Metrology Laboratory
Department of Mechanical Engineering

Experiment No. 5(a)

GEAR MEASUREMENT

Aim: To measure spur gear tooth elements.

Instruments: Flange micrometer, Gear tooth vernier caliper.

Theory:

Gears are mainly used for transmission of power and motion. It is a round wheel that has teeth, which meshes with another gear allowing force to be fully transferred without slippage. Depending on their construction and arrangement, geared devices can transmit forces at different speeds, torques, or in a different direction, from the power source. A gear can also mesh with any device having compatible teeth, such as linear moving racks. For closer control over the accuracy of manufacture of the gear, precision measurement of gear plays a vital role. A brief overview of different types of gear has been documented herewith.

Spur Gear - The edge of each tooth is straight and aligned parallel to the axis of rotation.

Fig 1 Spur gear

Helical Gear - The leading edges of the teeth are not parallel to the axis of rotation, but are set at an angle. The angled teeth engage more gradually than do spur gear teeth. This causes helical gears to run more smoothly and quietly than spur gears.

Fig 2 Helical gear

Bevel gear **-** The angle between the shafts of mating gears can be anything except zero or 180 degrees. Bevel gears with equal numbers of teeth and shaft axes at 90 degrees are called **miter gears**.

Fig 3 Bevel gear

Worm gear – Type of helical gear, but its helix angle is usually somewhat large and its body is usually fairly long in the axial direction; and it is these attributes which give it screw like qualities.

Fig 4 Worm gear

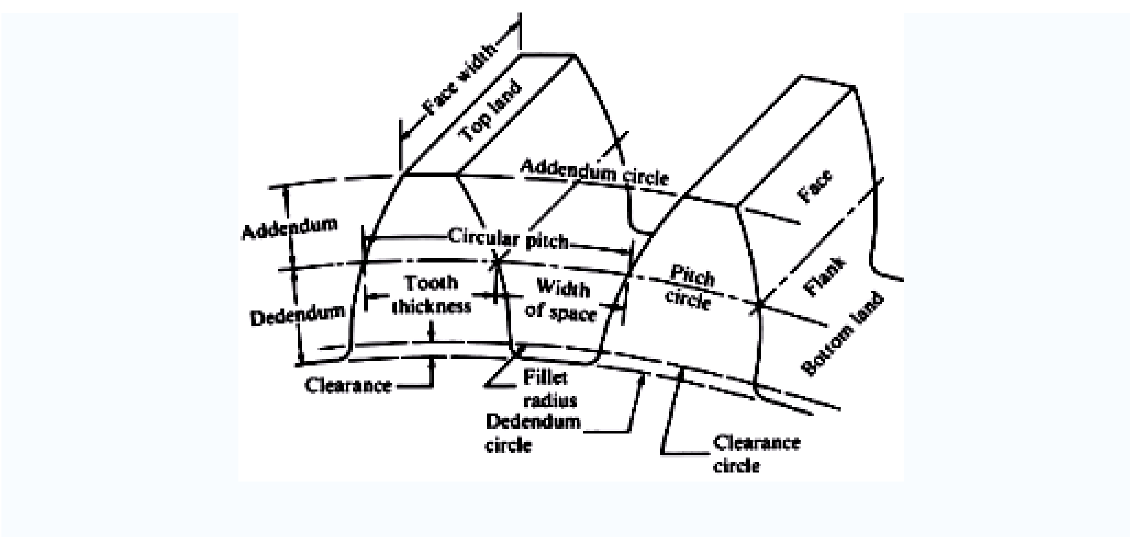
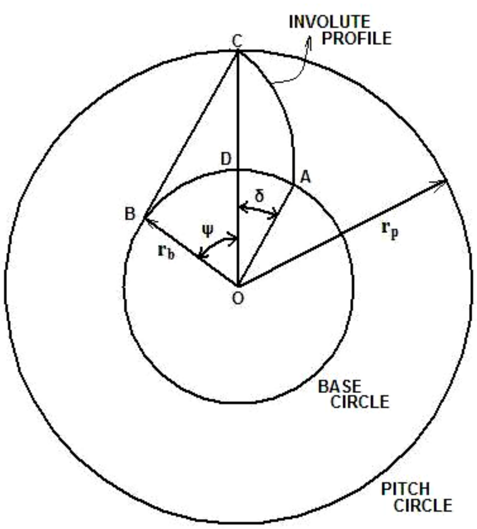


Fig.5. Gear nomenclature.

Gear geometric nomenclature:

The **tooth thickness** is generally measured at pitch circle shown in Fig 5. The curve most commonly used for gear-tooth profile is the **involute** of a circle. It may be defined as the curve traced by a point on a taut (line BC in Fig.6), inextensible string as it unwinds from another circle. The circle from which the involute is derived is called the base circle. The involute profile is shown in Fig.6. **Pressure Angle** (ψ) is defined as the angle between the line of action and the common tangent to the pitch circles shown in Fig.7. The base radius and the pitch radius are r_b and r_p respectively. Pitch circle radius is denoted by symbol R. The involute function (∂) is found from the fundamental principle of involute.



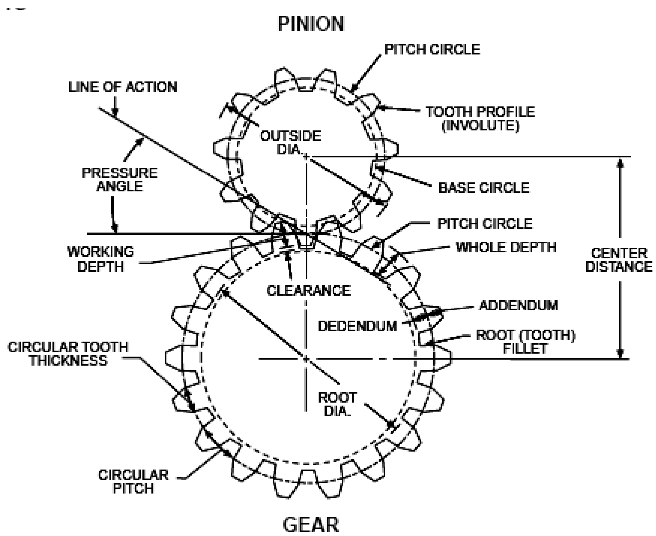


Fig.6. Involute profile

Fig.7. Gear in mesh with a pinion

From the Fig.6

$OB = OC\cos\psi = r_b$

$BC = arc\,AB = r_b\tan\psi$

$Arc\,BD = r_b\psi\,(radians)$

$r_b\delta = r_b\tan\psi - r_b\psi$

$$\delta = \tan\psi - \psi\,(radians)$$

The following gear tooth elements are measured using vernier

- Outside diameter
- Diametral pitch
- Pitch circle diameter
- Module
- Addendum
- Dedendum
- Tooth thickness of all teeth

- **Outside diameter (O.D):** Using vernier caliper, measure the outer diameter of the given gear with 6 different readings and record in the following tabular columns. If **odd number** of teeth is there then consider the **highest reading** as O.D. If **even number** of teeth is there then consider the **average reading** as O.D.

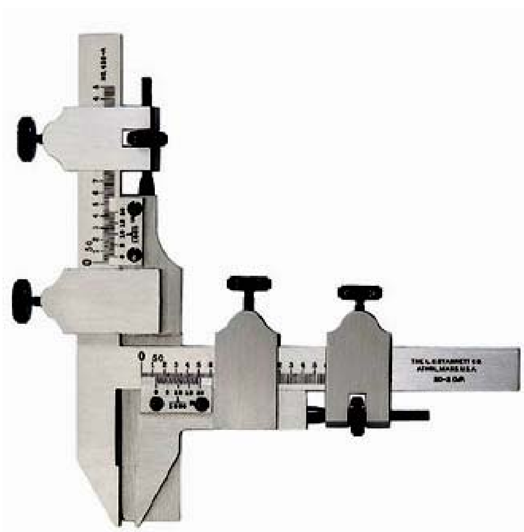
Sl No.	1	2	3	4	5	6	Avg Dia, mm
Outer diameter, mm							

Outside diameter = __________ mm

- **Diametral pitch (Dp):** Diametral pitch = (N+2) / Outside diameter

  Where, N= Number of teeth

- **Pitch circle diameter (P.C.D):** Pitch circle diameter = N / Diametral pitch
- **Module (m):** Module = 1 / Diametral pitch
- **Addendum (a):** Addendum = Module
- **Dedendum (d):** Dedendum = 1.157 X (Addendum)
- **Tooth thickness (t):**



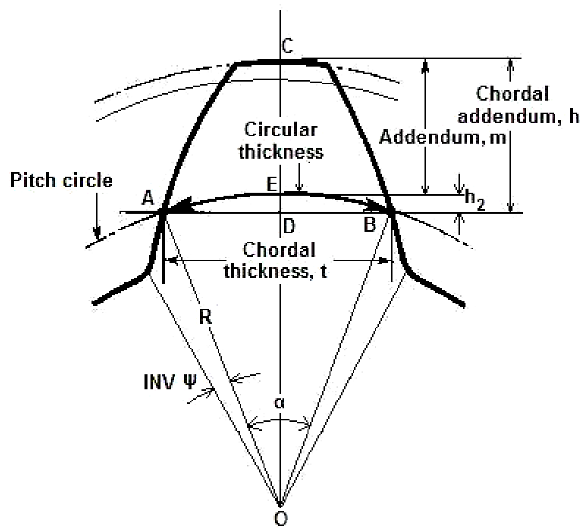


Fig.8. Gear tooth vernier caliper

Fig.9. Gear tooth geometry

Tooth thickness is measured by the gear tooth vernier**.** The vernier shown in Fig.8 consists of two vernier calipers set at 90º to each other. Since the gear tooth thickness varies from the root to the tip, the vernier must be capable of measuring the tooth thickness at a specified position on the tooth. The tooth thickness is measured at the pitch circle as shown in Fig.9. The thickness of the tooth at pitch line and the addendum is measured by an adjustable tongue, each of which is adjusted independently by adjustable screws on the graduated bars. The gear tooth vernier is set with its vertical scale at a distance equal to chordal addendum so that the thin slit will be at a height ‘m’ from the tip of the jaw. Hence the gear tooth slit will sit on the top land and the tip of the jaws will measure the chordal thickness, t.

$$h = (m + h_2)$$
$$t = AB = 2AD$$
$$\angle AOD = \alpha / 2 = 2\pi / 4N = \pi / 2N$$

Where, R = Pitch Circle Radius = Nm/2

$$t = 2AO\sin(\alpha / 2) = 2R\sin(\pi / 2N)$$
$$t = Nm\sin(\pi / 2N)$$
$$h_2 = DE = R(1 - \cos(\alpha / 2)) = \frac{Nm}{2}(1 - \cos\pi / 2N)$$

“t” is the chord ADB while tooth thickness is the arc AEB. Therefore the tooth thickness thus measured is called “Chordal tooth thickness”.

Procedure to measure tooth thickness: Start from any one tooth by marking it and measure its thickness as t_1. Leaving one tooth measure the next one as t_2. Leaving another tooth measure the next one as t_3. Follow the procedure till all the 30 teeth are measured.

Observation No.	t_1	t_2	t_3	Mean t	T	V
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Maximum variation of chordal tooth thickness = (Max mean t – Min mean t)

Chordal tooth thickness from theoretical formula = T

Variation between the observed and theoretical values = V = t-T

Checking the tooth thickness error with Flange Micrometer

[Span measurement/ Base tangent measurement]

From the principle of the involute profile the sum of the generators

$AF + FB = A'F + FB' =$ arc length CD along the base circle as shown in figure 10.

Hence the measurement of the span AB can be taken in any position with the Flange Micrometer touching tooth flange. Any tooth thickness error will show a corresponding error in the value of AB.

Let the number of teeth in the span of AB be "n"

Then $\beta = \frac{(n-1)2\pi}{N}$

$$OD = \frac{N\,m\cos(\gamma/2)}{2}$$

$$\gamma = \alpha + 2\,inv\psi$$

where

$$inv\psi = \tan\psi - \psi(radians)$$

$$CD = (\beta + \gamma)OD$$

$$AB = CD = A'B'$$

$$AB = \frac{(\beta + \gamma)}{2} Nm\cos(\gamma/2)$$

where, $\alpha = \pi/N$

$\beta = (n-1)2\pi/N$

$\gamma = \alpha + 2inv\psi$

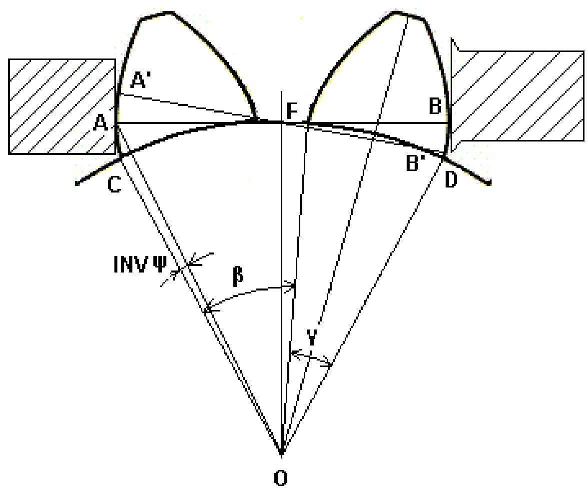


Fig 10. Measurement of tooth thickness error

The optimum number of teeth "n" for the measurement of the span can be found by taking the contact points near the pitch points.

$$AB = AF + FB = CD = 2OF(\psi + inv\psi)$$

n = nearest integer to $\frac{AB \times N}{\pi N\,m\cos\psi} = \frac{N(\psi + inv\psi)}{\pi}$

$n = \frac{N\tan\psi}{\pi}$ here $\psi = 20^o$

n = ________

Nearest integer = ________

Range of Micrometer = ________

Take 3 measurements at one place. Repeat those measurements at four places at 90^o spacing.

Observation no.	Span1	Span2	Mean value of the span S, mm
1			
2			
3			
4			

Maximum variation in values of the span measured =

Theoretically the value of the span is given by

$$AB = \frac{(\beta + \gamma) Nm \cos(\gamma / 2)}{2}$$

$$inv\psi = \tan\psi - \psi = \tan 20^{o} - 20\frac{\pi}{180} = \_\_\_\_\_\_\_\_ \ radians$$

$\alpha =$

$\beta =$

$\gamma =$

$AB =$ ________ mm

Difference between the theoretical and observed values = (AB - S) = ________ mm

Discussion: Discuss the results, especially the tooth thickness variation.