4.3 SCREW THREAD MEASUREMENT

➢ Screw threads are used to transmit the power and motion, and also used to fasten two components with the help of nuts, bolts and studs.
➢ There is a large variety of screw threads varying in their form, by included angle, head angle, helix angle etc.
➢ The screw threads are mainly classified into
  1) External thread
  2) Internal thread.

[Fig. 4.6 External thread]
[source: Metrology and Measurements, Dr. G. K. Vijayaraghavan, Pg. No 4.12]

[Fig. 4.7 Internal thread]
[source: Metrology and Measurements, Dr. G. K. Vijayaraghavan, Pg. No 4.13]
4.3.1 SCREW THREAD TERMINOLOGY

1) Screw thread:
It is a continuous helical groove of specified cross-section produced on the external or internal surface.

2) Crest:
It is top surface joining the two sides of thread.

3) Flank:
Surface between crest and root.

4) Root:
The bottom of the groove between the two flanks of the thread

5 Lead:
Lead = number starts x pitch

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

Fig. 4.8 Screw Thread Terminology
[source: Metrology and Measurements, Dr.G. K Vijayaraghavan, Pg. No 4.14]
7) Helix angle:
The helix is the angle made by the helix of the thread at the pitch line with the axis.

8) Flank angle:
Angle made by the flank of a thread with the perpendicular to the thread axis.

9) Depth of thread:
The distance between the crest and root of the thread.

10) Included angle:
Angle included between the flanks of a thread measured in an axial plane.

11) Major diameter:
Diameter of an imaginary co-axial cylinder which would touch the crests of external or internal thread.

12) Minor diameter (Root diameter or Core diameter):
Diameter of an imaginary co-axial cylinder which would touch the roots of an external thread.

13) Addendum
- Radial distance between the major and pitch cylinders for external thread.
- Radial distance between the minor and pitch cylinder for internal thread.

14) Dedendum:
- Radial distance between the pitch and minor cylinder = For external thread.
- Radial distance between the major and pitch cylinders = For internal thread.

4.3.2 ERROR IN THREAD
The errors in screw thread may arise during the manufacturing or storage of threads. The errors either may cause in following six main elements in the thread.

1) Major diameter error
2) Minor diameter error

3) Effective diameter error

4) Pitch error

5) Flank angles error

6) Crest and root error

1) **Major diameter error:**

   It may cause reduction in the flank contact and interference with the matching threads.

2) **Minor diameter error:**

   It may cause interference, reduction of flank contact.

3) **Effective diameter error:**

   If the effective diameter is small the threads will be thin on the external screw and thick on an internal screw.

4) **Pitch errors:**

   If error in pitch, the total length of thread engaged will be either too high or too small.

   **The various pitch errors may classify into**

   1. Progressive error.

   2. Periodic error.

   3. Drunken error.

   4. Irregular error.

1) **Progressive error:**

   The pitch of the thread is uniform but is longer or shorter its nominal value and this is called progressive.
Causes of progressive error:

1. In correct linear and angular velocity ratio.
2. In correct gear train and lead screw.
4. Variation in length due to hardening.

![Cumulative pitch error vs. Thread length graph](source: Metrology and Measurements, Dr.G. K Vijayaraghavan, Pg. No 4.16)

**Fig. 4.9 Progressive Error**

2. Periodic error

These are repeats itself at regular intervals along the thread

Causes of periodic error:

1. Un uniform tool work velocity ratio.
2. Teeth error in gears.
3. Lead screw error.
4. Eccentric mounting of the gears.

3) Drunken error

- Drunken errors are repeated once per turn of the thread in a Drunken thread.
- In Drunken thread the pitch measured parallel to the thread axis. If the thread is not cut to the true helix the drunken thread error will form
4) Irregular errors:

It is varying irregular manner along the length of the thread.

Irregular error causes:

2. Non-uniformity in the material.
3. Cutting action is not correct.
4. Machining disturbances.

Effect of pitch errors:

- Increase the effective diameter of the bolt and decreases the diameter of nut.
- The functional diameter of the nut will be less.
- Reduce the clearance.
- Increase the interference between mating threads.

4.3.3 MEASUREMENT OF VARIOUS ELEMENTS OF THREAD

To find out the accuracy of a screw thread it will be necessary to measure the following:

1) Major diameter.
2) Minor diameter.
3) Effective or Pitch diameter.

4) Pitch

5) Thread angle and form

1. Measurement of major diameter:

The instruments which are used to find the major diameter are by

- Ordinary micrometer
- Bench micrometer.

a) Ordinary micrometer:

- The ordinary micrometer is quite suitable for measuring the external major diameter.
- It is first adjusted for appropriate cylindrical size (S) having the same diameter (approximately). This process is known as ‘gauge setting’.
- After taking this reading ‘R’ the micrometer is set on the major diameter of the thread, and the new reading is ‘R2’

Then the major diameter, \( D = S \pm (R_1 - R_2) \)

\( S = \) Size of setting gauge

\( R_1 = \) Micrometer reading over setting gauge.

\( R_2 = \) Micrometer reading over thread.

b) Bench micrometer:

- For getting the greater accuracy the bench micrometer is used for measuring the major diameter.
- In this process the variation in measuring Pressure, pitch errors are being neglected.
- The fiducial indicator is used to ensure all the measurements are made at same pressure.
- The instrument has a micrometer head with a vernier scale to read the accuracy of 0.002mm. Calibrated setting cylinder having the same diameter as the major diameter of the thread to be measured is used as setting standard.
❖ After setting the standard, the setting cylinder is held between the anvils and the reading is taken.
❖ Then the cylinder is replaced by the threaded work piece and the new reading is taken.

![Bench micrometer](source: Metrology and Measurements, Dr.G. K Vijayaraghavan, Pg. No 4.20]

Fig. 4.11 Bench micrometer

\[ S = \pm (D_2 - D_1) \]

Where, \( S \) = Diameter of the setting cylinder.
\( D_2 \) = Micrometer Reading on screw thread
\( D_1 \) = Micrometer reading on setting cylinder.

Measurement of the major diameter of an Internal thread:

➢ The Inter thread major diameter is usually measured by thread comparator fitted with ball-ended styli.
➢ First the Instrument is setted for a cylindrical reference having the same diameter of major diameter of internal thread and the reading is taken.
➢ Then the floating head is retracted to engage the tips of the styli at the root of spring under pressure.
➢ For that the new reading is taken,
major diameter of internal thread is \( D = D \pm (R_2 - R_1) \)
\( D \) = Cylindrical standard diameter
\( R_0 \) = Thread reading
\( R_1 \) = Dial Indicator reading on the standard.

2) Measurement of Minor diameter:

- The minor diameter is measured by a comparative method by using floating carriage diameter measuring machine and small ‘V’ pieces which make contact with the root of the thread.
- These V pieces are made in several sizes, having suitable radii at the edges.
- V pieces are made of hardened steel.
- The floating carriage diameter-measuring machine is a bench micrometer mounted on a carriage.

![Fig. 4.12 Anvils being set](source: Metrology and Measurements, Dr.G. K Vijayaraghavan, Pg. No 4.23)

![Fig. 4.13 Thread being measured](source: Metrology and Measurements, Dr.G. K Vijayaraghavan, Pg. No 4.23)
Measurement process:

➢ The threaded work piece is mounted between the centers of the instrument and the V pieces are placed on each side of the work piece and then the reading is noted.
➢ After taking this reading the work piece is then replaced by a standard reference cylindrical setting gauge.

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

Where, $D$ = Diameter of cylindrical gauge

$R_2$ = Micrometer reading on threaded work piece.

$R_1$ = Micrometer reading on cylindrical gauge.

Measurement of Minor diameter of Internal threads:

The Minor diameter of Internal threads are measured by

1. Using taper parallels
2. Using Rollers.

1. Using taper parallels:

➢ For diameters less than 200mm the use of Taper parallels and micrometer is very common.
➢ The taper parallels are pairs of wedges having reduced and parallel outer edges.
➢ The diameter across their outer edges can be changed by sliding them over each other.

Fig. 4.14 Measurement of minor diameter of internal thread using taper parallels

[source: Metrology and Measurements, Dr.G. K Vijayaraghavan, Pg. No 4.24]
2. Using rollers:

➢ For more than 20mm diameter this method is used. Precision rollers are inserted inside the thread and proper slip gauge is inserted between the rollers.
➢ The minor diameter is then the length of slip gauges plus twice the diameter of roller.

![Fig. 4.15 Measurement of minor diameter of thread using rollers](source: Metrology and Measurements, Dr.G. K Vijayaraghavan, Pg. No 4.24)

3. Measurement of effective diameter

Effective diameter measurement is carried out by following methods.

1. One wire,
2. two wires, or
3. three wires method.

1. (a) One wire method:

➢ The only one wire is used in this method.
➢ The wire is placed between two threads at one side and on the other side the anvil of the measuring micrometer contacts the crests.
➢ First the micrometer reading $d_l$ is noted on a standard gauge whose dimension is approximately same to be obtained by this method.
➢ Now the setting gauge is replaced by thread and the new reading is taken as ‘$d_2$’.
b) Two wire method:

Two-wire method of measuring the effective diameter of a screw thread is given below.

- In this method wires of suitable size are placed between the standard and the micrometer anvils.
- First the micrometer reading is taken and let it be $R$.
- Then the standard is replaced by the screw thread to be measured and the new reading is taken.
- The new reading is $R$.

\[ \text{effective diameter} = D \pm (d_1 - d_2) \]

\[ \text{When } D = \text{Size of setting gauge} \]

Fig. 4.16 One wire method

[source: Metrology and Measurements, Dr.G. K Vijayaraghavan, Pg. No 4.25]

Fig. 4.17 Two wire method

[source: Metrology and Measurements, Dr.G. K Vijayaraghavan, Pg. No 4.26]
From the above reading,
The effective diameter \( E \) is calculated by \( E = T + P \)
Where, \( T = \) Dimension under the wires \( = M - 2d \)
\( M = \) Dimension over the wires
\( d = \) diameter of each wire
If \( P' = \) Pitch of thread then

\[
P = 0.9605 \, P' - 1.1657 \, d \Rightarrow \text{Whitworth thread.}
\]

\[
P = 0.856 \, P' - d \Rightarrow \text{For metric thread.}
\]

Here, \( P = \) The difference between the effective diameter and the diameter under the wires.
The diameter under the wires \( 'T' \) also can be determined by
\[T = S - (R_1 - R_2)\]
Where, \( S = \) The diameter of the standard.

---

The \( P \) value can be derived in terms of \( P \) (Pitch), \( d \) (Diameter of wire) and \( x \) thread angle as follows

\[BC \text{ lies on the effective diameter.}\]

\[\therefore BC = \frac{1}{2} P \text{Pitch} = \frac{1}{2} P\]

Next \( \text{OP} = \frac{d \cos \left(\frac{x}{2}\right)}{2} \)

And \( AQ = PQ - AP \)

Where,

\[PQ = QC \cot \left(\frac{x}{2}\right) = \frac{P}{4} \cot \left(\frac{x}{2}\right)\]

\[\therefore PQ = \frac{P}{4} \cot \left(\frac{x}{2}\right)\]

\[\therefore AQ = \frac{P}{4} \cot \left(\frac{x}{2}\right) - AP\]

Here,

\[AP = \frac{d \cos \left(\frac{x}{2} - 1\right)}{2}\]

\[\therefore AQ = \frac{PCot\left(\frac{x}{2}\right)}{4} - \frac{d (\cos \sec\frac{x}{2} - 1)}{2}\]
c. Three Wire method:

The three-wire method is the accurate method.

➢ In this method three wires of equal and precise diameter are placed in the groves at opposite sides of the screw.
➢ In this one wire on one side and two on the other side are used. The wires either may held in hand or hung from a stand.
➢ This method ensures the alignment of micrometer anvil faces parallel to the thread axis.

![Fig. 4.18 Three wire method](source: Metrology and Measurements, Dr.G. K Vijayaraghavan, Pg. No 4.28)

4.3.4 BEST WIRE SIZE-DEVIATION:

➢ Best wire diameter is that may contact with the flanks of the thread on the pitch line.
➢ The figure shows the wire makes contact with the flanks of the thread on the pitch.

Hence best wire diameter,

\[
P = \frac{P}{2} \cot \frac{x}{2} - d \left( \csc \frac{x}{2} - 1 \right)
\]
\[ db = 2Ap \sec x \]

Where, 
- \( db \) = Wire diameter
- \( x \) = Included angle

\[ AP = p/4 \]

\[ \therefore db = 2p/4 \sec x \]

\[ db = p_2 \sec x \]