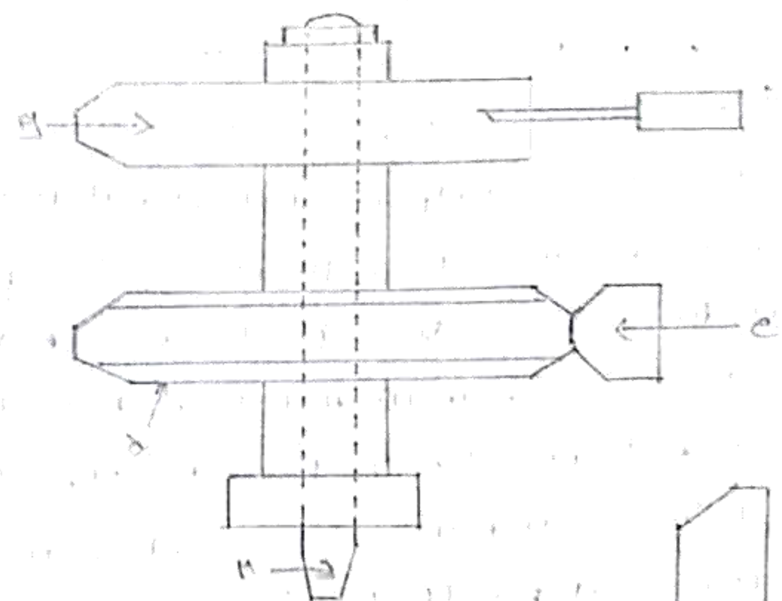
The gear which is to be tested should be held on the mandrel 'M', the mandrel carries a ground disc 'd' having exactly the same diameter as the base circle of the gear under test. A straight edge 'e' is installed on a slide on the body of the instrument, it is in contact with base circle disc such that when the straight edge moves along the slide, the gear and base circle disc are rotated without slip. A point on straight edge hence explains without slip. A corresponding to the base circle, if the top of the indicator of some kind is installed exactly in the plane of the straight edge and in contact with the tooth flank it is recorded by its movement any departure of the tooth profile from the theoretical involute resulting either from deliberate modification of the profile (or) from errors. the indicator can be replaced such that permanent records of the gear teeth profiles can be replaced made, the indicator can be replaced by the sensing element of a recorder.

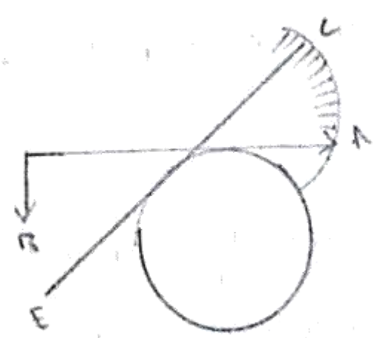
David - Brown involute machine :-

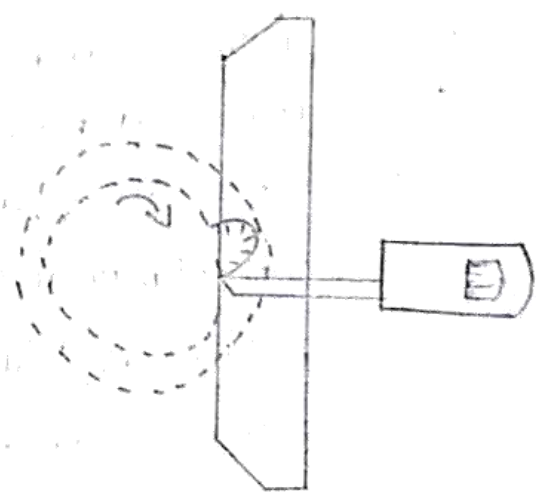
From the figure it is observed that the stylus, bearing against the involute flam is accurately located above the straight edge. such type of machines can be set to drop base circle radius values there by doing away the need of having base disc for each gear. this facility is given by master base ii - A waxed paper recorder fitted or gears mounted on sliding carriage. The line traced records the movement of the floating carriage, a circle is drawn. A typical charts are produced and result can be ascertained and same are shown in fig (2).

This test is used for accepting or rejecting a gear but not for finding out detailed reasons for rejections. It is used for detecting poor tooth form caused by worm or in accurate cutting tool eccentricity due to in accurate centering of gear blank on machine tool etc.

Checking of involute shape of gear:-







Principle of involute Testg

Define the tooth constant chord. Calculate the chord length and its distance below the tooth tip for a gear of module 3 and 20° pressure angle.

Constant chord.

It is defined as the chord joining those points on opposite of the tooth which make contact with the mating teeth when the centre line of the tooth lies on the line of the gears centres.

Given that

module of gear $m = 3$

Pressure angle $\phi = 20°$

To find

chord length and its distance below the tooth tip

chord length $= \frac{\pi}{2} \times m \times \cos^2\phi$

$= \frac{\pi}{2} \times 3 \times \cos^2 20°$

$=$ 4.16 units

Its distance below the tooth tip

$= m\left(1 - \frac{\pi}{4} \cos\phi \sin\phi\right)$

$= 3\left(1 - \frac{\pi}{4} \cos 20° \cdot \sin 20°\right)$

$=$ 2.243 units

Therefore, chord length = 4.16 units and its distance tooth tip = 2.243 units.

Screw thread Measurement Unit - 5

Screw -thread elements

In order to determine the accuracy of a screw thread, the following elements are required to be measured.

i) Major Diameter

It is also called as external diameter, out-side diameter, core diameter or full diameter of external thread. It is the diameter of an imaginary co-axial cylinder which touches the crests of an external thread or roots of an internal thread.

ii) Minor Diameter:

It is also called as core diameter or root diameter. It is the diameter of an imaginary co-axial Cylinder, which touches the crests of an internal thread or roots of an external thread.

iii) Effective Diameter:

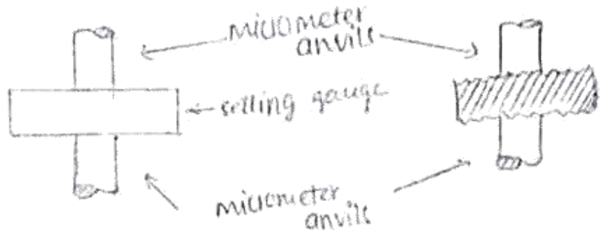
It is also called as pitch diameter. It is the diameter of an imaginary co-axial cylinder, which intersects the flanks of the threads such that widths of the spaces b/w the threads and widths of the threads are equal.

iv) Pitch:

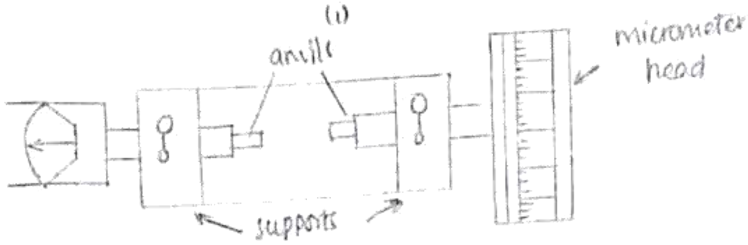
The distance measured b/w two consecutive crests are two consecutive throughs, when measured parallel to the axis from a point on the threads is called pitch.

Major Diameter Measurement.

The Major diameter of a screw-thread is defined as the diameter of an imaginary cylinder, which contains all points on the crests of the thread as shown in fig.



(i)



It is the most conveniently measured by means of a bench micrometer.

This instrument was designed by the national physical laboratory to eliminate the deficiencies inherent in the normal hand micrometer. These are,

a) variations in measuring pressure

b) pitch error in the micro meter head

The fixed anvil is replaced by a fiducial indicator, so that all measurements are made at the same pressure, and this indicator has a positional adjustment which not only increases the range of the instrument, but makes virtually impossible for it to be direct reading.

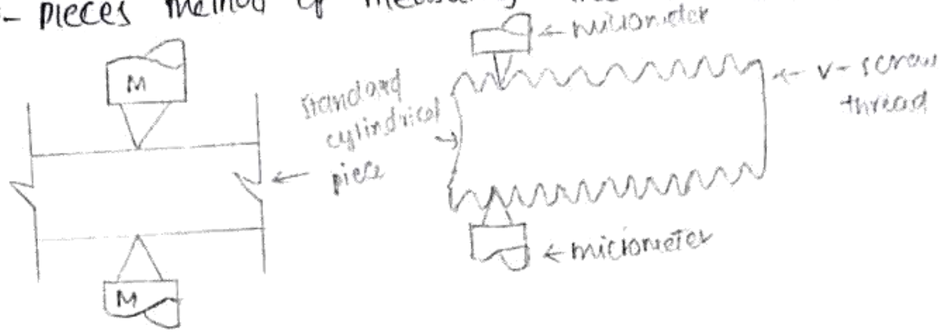
Instead it must be used as a comparator and set to a standarad. Thus, for a given reading the micrometer thread is used over a short length of travel and any pitch errors it contains are virtually eliminated.

The setting standard may be a guage block, but before preferences a calibrated setting cylinder should be used, as this gives greater similarity of contact at the anvils while reading on setting standard and on the gauge.

The procedure consists of simply nothing the reading obtained on the setting cylinder and that obtained on the thread.

Measurement of minor diameter:

Minor diameter of a V-screw thread can be measured by floating carriage diameter measuring machine with two small V-pieces mounted on a carriage and set to proceed perpendicularly to the centre axis by a V-ball slide whose ends have radius and included angles less than the root radius and thread angles respectively. This method is called as two V-pieces method of measuring the minor diameter.



Placing the thread work piece in b/w the centres of the measuring instrument. Note the reading by placing the V-pieces on either side of the threaded workpiece opposite to micrometer anvil such that it should make contact with the root of thread.

To measure the second reading, the threaded workpiece is replaced by a standard cylindrical gauge of diameter approximately equal to the minor diameter of the screw to be measured.

When,
R_1 = Micrometer reading of standard cylindrical gauge

R_2 = Micrometer reading of threaded workpiece

D = Diameter of standard cylinder gauge

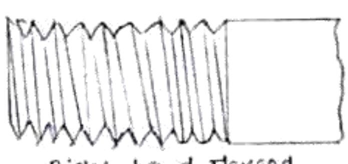
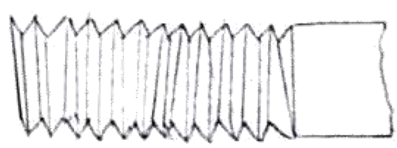
The minor diameter of thread is given by $D \pm (R_2 - R_1)$. At various positions note the readings to detect the taper and ovality of threaded workpiece.

Different elements of a screw thread:

The various screw thread parameters for metrological measurement are as follows:

v) Then for measuring thread angle and form a cast of thread is used. Therefore, measurements are taken by using microscope or optical projector.

Difference b/w Right hand and left hand thread:

Right hand thread	Left hand thread
* Right hand thread is defined as, the rotation of the screw in clock-wise direction, which causes the inward movement into the threaded hole.	* left hand thread is defined as, the rotation of screw in anti-clockwise direction, which causes the inward movement into the threaded hole.
* From the side view, this thread appears as inclined towards the left hand side	* From the side view, this thread appears as inclined towards the right hand side.
* these threads are not specially represented by notations on drawings	* These threads are represented by 'LH' notation on drawings
* threads are formed on lathe M/c by the relative movement b/w the tool and Job (or) workpiece. In right hand threads the tool moves from right to left side of workpiece	* This threads are formed on lathe M/c, where the tool moves from left to right side of the workpiece (or) Job.
* This threads are widely used in many applications such as, screw, nuts, bolts etc.	* This threads are applied where right hand threads are not suitable.
 Right hand Thread	 left Hand thread

Effective of Major Errors on Elements of threads:

1. Effect on Major Diameter:

In case of major diameter the error causes interference with the mating thread and reduces the flank contact. the errors, incase of internal threads reduces the wall thickness

2. Effect on Minor diameter:

Due to effect of errors in the minor diameter interference is caused with the mating threads may lead to the reduction of flank contact and the cross-section of the root.

3. Effect on Effective diameter:

The effect of pitch error in effective diameter determines, the amount of slackness or interference b/w the flanks of mating threads. With the Major and minor diameters at their maximum limits, if the effective diameter is small, the threads will be thin on the external screw and thick on an internal screw. The reverse conditions prevail, if the effective diameter is above its basic value. These errors who would produce more noise in the assembly while running.

4. Effect on pitch:

The errors in the pitch may lead to the progressive tightening and interference on assembly. Due to the cumulative pitch error the effective diameter increases and decreases the effective diameter of a nut.

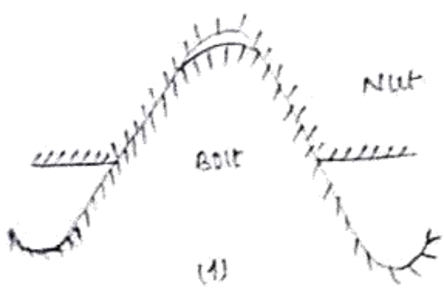
5. Effect on Flank Angle or thread angle:

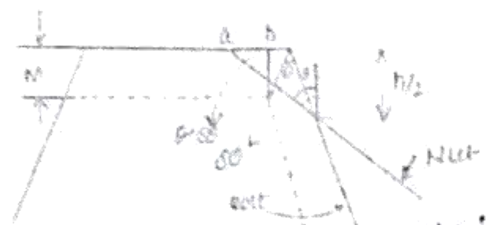
Error in the flank angle also cause a virtual increase in, the effective diameter of a bolt and a decrease in that nut. One thread of perfect bolt which is assembled a nut having one flank of incorrect angle. It is clear that, there is an interference which can be eliminated by a radial reduction of the bolt i.e., by a decrease in the bolt diameter. The amount of decrease in length effective diameter can be calculated by means of the formula.

Decrease in effective diameter = $h \times \csc 2\theta . \delta\theta$

Where, h = Depth of thread and

$\delta\theta$ = Error angle in radians.





The geometry by which this formula is derived as shown in fig (2). According to diagram the full lines show the bolt and nut with interference at the right hand flank. To remove this, the bolt profile must be moved to the position shown in dotted lines, the radial movement begin m.

$a+b = h/2 \times \tan(\theta+\delta\theta) - h/2 \times \tan\theta$

$a = m \times \tan(\theta+\delta\theta)$

$b = m \tan\theta$

Thus.

$m[\tan(\theta+\delta\theta)] = h/2 \; [\tan(\theta+\delta\theta)\} - \tan\theta]$.

Expanding the collecting terms, we get,

$m[2\times\tan\theta + \tan\delta\theta(1-\tan^2\theta)]$

$= h/2 \; \tan\theta \; [1+\tan^2\theta]$

Dividing by $\sec^2\theta$, we get

$m(\sin 2\theta + \tan\delta\theta \times \cos 2\theta) = h/2 \; \tan\delta\theta$

Since, $\delta\theta$ is very small, the expression $\tan\delta\theta \times \cos 2\theta$ can be ~~calculated~~ neglected in comparision with $\sin 2\theta$ and $\tan\delta\theta$ can be replaced by $\delta\theta$ radians.

Therefore,

$m \times \sin 2\theta = h/2 \times \delta\theta$

$m = h/2 \; \text{cosec}\; 2\theta \times \delta\theta$

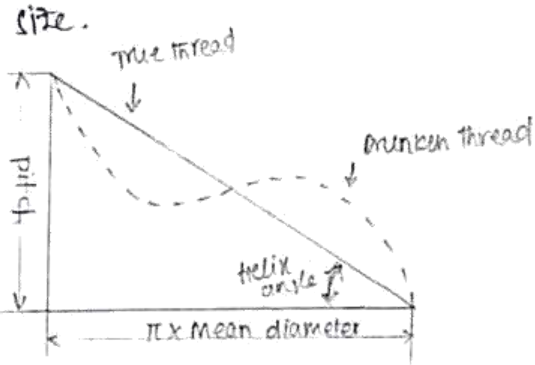
This is the amount of radial movement needed and must be doubled for the diametral effect. Thus, virtual decrease in effective diameter $= h \times \text{cosec}(2\theta \times \delta\theta)$.

If there is an error in the angle of the other flank. The change in the effective diameter is the sum of the two changes, regardless of the sign of the errors. Thus, if the angle of one flank is large by the amount of $\delta\theta$ and that of the other flank small by $\delta\theta_2$, the change in the effective diameter is given by, $= h \times \text{cosec}\,2\theta\,(\delta\theta_1 + \delta\theta_2)$.

Errors in threads:

a) Drunken thread:

Figure shows a drunken thread. Drunken error is similar to periodic error except that the helix is irregular and advances in one complete revolution of the thread. In such a case, the pitch measured parallel to the thread axis will be always correct. The only error because of drunken thread that does not cuts the true helix. Drunkenness can be visualised only when the screw thread is at an inclined plane wounded around the circumference of a cylinder and the thread can also be unwounded from the cylinder. This thread does not have much effect while working, unless it is of larger size.



b) pitch errors in screw threads:

If a screw thread is generated by a single point cutting tool, its pitch depends on the following.

1. The ratio of linear velocity of the tool and angular velocity of the work being correct.
2. This ratio being constant.

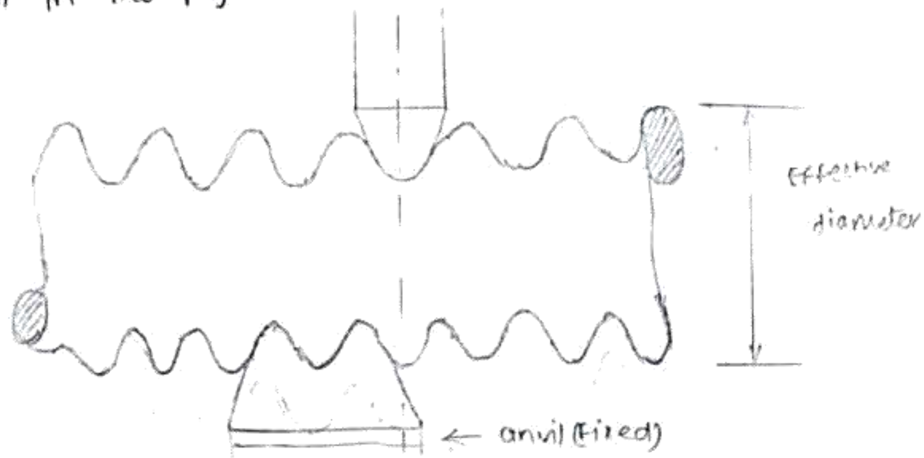
If these conditions are not satisfied, then pitch errors will occur. The type of error being determined is based on which condition is not satisfied.

Whatever type of error is present, the net result is to cause the total length of thread engaged to be too large or too small and this error in overall length of thread is called the cumulative pitch error. This is the error, which must be determined. It can be obtained either by.

i) Measuring individual thread to thread errors and adding them algebraically e.g., with regard to sign.

Measurement for effective diameter:

The exclusive method for effective diameter measurement which shows variation in drunken thread is thread micro meter method. the thread micrometer resembles, the ordinary micrometer which has special contact points to suit the end screw threads from there it is to be checked. the type of pitch of the thread to be measured will decide the contact points (anvil). the male contact point with V-form is fitted into the fixed anvil and the respective female contact with V-recess is fitted into the spindle of the thread micrometer as shown in the fig.



The V-recess are adjusted such that a perfect contact is established with threads and readings are noted which gives the pitch diameter or effective diameter of the thread. Hence, the measurement of effective diameter is obtained in b/w the major diameter and minor diameter present on either sides. Then, finally this diameter should match with the measurement of outer diameter and pitch from the given relation.

Pitch diameter $= D - 0.640\,p$
[incase of white worth thread]

where,
$0.1403p$ = Depth of thread
D = outer diameter
p = pitch

Effective diameter of internal threads:

A pair of ball tips engage the flanks of the thread in the work and measure the effective diameter.

The ball tip on the right is fixed at the end of a measuring jaw attached to a floating head in the sliding brackets (B), floating head is in contact with the dial indicator. the movement of floating head towards the indicator is constrained by a spring.

The instrument is set to a reference standard with the dial pointer coinciding with zero. the floating head is retracted and the ball-tips are interested in the internal threads of the work. It is then released so that the tips engage the flanks of the thread under the spring pressure. the dial indicator shows the deviation in the figure (a),

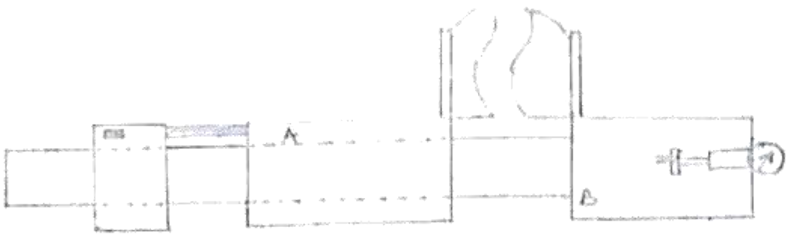
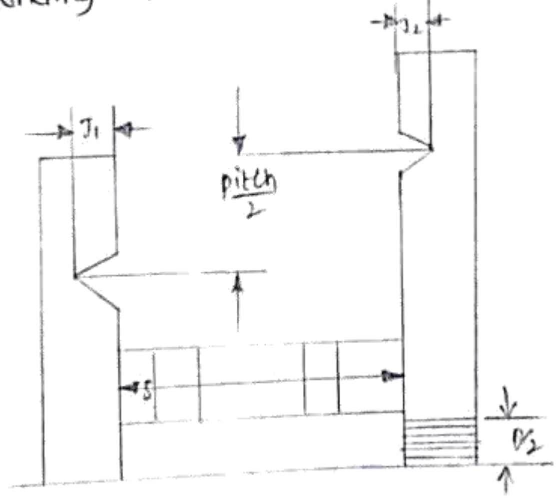


Fig (a)

The instrument may be used on work in the machine or on the working bench. the Fixed head (A) carrying the left hand ball tip is adjusted by a fine screw to set the gauge to the reference standard. the reference standard is built up from slip gauges. the two end pieces have V-Jaws of an angle of vee corresponding to the thread, ie., 55° or 60°.



The dimensions J_1 and J_2 are marked on the pieces. For a known effective diameter and pitch of the thread, the distance s is found by,

$$s = x + y - z$$

Where,

x = Mean effective diameter

y = Depth of thread from apex to the apex of V-form. it depends on included angle of the thread.

$\therefore K = 0.9605p - 1.1657d$ for white worth threads.

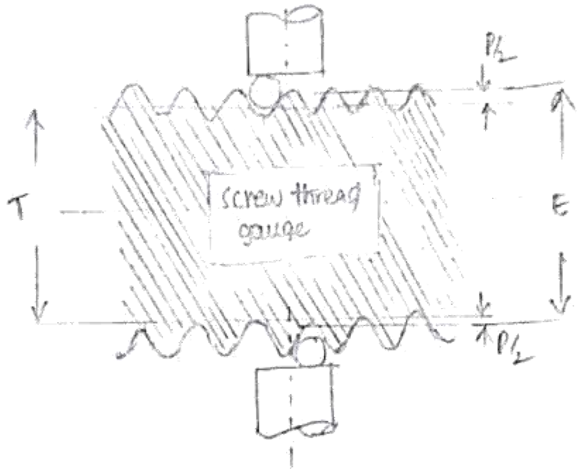
$K = 0.866p - d$ for isometric threads.

Where,

p = pitch of the threads

d = diameter of the wire

Two wire method is normally used, where the accuracy is not so concerned that is the reason why two wire method is carried out on the diameter measuring machine, because acting the perfect alignment by two wires is difficult and it can be easily conical out on the floating carriage machine as shown in figure (b),

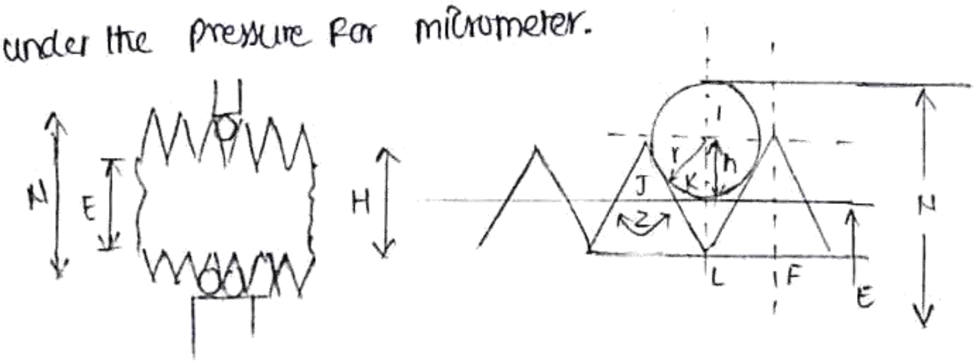


fig(b) : 2nd operation

For remaining answer

Three wire method for measuring Effective Diameter:

Three wire method is also called as three rod method. three wire method is the accurate method for measuring the effective diameter of the threads. In this method, three wires or rods of known diameter are used. Two rods on one side and one rod on other side. micrometer is aligned in such away that, the micrometer axis is perpendicular to the thread axis. These are rods are held in hand in order to ensure freedom to the rods to adjust themselves under the pressure for micrometer.



Where,

E = Effective diameter

N = Distance overwires

r = Radius of balls

d = Diameter of wires

h = Height of the centre from effective diameter

From the figure,

$IL = IJ \operatorname{cosec} Z/2$

$H = LF \cot Z/2 = P/2 \cot Z/2$ (∵ p = pitch)

$KL = H/2 = P/4 \cot Z/2$

$h = IL - KL$

Distance over rods,

$= N = E + 2h + 2r = E + 2(r \operatorname{cosec} Z/2 - P/4 \cot Z/2) + 2r$

$= E + 2r(1 + \operatorname{cosec} Z/2) - P/2 \cot Z/2$

$N = E + d(1 + \operatorname{cosec} Z/2) - P/2 \cot Z/2$

$N = E + Q$ (∵ $Q = d(1 + \operatorname{cosec} Z/2) - P/2 \cot Z/2$)

$\therefore E = N - Q$

$E = N - [d(1 + \operatorname{cosec} Z/2) - P/2 \cot Z/2]$

let, $Z/2 = \phi$

$E = N - [d(1 + \operatorname{cose} \phi) - P/2 \cot \phi]$

$\therefore \boxed{E = N - Q}$

Difference b/w Two wire and three wire method:

Two wire method:

1. Two wires or rods of identical diameters are used and keep in contact b/w the flanks of threads.
2. comparatively less accurate
3. carried out Floating carriage machine.
4. Effective diameter, $E = T + P$

Where,

T = Dimensions under the wires point

$T = M - 2d$

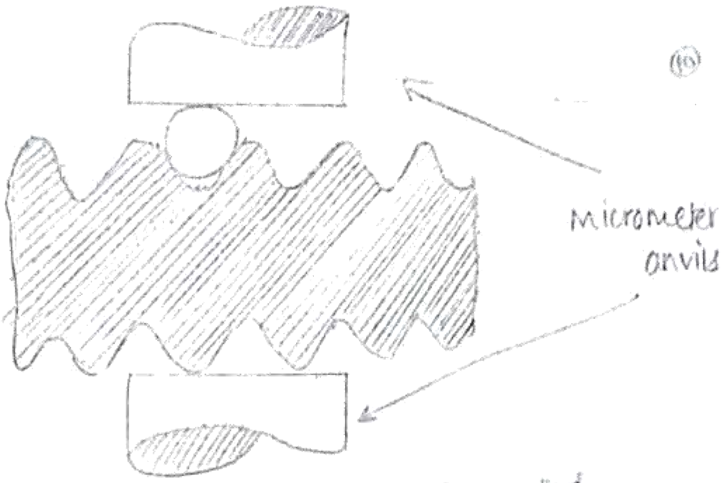
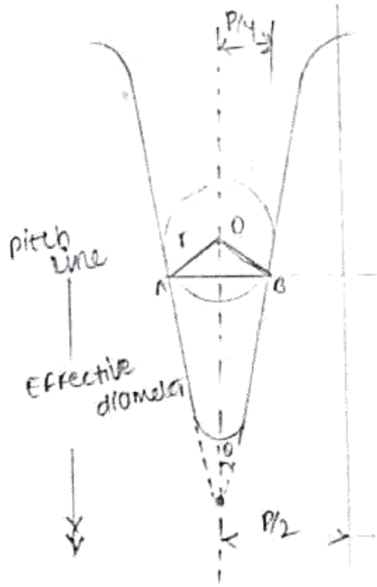


Fig: one wire method

Best size wire:

Best size wire is a wire of diameter, which makes contact with the flanks of the thread on the effective diameter or pitch line. Actually effective diameter can be measured with any diameter wire which makes contact on the true flank of the thread, but the values so obtained will differ from those obtained with 'best size wire' if there is an error in angle or form of thread. It is recommended that, for measuring the effective diameter, always the best size wire should be used and for this condition, the wire touches the flank at mean diameter line with in the flank length as shown in figure.



From the figure, the line OB is perpendicular to the flank position of the thread.

Let, 'θ' be half the included angle of the thread.

From Δ OAB, we get,

$$\sin BOA = \frac{AB}{OB}$$

$$\text{i.e., } \sin(90-\theta) = \frac{AB}{OB}$$

$$OB = \frac{AB}{\sin(90-\theta)} = \frac{AB}{\cos\theta}$$

$$= AB(\sec\theta)$$

But, OB = Radius of the wire (r)

Then,

Best wire diameter,

$$d_b = 2r = 2AB \cdot \sec\theta$$

Also, we know,

$$AB = \frac{p}{4}$$

$$\therefore d_b = 2 \times \frac{p}{4} \sec\theta = \frac{p}{2} \sec\theta$$

Terms involved in the expression $d_b = p/2 \sec\theta$

Here,

d_b = Diameter of best wire

p = pitch of the thread

θ = Half the included angle of the thread.

pitch of the thread is distance measured parallel to the axis from a point on the thread to the corresponding point on the adjacent thread.

Size of the Best wire:

If there is a probability of the thread angle being wrong, the wire used should be so as to touch the thread exactly on the pitch line.

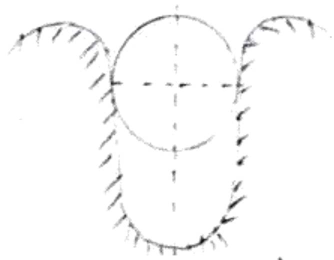


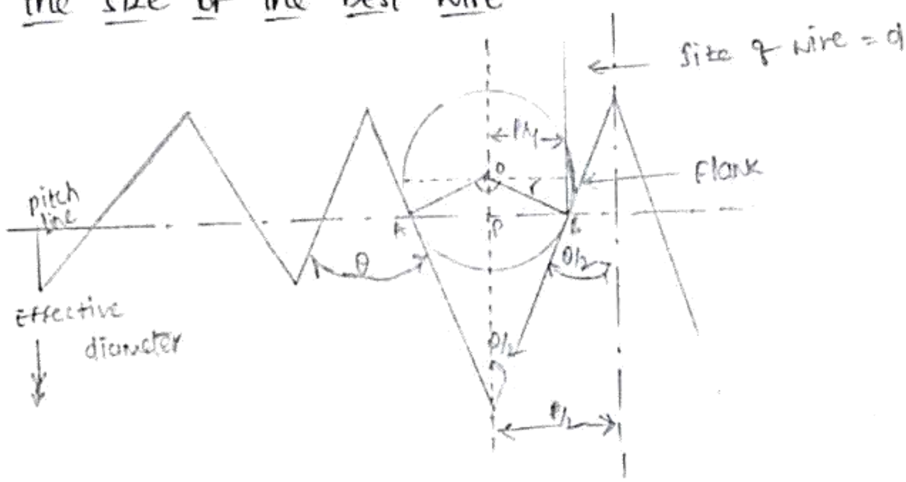
Fig: Best wire

The inspections of the effective diameter from a reading over such wires will not depend on any error in the thread angle. such wires are known as 'best wires'.

The best wire sizes are as follows,

S.NO	Form of thread	"Best wire" diameter
1.	B.A	0.546 P
2.	Metric, unified and American	0.577 P
3.	Whitworth	0.564 P

Expression for the size of the best wire



From the figure,

θ = Angle of thread

OB = radius of the wire (r)

d = size of the best wire

consider $\triangle OPB$, we get, $\sin\left(90 - \frac{\theta}{2}\right) = \frac{PB}{OB}$

$$OB = \frac{PB}{\sin\left(90 - \frac{\theta}{2}\right)}$$

$$OB = \frac{PB}{\cos\frac{\theta}{2}} = PB \sec \theta/2 \quad \text{— (1)}$$

$$\therefore r = PB \sec\frac{\theta}{2}$$

since, OB = r, diameter of wire = 2r

There fore, size of best wire diameter = 2r

$d = 2r$

$d = 2PB \sec \theta/2$ ($\because$ From equation (1))

Also, we know,

$PB = \frac{\theta}{2}$ — (2)

Where,
T = Diameter under the wires.

Rake correction is always subtracted from the measured diameter.

b) <u>compression correction</u>:

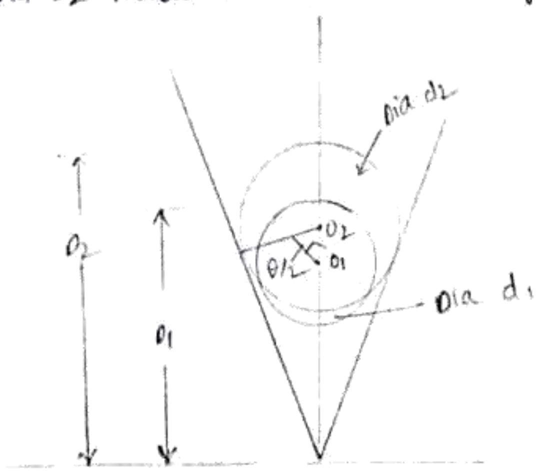
The micrometer exerts some force on the wires while measuring the effective diameter of threads. This force results in some degree of compression to take place and as a result, The diameter observed is less. therefore, this correction is added to the value of diameter obtained. this correction is of greater importance on fine threads and whose included angle is small (ex, B, A threads), For measuring forces upto 850 gm. For thread diameter is to about 3.5 mm, the correction is longer threads, for some measuring force, The compression is less and can be ignored.

$$\text{compression correction} = 0.001 \frac{E^{2/3}}{e^{1/3}} \text{ mm.}$$

Where,
E = Measuring force ~~and~~ in newtons and
e = effective diameter in mm

Measuring of thread angles:

It is a simple method employed for the measurement of thread angle by using two unequal balls. The included angle can be checked with the help of diameter measuring m/c with diameters D_1 and D_2 measured over the wires of diameters d_1 and d_2 as shown in figure.



Thus, we can get an included angle with the following relation,

$$\sin\frac{\theta}{2} = \frac{d_2 - d_1}{(D_2 - D_1) - (d_2 - d_1)}$$

Also, For the degree of accuracy let the distance b/w two centres O_1 and O_2 be,

$\frac{1}{2}(D_2 - D_1 - d_2 + d_1) = c$

Difference b/w radii $= \frac{1}{2}(d_2 - d_1) = r$

Then, the error in angle 'θ' is given by,

$$\delta\theta = \frac{2}{c\sqrt{c^2-r^2}} - (c.\delta r - r.\delta c) \text{ radians.}$$

As the error δr is very small, it can be neglected.

Therefore,

$$\delta\theta = \frac{2}{c\sqrt{c^2-r^2}} - [c.(0) - r\delta c]$$

$$\therefore \delta\theta = \frac{2.r\delta c}{c\sqrt{c^2-r^2}} \text{ radians}$$

Thus, it is the only method which gives the correct value of total thread angle, even the angle of each flank has an error.

Measure the pitch of external threads:

The pitch measurement of internal and external screw threads by various methods are as follows.

pitch measurement of internal screw threads:

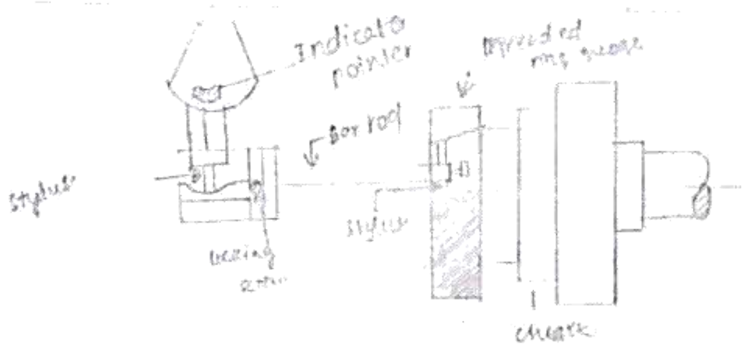
1. pitch measuring machine
2. Tool makers microscope

pitch measurement of external screw threads:

i) Zeiss pitch or lead measuring instrument
ii) screw measuring machine
iii) microscope method and

1. pitch measuring machine:

By using an adapter, the pitch of an internal screw thread of any pitch measuring machine can be measured. This adapter consists of a bar which can be inserted into the ring and at the end of bar, stylus is fitted with the help of a thread. Ring gauge is mounted on a face plate or chuck or on head stock of the machine which accommodate rings upto several centimeters (cm), as shown in figure (a), 125



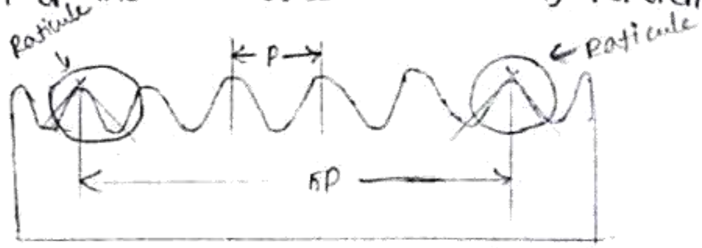
A special set of surface place is required with an indicator and slip gauges for very large rings. Here, micrometer is used to measure the movement of the stylus.

3. Tool maker's microscope:

It is an optical type of instrument used to measure the pitch of internal screw threads. It consists of a base with a vertical supporting column. The optical head is mounted on the column with a clamping screw by which it can move up and down. The component to be measured is placed on the table of the instrument and its position adjusted until the intersection of the cross lines seen through the eyepiece nearly coincides with the apex of an angle. The reticule is rotated to bring one cross line parallel to one edge of the angle and the instrument reading is noted by viewing the scale through the small eyepiece. The reticule is then again rotated to bring the same cross line parallel to the other edge and the scale reading is taken in this position. The difference b/w the two readings is either the angle turned through or 360° minus this angle.

Micro scope method:

It is more accurate method used to measure the pitch of external screw threads. It consists of two reticules which can be oriented to slopes of thread and point of intersection of these is used as measuring reference, as shown in the figure (b).



Micrometer microscope is used for the reading of movement of longitudinal carriage in linear scale. the accuracy of this instrument is 0.001mm and for angles it is 10 sec at arc.

Zeiss pitch or Lead Measuring instrument:

It is less accurate method used to measure the pitch of an external threads. It consists of two ball points applied to effective surface of the thread of contact members. These points are aligned parallel to axis either by a pin at the back over special back rest having a plane face parallel to thread axis, with the help of a special micrometer gauge, the instrument is adjusted to zero before taking measurement. further, applying the instrument to thread, it registers the pitch deviation from standard measurement.

Screw measuring machine:

By using screw measuring machine, pitch of external screw threads can be measured. It consists of threads which forms varying pitch. the pitch is the one which coincides perfectly with thread under test. Therefore, perfectness judges and accuracy of measurement in sighting.

Pitch measuring machine:

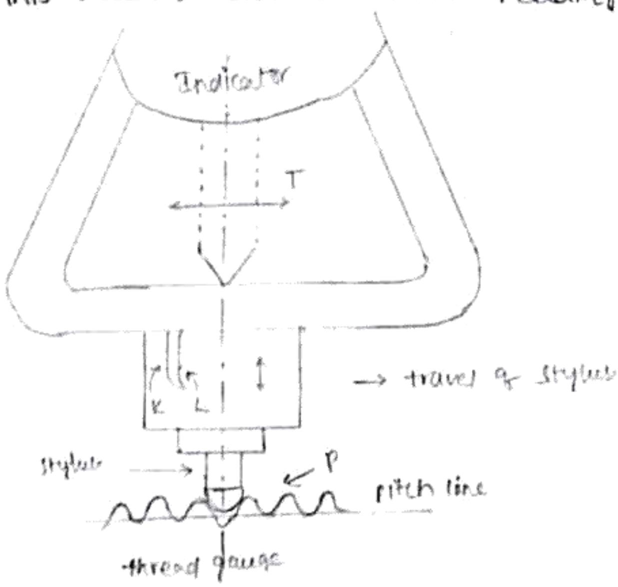
A simple and accurate method of measuring the pitch of the screw thread is by pitch measuring machine. The threaded component is mounted b/w the centres on the pitch measuring m/c, whose pitch is to be measured. then a stylus of a size, contacts the thread flanks at the pitch line and it is inserted in the indicator frame. A range of styli is provided with the m/c, along with the tables giving correct stylus to be used according to the pitch and type of the thread to be tested.

Working principle:

The principle of measurement is to move the stylus along the thread space and to measure the amount of movement by the micrometer. A flexible connection allows the stylus to move up the flank of the thread, it also allows the stylus to move down into the next space as it is moved along. stylus is exactly positioned b/w two flanks by ensuring that the pointer 'T' when readings are taken is always opposite to its index mark.

The indicator bracket is moved to bring the stylus opposite to the first thread space and is clamped in position, with the micrometer reading near the zero on the scale, Them indicator is then regulated radially until the pointer 'K' is opposite to the line 'L' and the stylus engages b/w the thread flanks. A small amount of rotation of the micrometer is required to move the stylus axially relatively to the thread, so as to bring the pointer 'T' opposite to its index mark. The micrometer reading is noted, when the point is accurately in position.

second reading is taken when the stylus is moved along into the next thread space by rotation of the micrometer. The pitch of the thread is nothing but the difference b/w the two readings until the whole length of the job is covered, readings are taken in this manner. Then, the stylus should be returned to the first position and readings taken should be checked, If there is any significant difference b/w this reading and the initial reading, the series of readings should be repeated.



Profile thread gauges:
Thread gauges are broadly classified into two groups i.e., one group of gauges are used to checked the product and another one for reference. The first group, working gauges are used to check the manufactured perfect also inspection gauges which comes under the same group, Judges the acceptance or rejection of the product.

The second group are the setting or checking gauges these are the gradually plug gauges - with the help of adjustable thread gauges, thread snap gauges and other comparators are set for checking size of master or basic size.

working gauges, inspection gauges and master gauges refers in respect of their accuracy. A working gauge is made to the widest tolerance and is therefore least accurate. While the master gauges have narrow tolerance and is most accurate. Finally, the accuracy of inspection gauge lies in b/w depending upon the intended application.

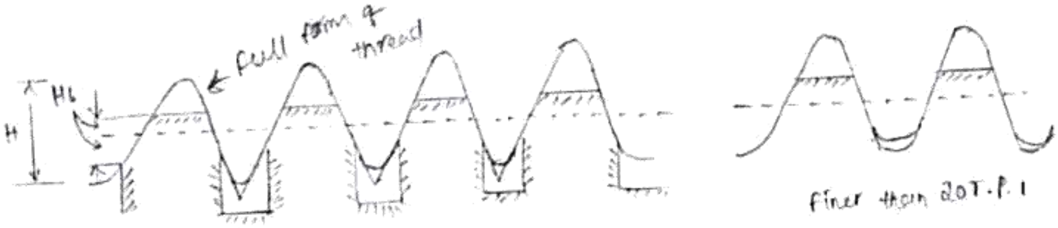
Threads gauges to measure screw threads:

There are three types of thread gauges to measure screw threads are as follows,

a) plug screw gauges:

For gauging nuts or internal threads, it is obvious that plug gauge must be accurately to the minimum, dimensions of the internal thread will ensure that all dimensions of the thread are not less than that minimum if it is assemble with the thread.

The various thread elements are, major, minor and effective diameters will be checked and it will ensure that firm of thread, angle and size of pitch should not be reduced below minimum. Individual errors of a particular component is not possible to judge. Strictly speaking a plain.



NO-GO gauge, is required for minor diameter. NO-GO gauge for both effective diameter and for major diameter is required. The NO-GO gauge (for major diameter) has its major diameter on the corresponding upper limit of the work when its flank and minor diameter being well cleared off the work dimensions.

Form of threads for NO-GO effective diameter gauge is shown in fig(1). It must be kept under consideration that NO-GO plug is truncated and their respective roots of the thread are cleared away to avoid contact with the crest of the mating thread, while being large on the effective diameter and have a minor diameter on low limit. The truncation of the gauge also avoid the contact with the roundness at the root of nut. All these modifications are to limit NO-GO and to check only the effective diameter.

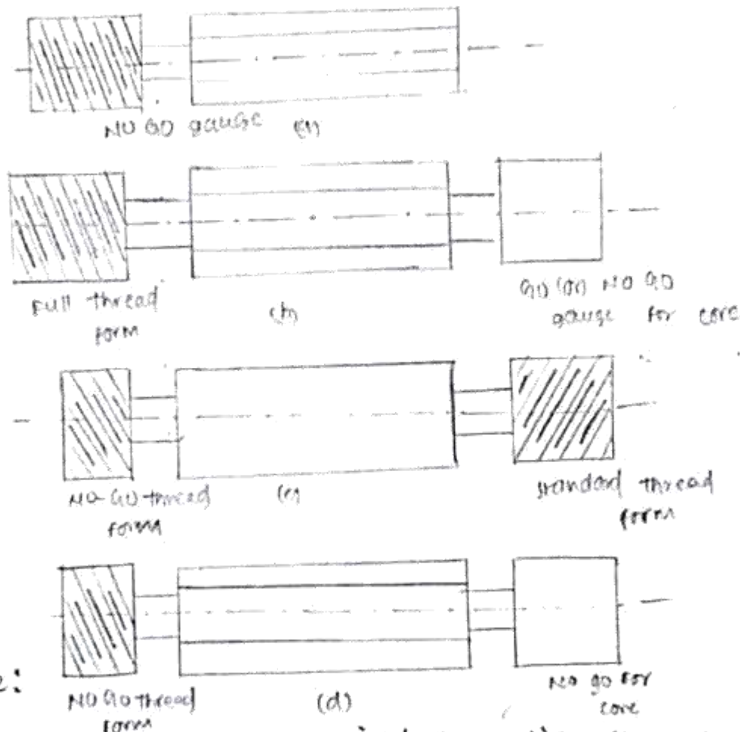
For gauging parallel internal screw threads, the following three gauges are recommended.

i) GO and NO-GO plug gauge to check the ~~minimum effective~~ Tolerance on the minor diameter.

ii) A GO screw plug gauge to check the mininum effective diameter.

iii) A NO-GO screw plug gauge to check the ~~minimum~~ maximum effective diameter

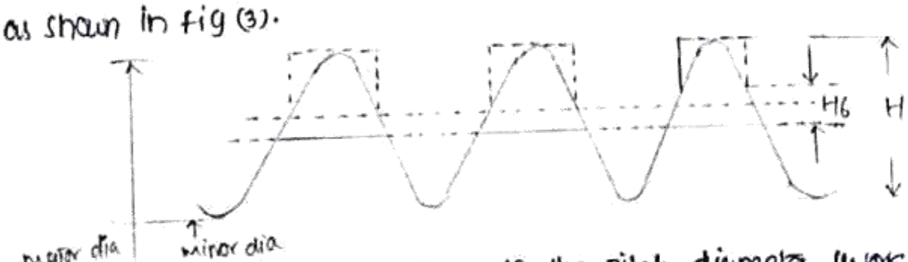
The gauges are made up of special quality steel, hardened before threads are grooved and finally lapped to perfect dimensions. Plug gauges are made in different designs according to the purpose. Most widely used patterns are shown in fig (4).



b) Ring screw gauge:

For the production gauging of bolts the equivalent mating surface of the bolt is said to be ring gauge. Ring gauges are also provided with the system of limits i.e., NO-GO and GO effective diameter ring gauges.

The NO-GO ring gauge is truncated on its minor diameter and cleared on major diameter as shown in fig (3).



A thread ring gauge will not engage, if the pitch diameter (work) is oversize, obviously neither it turn on as over size major diameter. If the minor diameter is off (i.e., the screw with roots filled with dirt, or made from worn die or late tool) the gauge will bind. Examine lead errors of screw threads like taper will be easily detected after a few turns of ring gauge. But, care must be taken while measuring five threads, that excessive force should not be applied to ring gauge.

c) Calliper gauges:

These gauges are equivalent of gap gauges with thread form on anvils. The front anvils have the full thread form cut on them and are set at a distance that it accept the screws below the upper size limit that means they are 'GO' gauge. The width of the anvils is such as to test the required length sufficient to raise the effective diameter to a value larger than anvils settings. If the screw passes through GO anvils it reaches near NO-GO root and truncated at crest and their function will not to be inference by any pitch error in the screw being engaged.

Hence, if a screw with correct effective diameter but has a pitch error, it will not be able to pass through GO anvils. The only way available except removing pitch error would be reduce its effective diameter, with this it will pass through GO and NO-GO anvils which will results in its rejection.

Gauging of screw threads:

Taylor's principle of limit gauging can be applied to threads also. According to Taylors principle of limit gauging, a GO gauges should check both size and geometric features and thus be of full form, whereas, NO-GO gauge should check only one dimension. In accordance with this, GO gauge is made to the full length and maximum diameter of thread. If NO-GO gauge is also made of full form, then due to pitch errors, virtual reduction in effective diameter and hence misleading results.

To overcome this difficulty and to account for taylor's principle, NO-GO gauges for threads are made to check for major and effective diameter, which are not influenced by pitch errors.

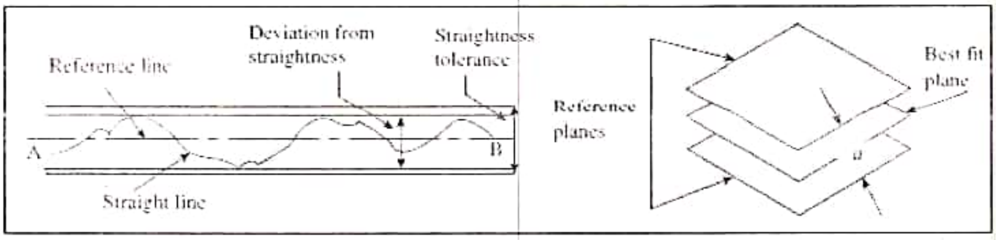
UNIT – VI

FLATNESS MEASUREMENT

Measurement of flatness of surface:

Machine tool tables, which hold work pieces during machining, should have a high degree of flatness. Many metrological devices like the sine bar invariably need a perfectly flat surface plate. Flatness error may be defined as the minimum separation of a pair of parallel planes that will just contain all the points on the surface. Figure 10.7 illustrates the measure of flatness error *a*. It is possible, by using simple geometrical approaches, to fit a best-fit plane for the macro surface topography.

Flatness is the deviation of the surface from the best-fit plane. According to IS: 2063-1962, a surface is deemed to be flat within a range of measurement when the variation of the perpendicular distance of its points from a geometrical plane (this plane should be exterior to the surface to be tested) parallel to the general trajectory of the plane to be tested remains below a given value.

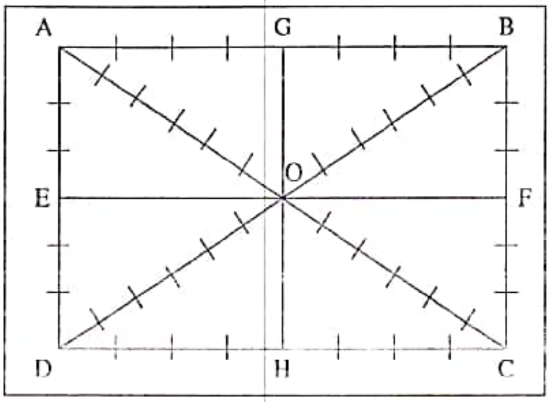


Straightness of a line measurement of flatness error

The geometrical plane may be represented either by means of a surface plane or by a family of straight lines obtained by the displacement of a straight edge, a spirit level, or a light beam. While there are quite a few methods for measuring flatness, such as the beam comparator method, interferometry technique, and laser beam measurement, the following paragraphs explain the simplest and most popular method of measuring flatness using a spirit level or a clinometer.

Measurement of flatness error

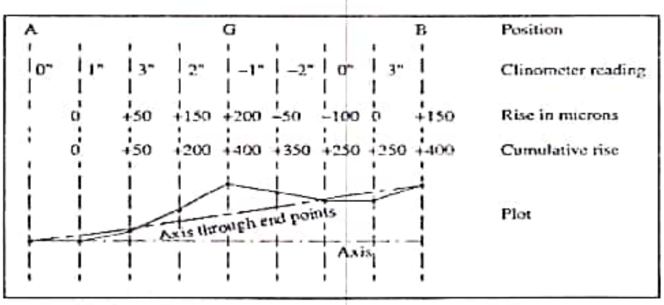
Assuming that a clinometer is used for measuring angular deviations, a grid of straight lines, as shown in Figure is formulated. Care is taken to ensure that the maximum area of the flat table or surface plate being tested is covered by the grid. Lines AB, DC, AD, and BC are drawn parallel to the edges of the flat surface; the two diagonal lines DB and AC intersect at the centre point O. Markings are made on each line at distances corresponding to the base length of the clinometer.



Grid lines for flatness test

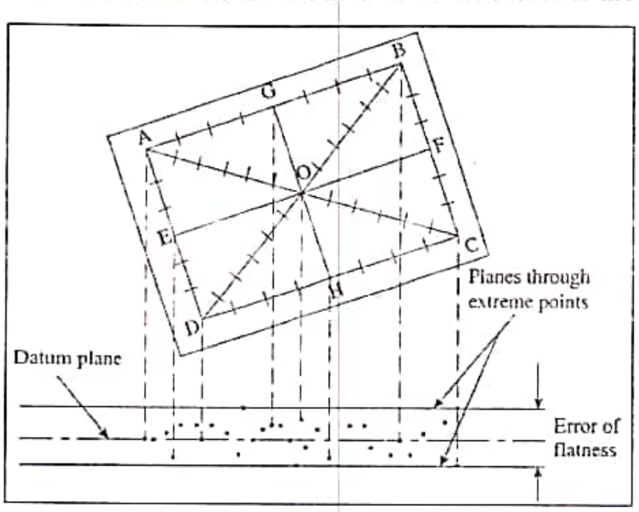
The following is a step-by-step procedure to measure flatness error:

1. Carry out the straightness test on all the lines and tabulate the readings up to the cumulative error column. Figure gives an example of line AB.
2. We know that a plane is defined as a 2D entity passing through a minimum of three points not lying on the same straight line. Accordingly, a plane passing through the points A, B, and D is assumed to be an arbitrary plane, relative to which the heights of all other points are determined. Therefore, the ends of lines AB, AD, and BD are corrected to zero and the heights of points A, B, and D are forced to zero.
3. The height of the centre 'O' is determined relative to the arbitrary plane ABD. Since O is also the mid-point of line AC, all the points on AC can be fixed relative to the arbitrary plane ABD. Assume A = 0 and reassign the value of O on AC to the value of O on BD. This will readjust all the values on AC in relation to the arbitrary plane ABD.
4. Next, point C is fixed relative to the plane ABD; points B and D are set to zero. All intermediate points on BC and DC are also adjusted accordingly.



Straightness plot for line AB

5. The same procedure applies to lines EF and GH. The midpoints of these lines should also coincide with the known midpoint value of O.
6. Now, the heights of all the points, above and below the reference plane ABD, are plotted as shown in Figure. Two lines are drawn parallel to and on either side of the datum plane, such that they enclose the
7. Outer most points. The distance between these two outer lines is the flatness error.



Plot of heights of all points with reference to the datum plane ABD

Some authors argue that the reference plane ABD that is chosen in this case may not be the best datum plane. They recommend further correction to determine the minimum separation between a pair of parallels that just contains all the points on the surface. However, for all practical purposes, this method provides a reliable value of flatness error, up to an accuracy of 10 μm.

Instruments used for flatness measurement:

1. Straight edge
2. Surface plate
3. Auto collimator...Etc.

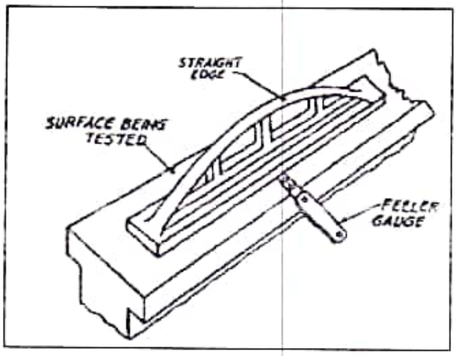
1. Straight edge:

A **straightedge** is a tool with an edge free from curves, or straight, used for transcribing straight lines, or checking the straightness of lines. If it has equally spaced markings along its length, it is usually called a ruler.

Straightedges are used in the automotive service and machining industry to check the flatness of machined mating surfaces.

True straightness can in some cases be checked by using a laser line level as an optical straightedge: it can illuminate an accurately straight line on a flat surface such as the edge of a plank or shelf.

A pair of straightedges called winding sticks are used in woodworking to amplify twist (wind) in pieces of wood.



Straight edge

An idealized straightedge is used in compass-and-straightedge constructions in plane geometry. It may be used:

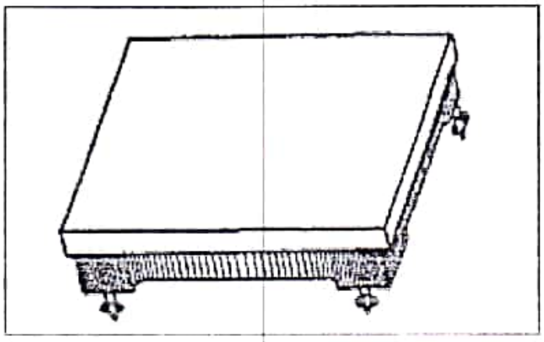
- Given two points, to draw the line connecting them.
- Given a point and a circle, to draw either tangent.
- Given two circles, to draw any of their common tangents.

It may not be marked or used together with the compass so as to transfer the length of one segment to another.

It is possible to do all compass and straightedge constructions without the straightedge. That is, it is possible, using only a compass, to find the intersection of two lines given two points on each, and to find the tangent points to circles. It is not, however, possible to do all constructions using only a straightedge. It *is* possible to do them with straightedge alone given one circle and its center.

2. Surface plate:

A **surface plate** is a solid, flat plate used as the main horizontal reference plane for precision inspection, marking out (layout), and tooling setup. The surface plate is often used as the baseline for all measurements to the work piece, therefore one primary surface is finished extremely flat with accuracy up to 0.00001 in or 250 nm for a grade AA or AAA plate. Surface plates are a very common tool in the manufacturing industry and are often permanently attached to robotic type inspection devices such as a coordinate-measuring machine. Plates are typically square or rectangular. One current British Standard includes specifications for plates from 160 mm x 100 mm to 2500 mm x 1600 mm.



Surface plate

3. Autocollimator

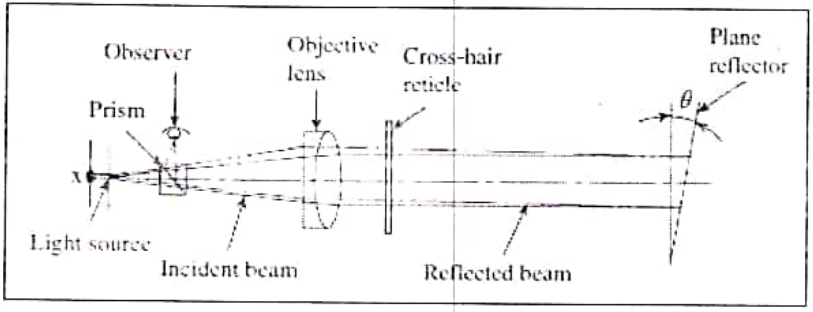
It is a special form of telescope that is used to measure small angles with a high degree of resolution. It is used for various applications such as precision alignment, verification of angle standards, and detection of angular movement, among others. It projects a beam of collimated light onto a reflector, which is deflected by a small angle about the vertical plane. The light reflected is magnified and focused on to an eyepiece or a photo detector. The deflection between the beam and the reflected beam is a measure of the angular tilt of the reflector. Figure illustrates the working principle of an autocollimator.

The reticle is an illuminated target with a cross-hair pattern, which is positioned in the focal plane of an objective lens. A plane mirror perpendicular to the optical axis serves the purpose of reflecting an image of the pattern back on to the observation point. A viewing system is required to observe the relative position of the image of the cross-wires. This is done in most of the autocollimators by means of a simple eyepiece. If rotation of the plane reflector by an angle q results in the displacement of the image by an amount d, then, $d = 2fq$, where f is the focal length of the objective lens.

It is clear from this relationship that the sensitivity of an autocollimator depends on the focal length of the objective lens. The longer the focal length, the larger the linear displacement for a given tilt of the plane reflector. However, the maximum reflector tilt that can be accommodated is consequently reduced. Therefore, there is a trade-off between sensitivity and measuring range. The instrument is so sensitive that air currents between the optical path and the target mirror can cause fluctuations in the readings obtained. This effect is more severe when the distance between the two increases. Therefore, an autocollimator is housed inside a sheet-metal or a PVC plastic casing to ensure that air currents do not hamper measurement accuracy.

Autocollimators may be classified into three types:

1. Visual or conventional autocollimator
2. Digital autocollimator
3. Laser autocollimator



Principle of autocollimator

Visual Autocollimator

In this type of autocollimator, the displacement of the reflected image is determined visually. A pinhole light source is used, whose reflected image is observed by the operator through an eyepiece. Visual collimators are typically focused at infinity, making them useful for both short and long-distance measurements. The plane reflector is one of the vital parts of an autocollimator, because a mirror that is not flat will defocus the return image, resulting in poor definition of the image. High-quality mirrors with a flatness tolerance of 1 μm per 100 mm are used. Most visual collimators have a resolution of 3–5" over a distance of 1.5 m.

The following are some of the typical applications of visual autocollimators:

1. Determination of angular measurements up to 3"
2. Determination of straightness of machine guide ways
3. Determination of parallelism of slide movements with respect to guide ways
4. Flatness estimation of machine tables, surface plates, etc.
5. Verification of right angle prisms for angular errors
6. Angle comparisons of reflecting surfaces

Digital Autocollimator

A digital autocollimator uses an electronic photo detector to detect the reflected light beam. A major advantage of this type of collimator is that it uses digital signal processing technology to detect and process the reflected beam. This enables the filtering out of stray scattered light, which sharpens the quality of the image. The illuminated target reticle slit is imaged back in its own plane through the objective lens and reflecting mirror. It is then re-imaged onto a vibrating slit by means of a relay lens. A photocell positioned behind the vibrating slit generates an output, which captures both the magnitude and the direction of rotation of the mirror from a central null position. These instruments have a resolution of up to 0.01 arc-second and a linearity of 0.1%. Since the output is digital in nature, it can be transferred to a data acquisition system, thereby facilitating storage and further processing of data. Another major advantage is that it can also measure angles of dynamic systems to a high degree of resolution, thanks to high sampling rates of digital electronic systems.

The following are some of the applications of a digital autocollimator:

1. Angular measurement of static as well as dynamic systems
2. Alignment and monitoring of robotic axes
3. Verification of angular errors of rotary tables, indexing heads, and platforms of machine parts
4. Remote monitoring of alignment of large mechanical systems

Laser Autocollimator

Laser autocollimators represent the future of precision angle measurement in the industry. Superior intensity of the laser beam makes it ideal for the measurement of angles of very small Objects (1 mm in diameter) as well as for long measuring ranges that extend to 15 m or more. Another marked advantage is that a laser autocollimator can be used for the measurement of Non-mirror-quality surfaces. In addition, the high intensity of the laser beam creates ultra-low noise measurements, thereby increasing the accuracy of measurement. TL40 and TL160 lasers are popular in autocollimators.

MACHINE TOOL ALIGNMENT TESTS

The basic objective of conducting acceptance tests is to ensure that all relative movements of the machine tool conform well within the accepted limits of deviations from designed values. This is important since the dimensions of the work part depend, to a large extent, on the accuracy of the mating parts of the machine tool. The phrase *acceptance test* is coined to signify the fact that the machine buyer will inspect the alignment of various parts of the machine tool in detail and will 'accept' the machine tool from the vendor's factory only after it conforms to accepted norms.

We can broadly classify the various tests under the following groups:

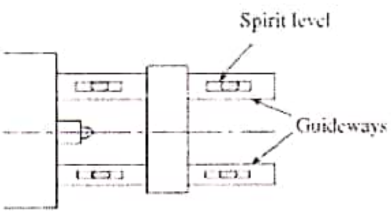
1. Tests for ensuring levelling of the machine tool in both horizontal and vertical planes
2. Tests for flatness of machine bed and straightness as well as parallelism of bed ways and bearing surfaces
3. Tests for Perpendicularity of guide ways with respect to other guide ways or bearing surfaces
4. Tests for true running of the machine spindle and its axial movements
5. Tests for assessing parallelism of spindle axis to guide ways or bearing surfaces
6. Tests for line of movements for slides, cross-slides, and carriages
7. Practical tests for assessing dimensional and geometric accuracy in machining

The following are the important tests carried out on a lathe:

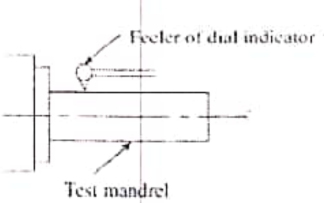
Levelling of machine First and foremost, the machine should be checked for accuracy of levelling. The machine should be installed such that the lathe bed is truly horizontal. A sensitive spirit level or a clinometer can be used to verify the levelling of the machine. The spirit level is moved over the designated distance specified in the test chart, and the deviation is noted down. The test is carried out in both longitudinal and transverse directions.

True running of main spindle The main spindle, while running, should not have any play or radial deviations from its axis. This is tested using a test mandrel of acceptable quality. The mandrel is fitted to the spindle bore and the dial indicator feeler is made to contact the mandrel surface as shown in Figure. The spindle is gently rotated by hand, and the deviations of the dial indicator are noted down. The dial indicator base is mounted on the carriage. The deviation should be within acceptable limits.

Axial slip of main spindle The spindle should have true running in a direction parallel to its axis. This is easily checked by placing the dial indicator feeler against the spindle face and giving slight rotation to the spindle. The deviations should be within acceptable limits. The test is repeated at a diametrically opposite location to ensure that the spindle does not have an axial slip.



Levelling of the machine

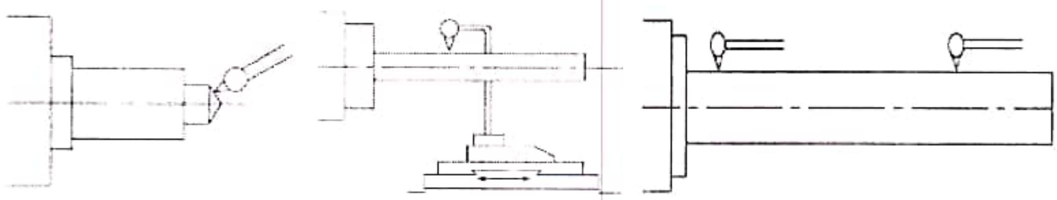


true running of main spindle

axial slip of main spindle

True running of headstock centre The headstock centre is the live centre of the machine; if it is not true, accuracy of the work piece will suffer. The work piece will develop eccentricity if the error is too much. The feeler of the dial indicator is pressed perpendicular to the taper surface of the centre, and the spindle is rotated. The deviation indicates the trueness of the headstock centre. The test procedure is illustrated in Figure.

Parallelism of main spindle Parallelism of the spindle is crucial for generating accurate dimensions. Any error in parallelism will result in a tapered surface after machining. In order to test parallelism, a test mandrel is made use of. It is fitted into the spindle bore and dial gauge readings are taken over a specified length, as shown in Figure. Two readings are taken, one in a horizontal plane and the other in a vertical plane, on one of the sides of the mandrel. It is important to see that excess overhang of the mandrel does not result in a sag due to its own weight.

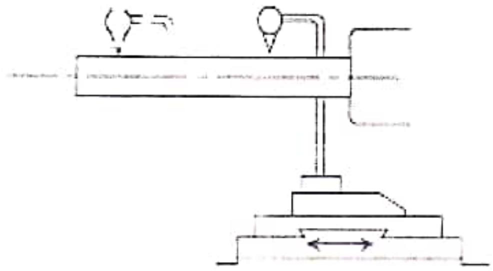


True running of head stock center **parallelism of main spindle** **true running of spindle taper bore**

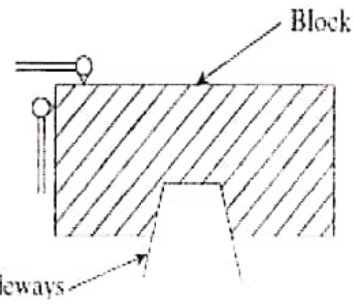
True running of taper bore of main spindle The lathe spindle bore has a standard taper. Unless this taper is concentric with the spindle axis, work pieces will have undesired taper or eccentricity. A test mandrel is fitted to the tapered bore of the spindle, and dial gauge readings are taken at the two extreme ends of the mandrel. This value should be well within the allowable limits.

Parallelism of tailstock sleeve to carriage movement A tailstock is generally used to hold long work pieces. The dead centre of the tailstock is mounted on the end of the sleeve, which moves in an axial direction. The sleeve surface should be perfectly parallel to the movement of the carriage. A mandrel is put in the sleeve socket and dialling is done by mounting the dial gauge base on the tool post, as shown in Figure. The test should be carried out in both the horizontal and vertical planes.

Parallelism of tailstock guide ways to carriage movement The tailstock guide ways should be parallel to the movement of the carriage. Whenever long jobs are being turned, it becomes necessary to shift the tailstock along its guide ways. While doing so, the job axis should perfectly coincide with the tailstock centre. If this condition is not satisfied, the work piece will develop an undesirable taper. A test block, specially designed for the purpose, is placed on the guide ways, as shown in Figure. The dial indicator base is mounted on the carriage and the feeler is made to contact the work piece. The carriage is moved for the specified distance and the deviation is noted down. The test is carried out in both the horizontal and vertical planes.



Parallelism of a tail stock sleeve



Parallelism of a tail stock guide ways

Practical tests Actual machining is carried out in order to ascertain not only the accuracy of alignment but also the rigidity of the machine tool. At least three turning operations are mandatory, namely chucking (using the chuck only), turning between centres, and facing. The operations are performed with prescribed values of cutting speed, feed rate, and depth of cut. Table illustrates the recommended ways of conducting practical tests on lathes.

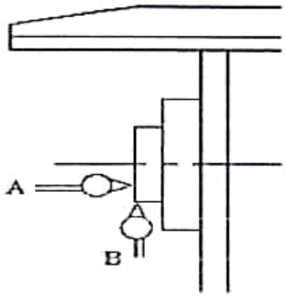
Operation	Workpiece diameter (mm)	Permissible error (mm)
Chucking	50–100	0.01
Turning between centres	100–200	0.02
Facing	100–200	0.02

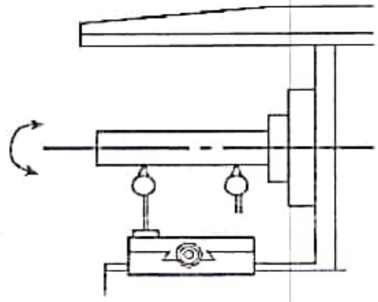
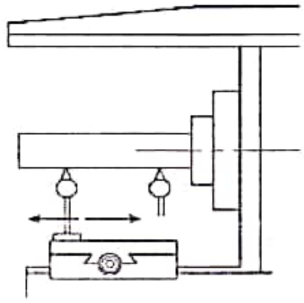
Recommended practical tests

Acceptance Tests for Milling Machines

It is presumed that the student is aware of the various types of milling machines. However, we will deal with some of the important tests conducted on a horizontal milling machine in order to provide the student with a fair knowledge of the methodology.

Axial slip of spindle A spindle may have an axial slip, which is the axial movement of the spindle during its rotation. Axial slip may occur due to the following reasons: errors due to worn-out spindle bearings, face of the locating shoulder of the spindle not being in a plane perpendicular to the axis of the spindle, and irregularities in the front face of the spindle. Figure 10.25 illustrates the test for measuring the axial slip of the spindle. The feeler of the dial gauge is held against the front face of the spindle and the base is mounted on the table. The position of the dial gauge (in order to measure axial slip) is denoted by A in the figure. The spindle is gently rotated by hand and the dial gauge reading is noted down. The test is repeated at a diametrically opposite spot. The maximum deflection should be well within the prescribed limits.



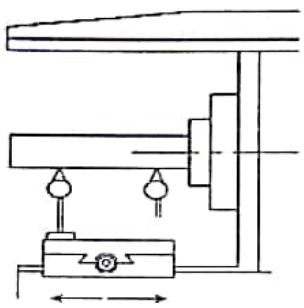



Measuring axial slip of spindle   true running of spindle taper   parallelism of work table to spindle axis

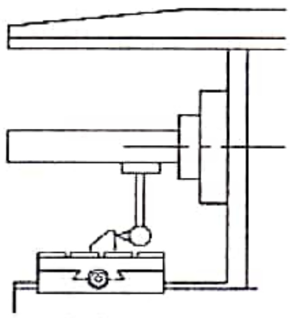
Eccentricity of external diameter of spindle Position B of the dial gauge shown in Figure is used to determine the eccentricity of the external diameter of the spindle. The feeler is made to contact the spindle face radially, and the dial gauge base is mounted on the machine table. The spindle is gently rotated by hand and the dial gauge deviation is noted down. The maximum deviation gives the eccentricity of the external diameter of the spindle, and it should be well within specified limits.

True running of inner taper of spindle The spindle of a milling machine is provided with a standard taper, which matches with the tooling used on the machine. The axis of the taper should be perfectly coincident with the axis of the spindle. Otherwise, the work pieces will develop undesired taper or eccentricity after machining. This condition is checked by using a test mandrel that fits into the spindle taper. The dial gauge is mounted on the machine table, and the feeler is made to contact the mandrel at one end of the mandrel, as shown in Figure. The maximum deviation of the dial gauge is noted by gently rotating the spindle by hand. The test is repeated at the other end of the mandrel.

Parallelism of work table surface to spindle axis Work pieces are clamped on the top surface of the work table of the machine. We should ensure that the work table surface is parallel to the spindle axis; otherwise, milled surfaces will not meet quality requirements. A test mandrel is fitted to the spindle. If the machine has an arbour, the arbour surface is checked for parallelism. The feeler of the dial gauge is made to contact the mandrel or arbour, as the case may be, and the base of the dial gauge is kept on the table surface. Now the dial gauge base is moved on the table surface in a direction parallel to the spindle axis till the extreme end, as shown in Figure. The dial gauge deflection is noted down, which should be well within the permissible limits.



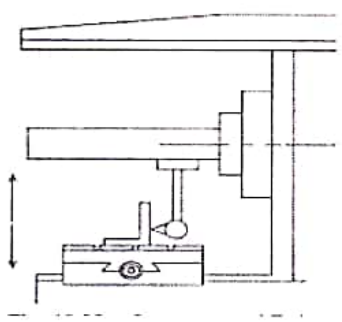
Parallelism of table movement with spindle axis



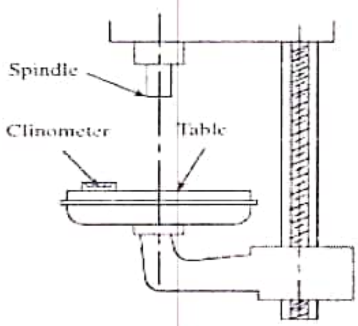
parallelism of T-slots with table movement

Parallelism of transverse movement of table to spindle axis The machine table is set in its mean position and the dial gauge base is mounted on the table. The feeler is made to contact the mandrel and the table is given motion in the transverse direction. The test is carried out both in the horizontal and vertical planes of the mandrel. The deviation on the dial indicator should be within permissible limits.

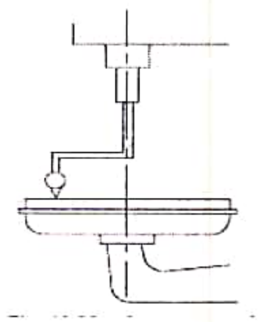
Parallelism of T-slots to table movement A number of T-slots are provided on the machine table to enable accurate clamping of work holding devices, which in turn hold the work pieces. The vertical surfaces of the T-slots should be perfectly parallel to the longitudinal axis of the machine in the horizontal plane. Generally, the test is carried out for the central T-slot, and an accessory, namely a Tenon, is used. A Tenon is a 150 mm long simple bracket, which fits into the T-slot. While sitting in a T-slot, a butting surface projects out, which is parallel to the vertical surface of a T-slot. The dial gauge base is mounted on the spindle and the feeler is made to contact the Tenon, as shown in Figure. Now, the machine table is moved longitudinally while the tennon block is held stationary. Deviations from parallelism are noted from the dial gauge.



Squareness of T-slots with the spindle



flatness o table



Squareness of table with the Spindle axis

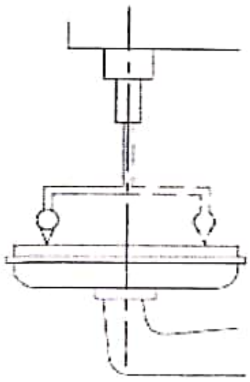
Squareness of T-slots with machine spindle Un less the T-slots are parallel to the spindle axis, slots or key ways cut on the work piece will not be aligned in the required direction. As in the previous case, this test is also generally carried out for the central T-slot. The table is approximately set in a mid-position, and a Tenon block is inserted in the T-slot. The dial gauge base is fixed to the mandrel and the feeler is brought in contact with the vertical surface of the Tenon. Now, the Tenon is moved towards one of the ends and the dial gauge swung to establish contact with the Tenon. The reading on the dial gauge is noted. The Tenon block is moved towards the other end and the dial gauge swung the other way in order to establish contact again. The difference in reading, which is a measure of the squareness error, is noted down. The preceding paragraphs provided some insight into the important acceptance tests carried out on a horizontal milling machine. It is recommended that 25–30 different tests be carried out on a milling machine before it can be accepted for production work. Only a few tests are highlighted here. The student is advised to visit the metrology laboratory in the institute and go through the detailed acceptance charts provided by the machine suppliers. Subsequent to the aforementioned tests, it is recommended to carry out practical tests by milling test pieces. One has to check for accuracy in surface milling, end milling, and slot milling before certifying the machine to be fit for use on a production shop floor.

Acceptance Tests for Drilling Machines

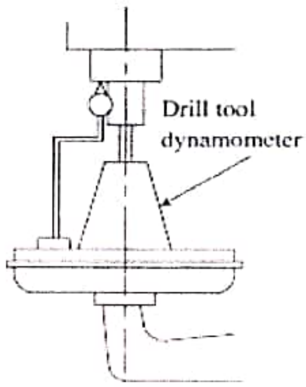
There are various types of drilling machines such as sensitive drilling machine, pillar-type drilling machine, and radial drilling machine. This section deals with the acceptance tests recommended for a pillar-type drilling machine.

Flatness of clamping surface of table This test is performed for the table of the milling machine. The table surface provides support to either clamp the work piece directly or to clamp a fixture that holds the work piece. The test is performed using a sensitive spirit level or a clinometer with good resolution. **Squareness of clamping surface of table with spindle axis** It is important to ensure that the clamping surface of the machine table is perfectly square with the axis of the spindle. Unless this condition is satisfied, the drilled hole will not be parallel to the spindle axis. The arrangement for the test is shown in Figure. The dial gauge base is mounted on the spindle, and the feeler is made to touch the machine table and set to zero. Now, the table is rotated slowly by 180°, without disturbing the dial gauge base, which is in the spindle. The change in reading is noted down; it is then checked to see if it is within the permissible limits.

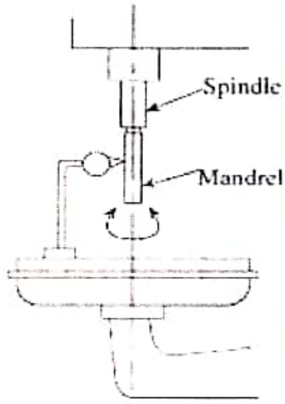
Squareness of spindle axis with table This is the corollary to the aforementioned test. Even though the mounting arrangement for the dial gauge is the same, the spindle rather than the table is moved by 180°, in order to determine the error in squareness



Squareness of the spindle axis with the table

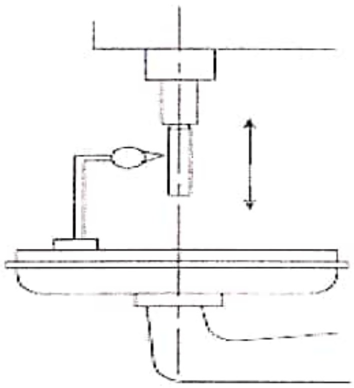


deflection of a spindle

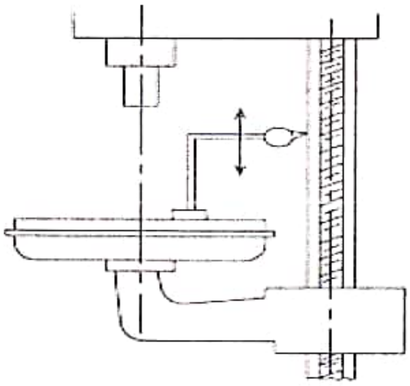


true running of a spindle taper

Total deflection of spindle During the drilling operation, the spindle experiences high axial force. The spindle should not deflect excessively due to this force. Otherwise, the drilled hole will have error of straightness and eccentricity. In order to evaluate deflection of the spindle, a drill tool dynamometer (DTD) is used. The DTD provides a means of applying a known amount of load on the spindle. The drill spindle is loaded by moving the drill head downwards and recording the value of force on the DTD display screen. The base of the dial indicator is placed on the machine table. The feeler is held against the spindle face. The recommended pressure is applied on the spindle and the dial gauge deflection is noted down.



Parallelism of a spindle axis with its vertical movement



Squareness of guide ways with table

True running of spindle taper The true running of a spindle taper is tested using a test mandrel. The test mandrel is loaded in the spindle and the dial gauge base is fixed on the machine table. The feeler is made to contact the mandrel surface and the spindle is gently rotated by hand. The dial indicator reading is noted down and it is ascertained if the reading is within permissible limits. The test is repeated at three different locations to ensure its validity.

Parallelism of spindle axis to its vertical movement While drilling holes, the spindle is given feed in the vertical direction, and therefore, it is necessary to ensure that the vertical movement of the spindle is parallel to its axis. The test setup is illustrated in Fig. 10.36. The mandrel is fixed in the spindle, and the dial gauge is mounted with the feeler making contact with the mandrel at the bottom. The spindle is moved vertically by hand feed and the dial gauge reading is noted down. The test is repeated in another plane by rotating the spindle through 90°. The total deflection shown by the dial gauge should be well within the allowable limits.

Squareness of drill head guide ways with table The drill head in a pillar-type machine moves up and down in order to accommodate various work piece sizes. This up and down movement is facilitated by guide ways. Therefore, it is important to ensure that this motion of the drill head is perfectly square with the clamping surface of the work table. If this condition is not met, the drilled holes will be skewed from the vertical axis and the work piece will fail to pass inspection.