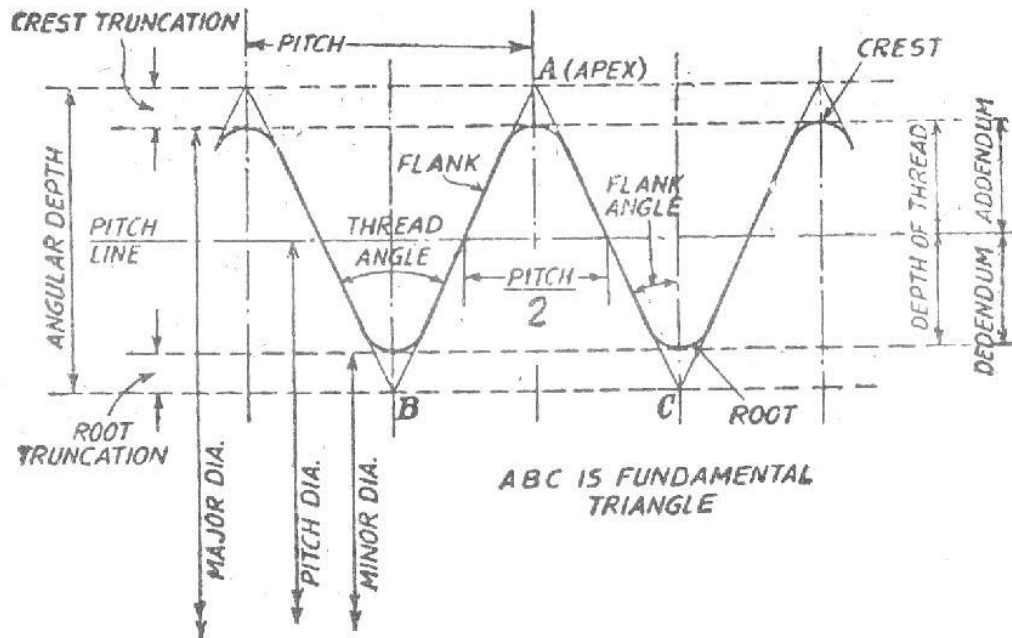


CHAPTER 5

SCREW THREADS

5.1 Terminology of Screw Threads:



1. **Screw thread.** A screw thread is the helical ridge produced by forming a continuous helical groove of uniform section on the external or internal surface of a cylinder or cone. A screw thread formed on a cylinder is known as straight or parallel screw thread, while the one formed on a cone or frustum of a cone is known as tapered screw thread.
2. **External thread.** A thread formed on the outside of a workpiece is called external thread e.g., on bolts or studs etc.
3. **Internal thread.** A thread formed on the inside of a workpiece is called internal thread e.g. on a nut or female screw gauge.
4. **Multiple-start screw thread.** This is produced by forming two or more helical grooves, equally spaced and similarly formed in an axial section on a cylinder. This gives a 'quick traverse' without sacrificing core strength.
5. **Axis of a thread.** This is imaginary line running longitudinally through the centre of the screw.
6. **Hand (Right or left hand threads).** Suppose a screw is held such that the observer is looking along the axis. If a point moves along the thread in clockwise direction and thus moves away

from the observer, the thread is right hand ; and if it moves towards the observer, the thread is left hand.

7. **Form, of thread.** This is the shape of the contour of one- complete thread as seen in axial section.

8. **Crest of thread.** This is defined as the prominent part of thread, whether it is external or internal.

9. **Root of thread.** This is defined as the bottom of the groove between the two flanks of the thread, whether it be external or internal.

10. **Flanks of thread.** These are straight edges which connect the crest with the root.

11. **Angle of thread {Included angle}.** This is the angle between the flanks or slope of the thread measured in an axial plane.

12. **Flank angle.** The flank angles are the angles between individual flanks and the perpendicular to the axis of the thread which passes through the vertex of the fundamental triangle. The flank angle of a symmetrical thread is commonly termed as the half- angle of thread.

13. **Pitch.** The pitch of a thread is the distance, measured parallel to the axis of the thread, between corresponding points on adjacent thread forms in the same axial plane and on the same side of axis. The basic pitch is equal to the lead divided by the number of thread starts. On drawings of thread sections, the pitch is shown as the distance from the centre of one thread crest to the centre of the next, and this representation is correct for single start as well as multi-start threads.

14. **Lead.** Lead is the axial distance moved by the threaded part, when it is given one complete revolution about its axis with respect to a fixed mating thread. It is necessary to distinguish between measurements of lead from measurement of pitch, as uniformity of pitch measurement does not assure uniformity of lead. Variations in either lead or pitch cause the functional or virtual diameter of thread to differ from the pitch diameter.

15. **Thread per inch.** This is the reciprocal of the pitch in inches.

16. **Lead angle.** On a straight thread, lead angle is the angle made by the helix of the thread at the pitch line with plane perpendicular to the axis. The angle is measured in an axial plane.

17. **Helix angle.** On straight thread, the helix angle is the angle made by the helix of the thread at the pitch line with the axis. The angle is measured in an axial plane.

18. **Depth of thread.** This is the distance from the crest or tip of the thread to the root of the thread measured perpendicular to the longitudinal axis or this could be defined as the distance measured radially between the major and minor cylinders.

19. **Axial thickness.** This is the distance between the opposite faces of the same thread measured on the pitch cylinder in a direction parallel to the axis of thread.

20. **Fundamental triangle.** This is found by extending the flanks and joining the points B and C. Thus in Fig. 13.2, triangle ABC is referred to as fundamental triangle. Here BC=pitch and the vertical height of the triangle is called the angular or theoretical depth. The point A is the apex of the triangle ABC.

21. **Truncation.** A thread is sometimes truncated at the crest or at the root or at both crest and root. The truncation at the crest is the radial distance from the crest to the nearest apex of the fundamental triangle. Similarly the truncation at the root is the radial distance from the root to the nearest apex.

22. **Addendum.** For an external thread, this is defined as the radial distance between the major and pitch cylinders. For an internal thread this is the radial distance between the minor and pitch cylinders.

23. **Dedendum.** This is the radial distance between the pitch and minor cylinder for external thread, and for internal thread, this is the radial distance between the major and pitch cylinders.

24. **Major diameter.** In case of a straight thread, this is the diameter of the major cylinder (imaginary cylinder, co-axial with the screw, which just touches the crests of an external thread or the root of an internal thread). It is often referred to as the outside diameter, crest diameter or full diameter of external threads.

25. **Minor diameter.** In case of straight thread, this is the diameter of the minor cylinder (an imaginary cylinder, co-axial with the screw Which just touches the roots of an external thread or the crest of an internal thread). It is often referred to as the root diameter or cone diameter of external threads.

26. **Effective diameter or pitch diameter.** In case of straight thread, this is the diameter of the pitch cylinder (the imaginary' cylinder which is co-axial with the axis of the screw, and intersects the flank of the threads in such a way as to make the width of threads and width of the spaces between the threads equal). If the pitch cylinder be imagined as generated by a straight line parallel to the axis of screw that straight line is then referred to as the pitch line. Along the

pitch line, the widths of the threads and the widths of the spaces are equal on a perfect thread. This is the most important dimension as it decides the quality of the fit between the screw and the nut.

27. Functional (virtual) diameter. For an external or internal thread, this is the pitch diameter of the enveloping thread of perfect pitch, lead and flank angles having full depth of engagement but clear at crests and roots. This is defined over a specified length of thread. This may be greater than the simple effective diameter by an amount due to errors in pitch and angle of thread. The virtual diameter being the modified effective diameter by pitch and angle errors, is the most important single dimension of a screw thread gauge.

5.2. ERRORS IN THREADS

- In the case of plain shafts and holes, there is only one dimension (i.e. diameter), which has to be considered
- While in the case of screw threads there are at least five important elements, Major Diameter, Minor Diameter, Effective Diameter, Pitch And Angle Of The Thread Form
- Errors on the major and minor diameters will cause interference with the mating thread. Similarly pitch and angle errors are also not desirable as they cause a progressive tightening and interference on assembly.

PITCH ERRORS IN SCREW THREADS:

Generally the threads are generated by a point cutting tool.

The ratio of the linear velocity of tool and angular velocity of the work must be correct and constant, otherwise pitch errors will occur.

If there is some error in pitch, then the total length of thread engaged will be either too great or too small, the total pitch error in overall length of the thread being called the cumulative pitch error.

Various pitch errors can be classified as:

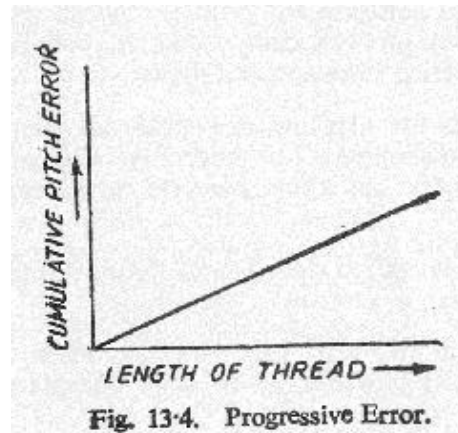
- Progressive
- Periodic
- Irregular
- Erratic.

(i) **PROGRESSIVE PITCH ERROR.**

This error occurs when the tool work velocity ratio is incorrect.

May caused due to pitch errors in the lead screw of the lathe or other generating machine.

The other possibility is by using an incorrect gear or an approximate gear train between work and lead screw e.g.,



II. PERIODIC PITCH ERROR

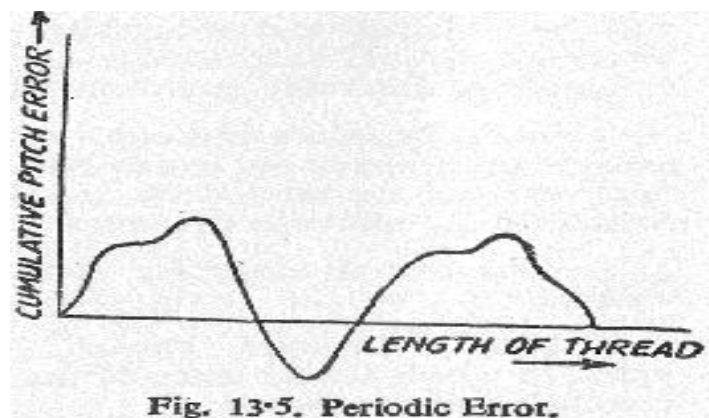
This repeats itself at regular intervals.

Successive portions of the thread are either longer or shorter than the mean.

Error occurs when the tool work velocity ratio is not constant.

Results when a thread is cut from a leadscrew which lacks squareness causing leadscrew to move backward and forward once in each revolution.

Errors are cyclic and pitch increases to a maximum, and then reduces through normal value to a minimum and so on. The graph between the cumulative pitch error and length of threads for this error will, therefore, be of sinusoidal form.



iii) Irregular Errors. These arise from disturbances in the machining set-up, variations in the cutting properties of material etc. Thus they have no specific causes and correspondingly no specific characteristics also.

Erratic Pitch. This is the irregular error in pitch and varies irregularly in magnitude over different lengths of thread.

iv) Drunken error:

- Error occurs when thread is not cut to the true helix angle.
-

6.3 Measurement of various elements in screw threads:

Most important six elements

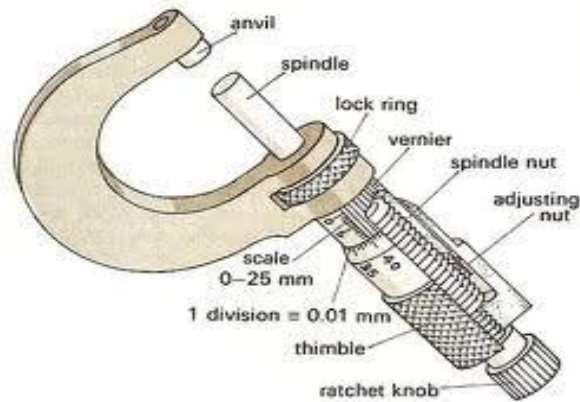
- a) Major Diameter
- b) Minor Diameter
- c) Effective Diameter
- d) Pitch
- e) Thread Angle
- f) Thread Form.

a) Major Diameter:

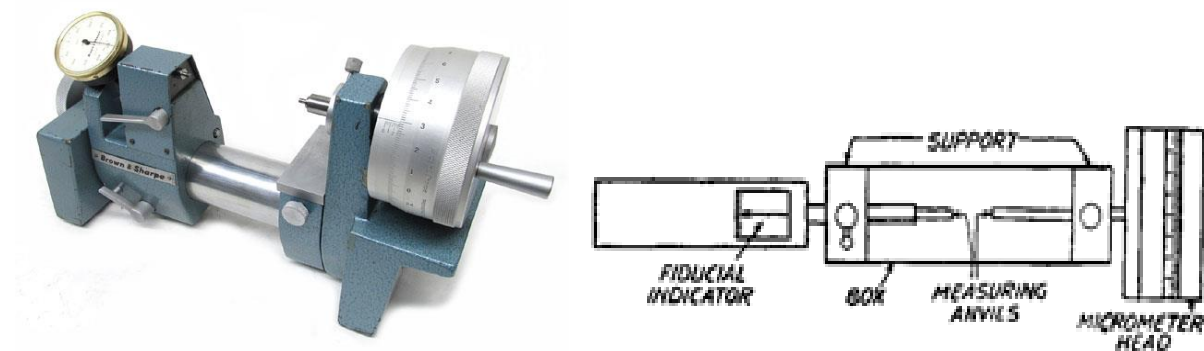
Major Diameter is usually measured by

- ❑ MICROMETER
- ❑ BENCH MICROMETER

A good quality hand micrometer is quite suitable. In taking readings, a light pressure must be used as the anvils make contact with the gauge at points only and otherwise the errors due to compression can be introduced. It is, however, also desirable to check the micrometer reading on a cylindrical standard of approximately the same size, so that the zero error etc., might not come into picture.

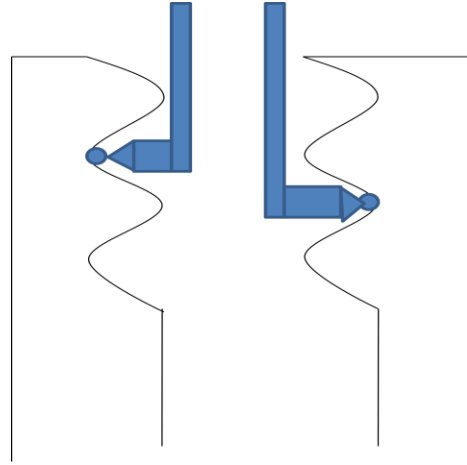


For greater accuracy and convenience, the major diameter is measured by bench micrometer. This instrument was designed by N.P.L. to estimate some deficiencies inherent in the normal hand micrometer. It uses constant measuring pressure and with this machine the error due to pitch error in the micrometer thread is avoided. In order that all measurements are made at the same pressure, a fiducial indicator is used in place of the fixed anvil. In this machine there is no provision for mounting the workpiece between the centres and it is to be held in hand. This is so, because, generally the centres of the workpiece are not true with its diameter. This machine is used as a comparator in order to avoid any pitch errors of micrometers, zero error setting etc. A calibrated setting cylinder is used as the setting standard.



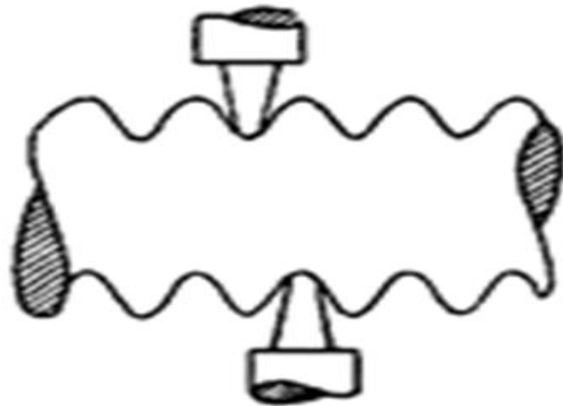
Measurement of Major Dia for Internal Screw Thread:

Stylus probe instrument is used for MEASURING Major diameter of internal screw thread as shown



b) Measurement of Minor Diameter:

This is also measured by a comparative process using small Vee-pieces which make contact with a root of the thread. The Vee-pieces are available in several sizes having suitable radii at the edges. The included angle of Vee-pieces is less than the angle of the thread to be checked so that it can easily probe to the root of the thread. To measure the minor diameter by Vee-pieces is suitable for only Whitworth and B.A. threads which have a definite radius at the root of the thread. For other threads, the minor diameter is measured by the projector or microscope.



The measurement is carried out on a floating carriage diameter measuring machine in which the threaded work-piece is mounted between centres and a bench micrometer is constrained to move at right angles to the axis of the centre by a Vee-ball slide. The method of the application of Vee-pieces in the machine is shown diagrammatically in Fig.. The dimensions of Vee-pieces play no important function as they are interposed between the micrometer faces and the cylindrical standard when standard reading is taken. It is important while taking

readings, to ensure that the micrometer be located at right angles to the axis of the screw being measured. The selected Vees are placed on each side of the screw with their bases against the micrometer faces. The micrometer head is then advanced until the pointer of the indicator is opposite the zero mark, and note being made of the reading. The screw is then replaced by standard reference disc or a plain cylindrical standard plug gauge of approximately the core diameter of the screw to be measured and second reading of the micrometer is taken.

c) **Effective Diameter Measurements.**

The effective diameter or the pitch diameter can be measured by . any one of the following methods :

- (i) The micrometer method
- ii) The one wire, two wire, or three wire or rod method.

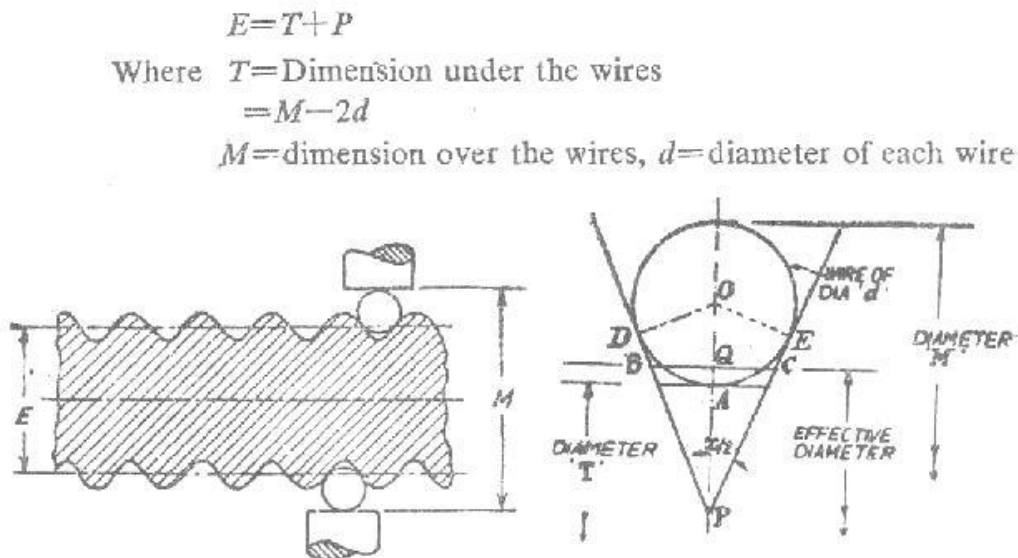
Two Wire Method.

The effective diameter of a screw thread may be ascertained by placing two wires or rods of identical diameter between the flanks of the thread, as shown in Fig. 13.15, and measuring the distance over the outside of these wires. The effective diameter E is then calculated as

$$E = T + P$$

Where T = Dimension under the wires $= M - 2d$

M = dimension over the wires, d = diameter of each wire



The wires used are made of hardened steel to sustain the wear and tear in use. These are given a high degree of accuracy and finish by lapping to suit different pitches. Dimension T can also be determined by placing wires over a standard cylinder of diameter greater than the diameter under the wires and noting the reading R1 and then taking reading with over the gauge, say R2.

Then $T = S - (R1 - R2)$.

P = It is a value which depends upon the dia of wire and pitch of the thread.

If P = pitch of the thread, then

$P = 0.9605p - 1.1657d$ (for Whitworth thread).

$P = 0.866p - d$ (for metric thread).

Actually P is a constant Value which has to be added to the diameter under the wires to give the effective diameter. The expression for the value of P in terms of p (pitch), d (diameter of wire) and x (thread angle) can be derived as follows :

In Fig (b), since BC lies on the effective diameter line

$$BC = \frac{1}{2} \text{ pitch} = \frac{1}{2} p$$

$$OP = d \operatorname{cosec} \frac{x}{2}$$

$$PA = d (\operatorname{cosec} \frac{x}{2} - 1)$$

$$PQ = QC \cot \frac{x}{2} = \frac{p}{4} \cot \frac{x}{2}$$

$$AQ = PQ - AP = \frac{p}{4} \cot \frac{x}{2} - d (\operatorname{cosec} \frac{x}{2} - 1)$$

AQ is half the value of P

$$\therefore P \text{ value} = 2AQ$$

$$= \frac{p}{2} \cot \frac{x}{2} - d (\operatorname{cosec} \frac{x}{2} - 1)$$

Two wire method can be carried out only on the diameter measuring machine described for measuring the minor diameter, because alignment is not possible by 2 wires and can be provided only by the floating carriage machine. In the case of three wire method, 2 wire, on one side help in aligning the micrometer square to the thread while the third placed on the other side permits taking of readings.

Three Wire Method.

This method of measuring the effective diameter is an accurate method. In this three wires or rods of known diameter are used ; one on one side and two on the other side {Fig. (a) and (b)}. This method ensures the alignment of micrometer anvil faces parallel to the thread axis. The

$$= D + 3.1657d - 1.6005p$$

$$M = D + 3.1657d - 1.6p$$

where D = outside dia.

(ii) In case of metric threads:

$$\text{Depth of thread} = 0.6495p$$

$$\text{so, } E = D - 0.6495p.$$

$$x = 60^\circ, \operatorname{cosec} x/2 = 2; \cot x/2 = 1.732$$

$$M = D - 0.6495p + d(1 + 2) - p/2 (1.732)$$

$$= D + 3d - (0.6495 + 0.866)p$$

$$= D + 3d - 1.5155p.$$

We can measure the value of M practically and then compare with the theoretical values with the help of formulae derived above. After finding the correct value of M and knowing d, E can be found out. If the theoretical and practical values of M (i.e. measured over wires) differ, then this error is due to one or more of the quantities appearing in the formula.

Effect of lead angle on measurement by 3- wire method. If the lead angle is large (as with worms; quick traversing lead screw, etc.) then error in measurement is about 0.0125 mm when lead angle is 41° for 60° single thread series. For lead angles above 45° , the compensation for rake and compression must also be taken into account. There is no recommendation for **B.S.W.** threads.

Rake Correction in U.S. Standard :

$$E = M + \cot x/2 \cdot 2n - x(1 + \operatorname{cosec} x/2 + s/2 \cos x/2 \cot x/2)$$

where

$x/2$ = half the included angle of threads.

E = effective diameter

M = actually measured diameter over wires:

n = number of threads/inch.

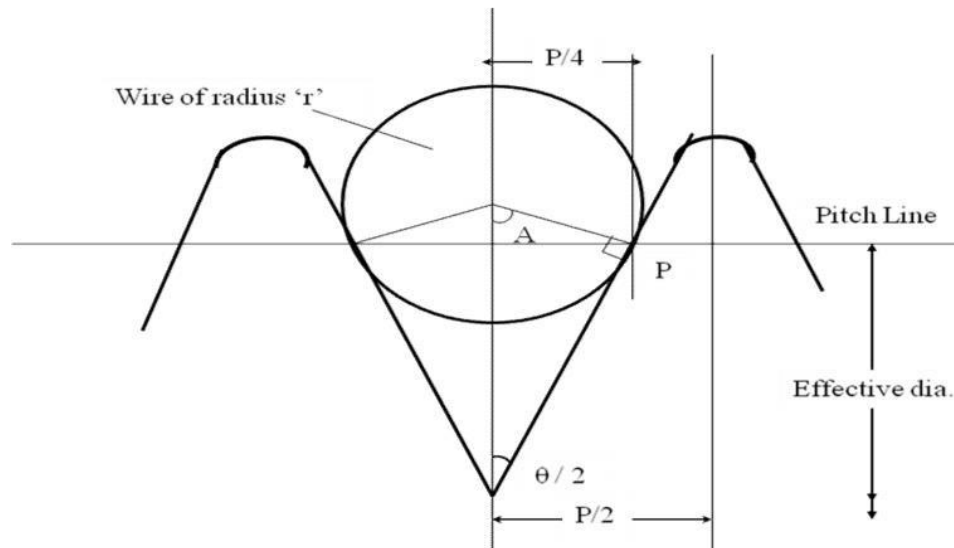
d = diameter of wire.

S = tangent of the helix angle in thread.

Best size wire Method.

This wire is of such diameter that it makes contact with the flanks of the thread on the effective diameter or pitch line. The 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' wires if there is any 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 within $\pm 1/5$ of flank length



Let the thread angle be $\theta/2$

Then in ΔOAP , $\sin POA = \frac{AP}{OP}$

Or $\sin(90^\circ - \frac{\theta}{2}) = \frac{AP}{OP}$

$OP = \frac{AP}{\sin(90^\circ - \frac{\theta}{2})} = \frac{AP}{\cos \frac{\theta}{2}} = AP \sec \frac{\theta}{2}$

Since, $OP = r = AP \sec \frac{\theta}{2}$

And wire diameter = $D_b = 2r = 2AP \sec \frac{\theta}{2}$

Since AP lies on the pitch line

$AP = \frac{P}{4}$ where, p is the pitch of the thread

Therefore, $D_b = \frac{2P}{4} \sec \frac{\theta}{2}$

Therefore, $D_b = \frac{P}{2} \sec \frac{\theta}{2}$

Gear Measurement

Gears are a mechanical drive which transmits power through toothed wheel. In this gear drive, the driving wheel is in direct contact with driven wheel. The accuracy of gearing is the very

important factor when gears are manufactured. The transmission efficiency is almost 99 in gears. So it is very important to test and measure the gears precisely. For proper inspection of gear, it is very important to concentrate on the raw materials, which are used to manufacture the gears, also very important to check the machining the blanks, heat treatment and the finishing of teeth. The gear blank should be tested for dimensional accuracy (face width, bore, hub, length, and outside diameter), and eccentricity. As outside diameter forms the datum from where the tooth thickness is measured, it forms an important item to be controlled. Concentricity of the blanks is also essential and the side faces should be true to the bore. On very precise gears details like tip radius, shape of root provided and surface finish are also measured.

The most commonly used forms of gear teeth are

1. Involute
 2. Cycloidal
- ☐ The involute gears also called as straight tooth or spur gears.
 - ☐ The cycloidal gears are used in heavy and impact loads.
 - ☐ The involute rack has straight teeth.
 - ☐ The involute pressure angle is either 20° or 14.5°

Types of gears

1. Spur gear:-

Cylindrical gear whose tooth traces is straight line.

These are used for transmitting power between parallel shafts.

2. Spiral gear :-

The tooth of the gear traces curved lines.

3. Helical gears:-

These gears used to transmit the power between parallel shafts as well as non-parallel and non-intersecting shafts.

It is a cylindrical gear whose tooth traces is straight line.

4. Bevel gears:-

The tooth traces are straight-line generators of cone.

The teeth are cut on the conical surface. It is used to connect the shafts at right angles.

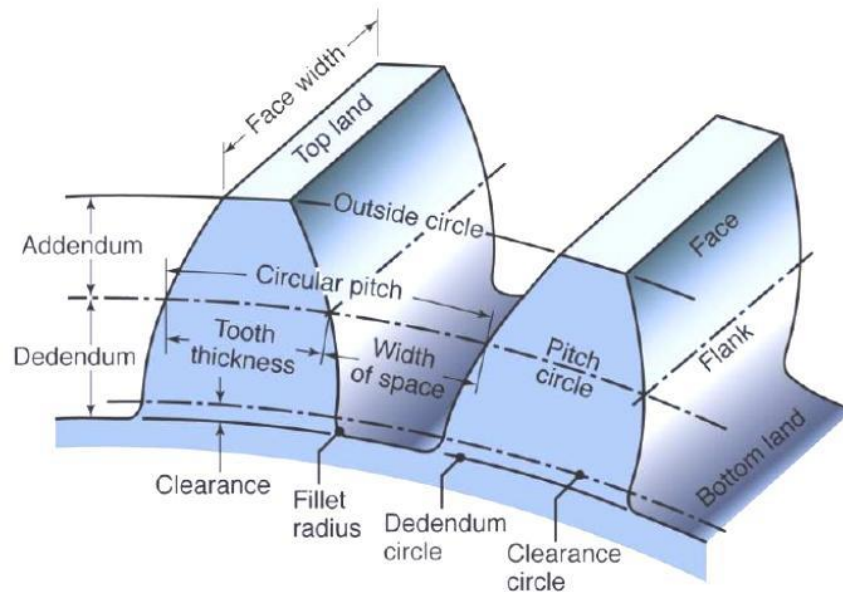
5. Worm and Worm wheel :

It is used to connect the shafts whose axes are non-parallel and non-intersecting.

6. Rack and Pinion:-

Rack gears are straight spur gears with infinite radius.

Terminology of gears:



1. Tooth profile:

- It is the shape of any side of gear tooth in its cross section.

2. Base circle:

- It is the circle of gear from which the involute profile is derived.
- Base circle diameter Pitch circle diameter $\times$ Cosine of pressure angle of gear

3. Pitch circle diameter (PCD):

- The diameter of a circle which will produce the same motion as the toothed gear wheel

4. Pitch circle

- It is the imaginary circle of gear that rolls without slipping over the circle of its mating gear.

5. Addendum circle:

- The circle coincides with the crests (or) tops of teeth.

6. Dedendum circle (or) Root circle:

- This circle coincides with the roots (or) bottom on teeth.

7. Pressure angle (a):

- It is the angle making by the line of action with the common tangent to the pitch circles of mating gears.

8. Module(m):

- It is the ratio of pitch circle diameter to the total number of teeth.

9. Circular pitch

- It is the distance along the pitch circle between corresponding points of adjacent teeth

10. Addendum:

- Radial distance between tip circle and pitch circle. Addendum value = 1 module.

11. Dedendum:

- Radial distance between pitch circle and root circle, Dedendum value = 1.25 module.

12. Clearance (C):

- A amount of distance made by the tip of one gear with the root of mating gear.

Clearance = Difference between Dedendum and addendum values

13. Blank diameter:

- The diameter of the blank from which gear is out. Blank diameter = $PCD + 2m$

14. Face:

- Part of the tooth in the axial plane lying between tip circle and pitch circle.

15. Flank:

- Part of the tooth lying between pitch circle and root circle.

16. Top land:

- Top surface of a tooth

17. Lead angle:

- The angle between the tangent to the helix and plane perpendicular to the axis of cylinder.

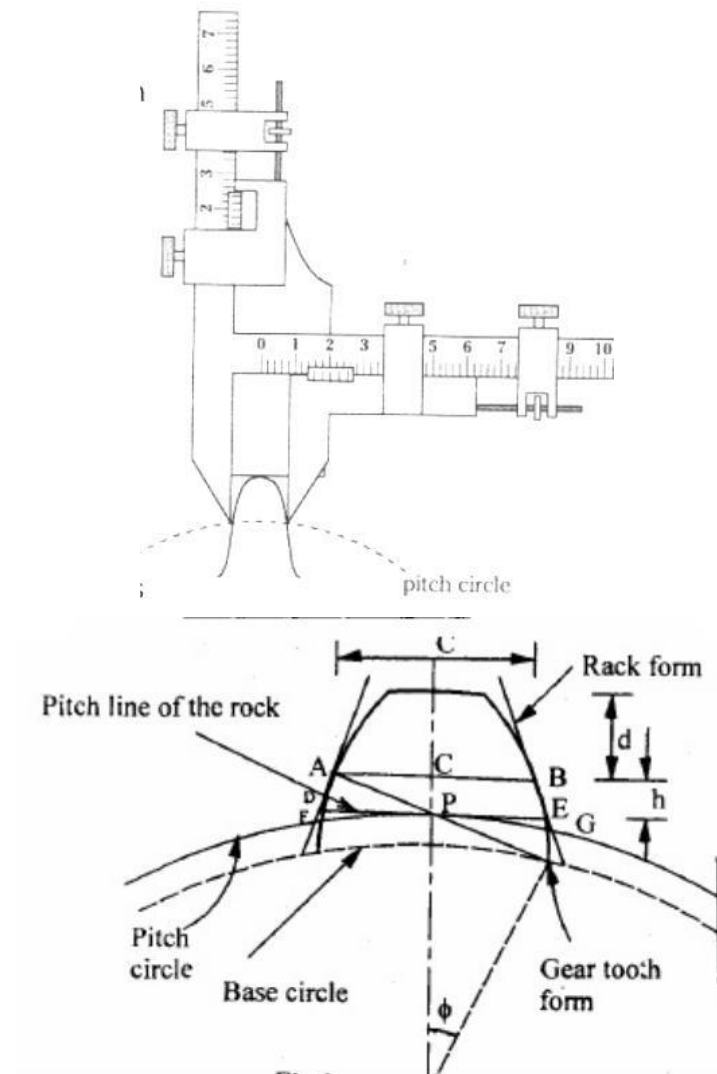
18. Backlash:

- The difference between the tooth thickness and the space into which it meshes.

Gear Tooth Caliper

In gear tooth vernier method the thickness is measured at the pitch line. Gear tooth thickness varies from the tip of the base circle of the tooth, and the instrument is capable of measuring the thickness at a specified position on the tooth. The tooth vernier caliper consists of vernier scale and two perpendicular arms. In the two perpendicular arms one arm is used to

measure the thickness and other arm is used to measure the depth. Horizontal vernier scale reading gives chordal thickness (W) and vertical vernier scale gives the chordal addendum. Finally the two values are compared. The theoretical values of ' W ' and ' d ' can be found out by considering one tooth in the gear and it can be verified.



In fig note that w is a chord ADB and tooth thickness is specified by AEB . The distance d is noted and adjusted on instrument and it is slightly greater than addendum CE . Therefore, ' W ' is chordal thickness and ' d ' is named as chordal addendum.

$$\text{So, } W = AB = 2AD$$

$$\text{And angle, } AOD = \theta = \frac{360}{4n}$$

$$\begin{aligned} \text{Where, } n &= \text{number of teeth} \\ W = 2AD &= 2 \times AO \sin \theta \\ &= 2R \sin 360 / 4n \end{aligned}$$

$$\text{Where, } R = \text{Pitch circle radius}$$

$$\text{Module, } m = \frac{\text{Pitch Circle Diameter}}{\text{No. of teeth}} = \frac{2R}{n}$$

$$\text{Therefore, } R = \frac{nm}{2}$$

$$\text{And } OD = R \cos \theta = \frac{nm}{2} \cos \left(\frac{90}{n} \right)$$

$$OD = \frac{nm}{2} \cos \left(\frac{90}{n} \right)$$

$$\begin{aligned} \text{Also from the figure,} \\ d = OC - OD \end{aligned}$$

Addendum is the radial distance from the pitch circle to the tip of the tooth. Its value is equal to one module

$$\begin{aligned} \text{But } OC &= OE + \text{Addendum} = R + m \\ &= \frac{nm}{2} + m \end{aligned}$$

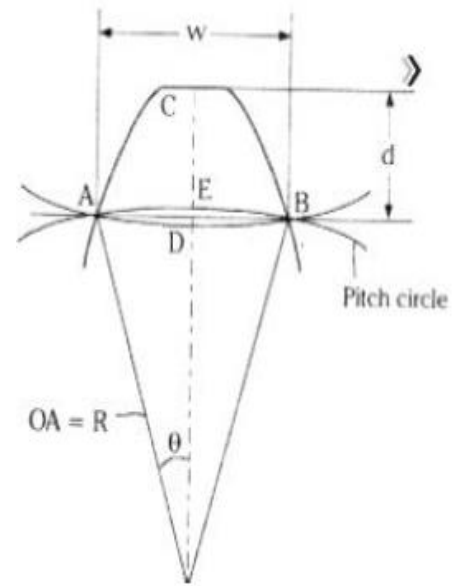
And

$$OD = R \cos \theta$$

$$= \frac{nm}{2} \cos \left(\frac{90}{N} \right)$$

Therefore, $d = \frac{Nm}{2} + m - \frac{Nm}{2} \cos \left(\frac{90}{N} \right)$

$$d = \frac{Nm}{2} \left[1 + \frac{2}{N} - \cos \left(\frac{90}{N} \right) \right]$$



Vernier method like the chordal thickness and chordal addendum are depends upon the number of teeth. Due to this for measuring large number of gears different calculations are to be made for each gear. So these difficulties are avoided by this constant chord method.