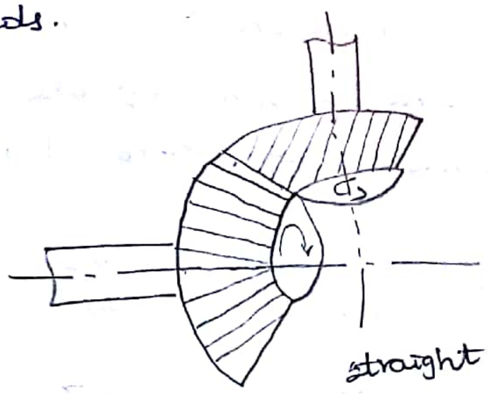
UNIT-III -> BEVEL AND WORM GEARS

BEVEL GEARS:-

1) Straight Bevel Gears:-

If the teeth on the bevel gears are parallel to the lines generating the pitch cones, then they are called straight bevel gears. The teeth are straight, radial to the point of intersection of the shaft axes and vary in cross-section throughout their length. Usually, they are used to connect shafts at right angles which run at low speeds.



straight Bevel gear.

Bevel gear nomenclature:-

The geometry of bevel gear is shown in fig. The various terms used in the study of bevel gears have been explained below.

1) Pitch cone:-

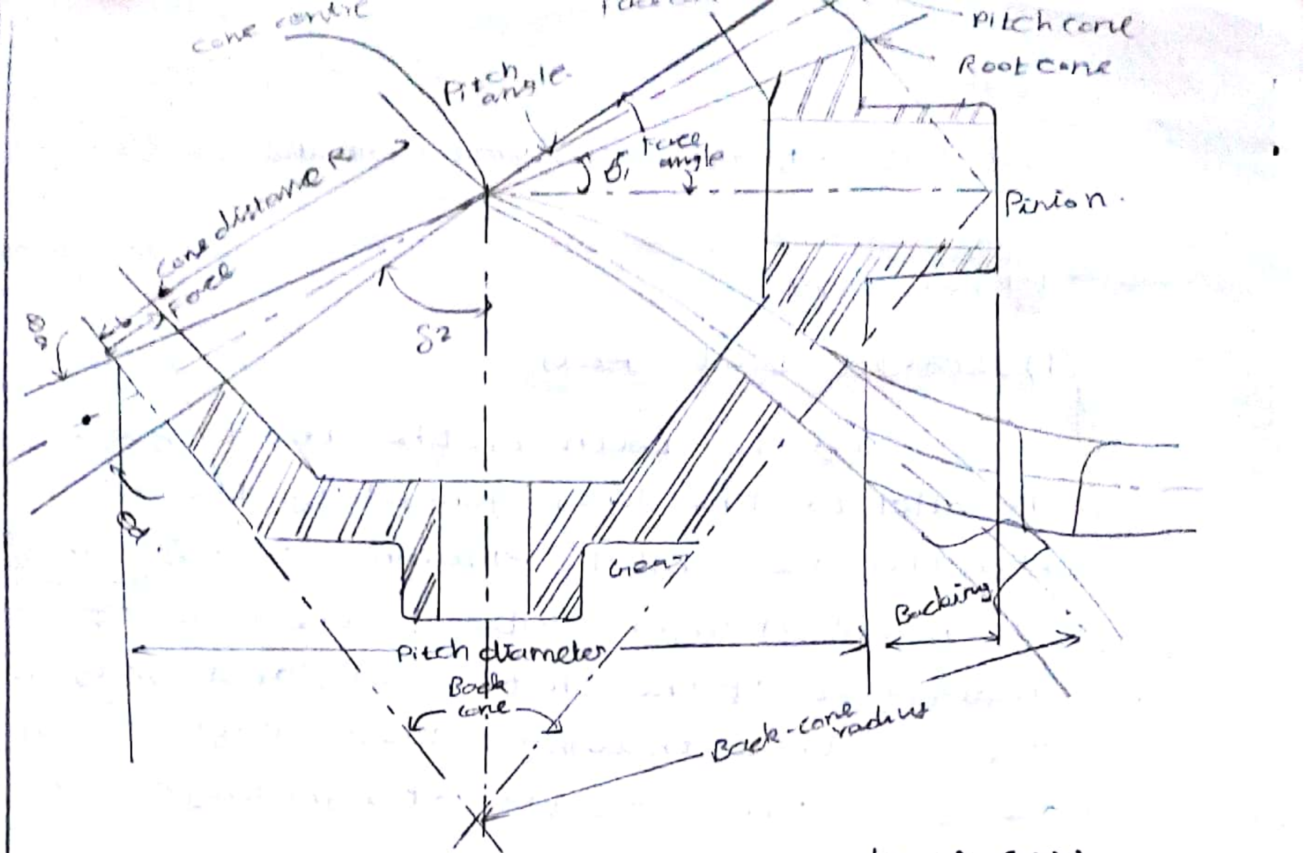
It is the cone containing the pitch elements of the teeth.

2) cone centre:-

It is the point where the axes of two mating gears intersect each other. In other words, it is the apex of the pitch cone.

3) Pitch angle (or semi cone angle):- (δ):-

It is the angle made by the pitch line of a gear with the gear axes.



4) Cone distance (or Pitch cone radius) (R):-

It is the length of the pitch cone Element. Mathematically, cone distance (R) is given by..,

$$R = \frac{\text{Pitch radius}}{\sin\delta} = \frac{d_1/2}{\sin\delta_1} = \frac{(d_2/2)}{\sin\delta_2}$$

$$R \Rightarrow \frac{m_t \times z_1}{2\sin\delta_1} = \frac{m_t \times z_2}{2.\sin\delta_2}.$$

$$R \Rightarrow \left[\left(\frac{d_1}{2}\right)^2 + \left(\frac{d_2}{2}\right)^2\right]^{1/2} = \frac{1}{2}\sqrt{d_1^2+d_2^2}$$

5) Addendum angle (θ_a):

It is the angle between by the addendum of the tooth at the at the cone Centre.

Mathematically

$$\text{Addendum angle, } \theta_a = \tan^{-1}\left(\frac{\text{addendum}}{\text{Cone distance}}\right)$$

$$\Rightarrow \tan^{-1}\left(\frac{h_a}{R}\right).$$

VIRTUAL (OR) FORMATIVE (or) Equivalent number (of) tooth For bevel gears:-

In order to simplify the design calculation and analysis, bevel gears are replaced by equivalent spur gears. An Imaginary spur gear considered in a plane perpendicular to the tooth at the larger end, is known as Virtual or formative or equivalent spur gear. The virtual spur gear has pitch circle radius equal to the pitch cone radius 'R' of the bevel gear.

The number of teeth Z_v on this imaginary spur gear is called virtual (or) formative (or) equivalent number of teeth.

$$Z_v = \frac{Z}{\cos \delta}$$

Proportions for Bevel gears:-

1) Addendum $h_a = 1 m_t$.

2) Dedendum $h_f = 1.2 m_t$

3) Clearance $c = 0.2 m_t$

4) Working depth $h_w = 2 m_t$

5) Thickness of tooth $= 1.5708 m_t$.

where m_t = Transverse Module.

Basic Dimensions of Bevel gears:-

The basic dimensions of straight bevel gears are listed in Table 7.1 (From data book, P.g No 8.38)

Force Analysis of Bevel gears:-

→ In force Analysis of bevel gears, it is assumed that the resultant tooth force between two meshing gears is concentrated at the midpoint along the face width of the tooth. The forces acting at the at the centre of tooth are shown in fig..,

The components of the resultant force are.,

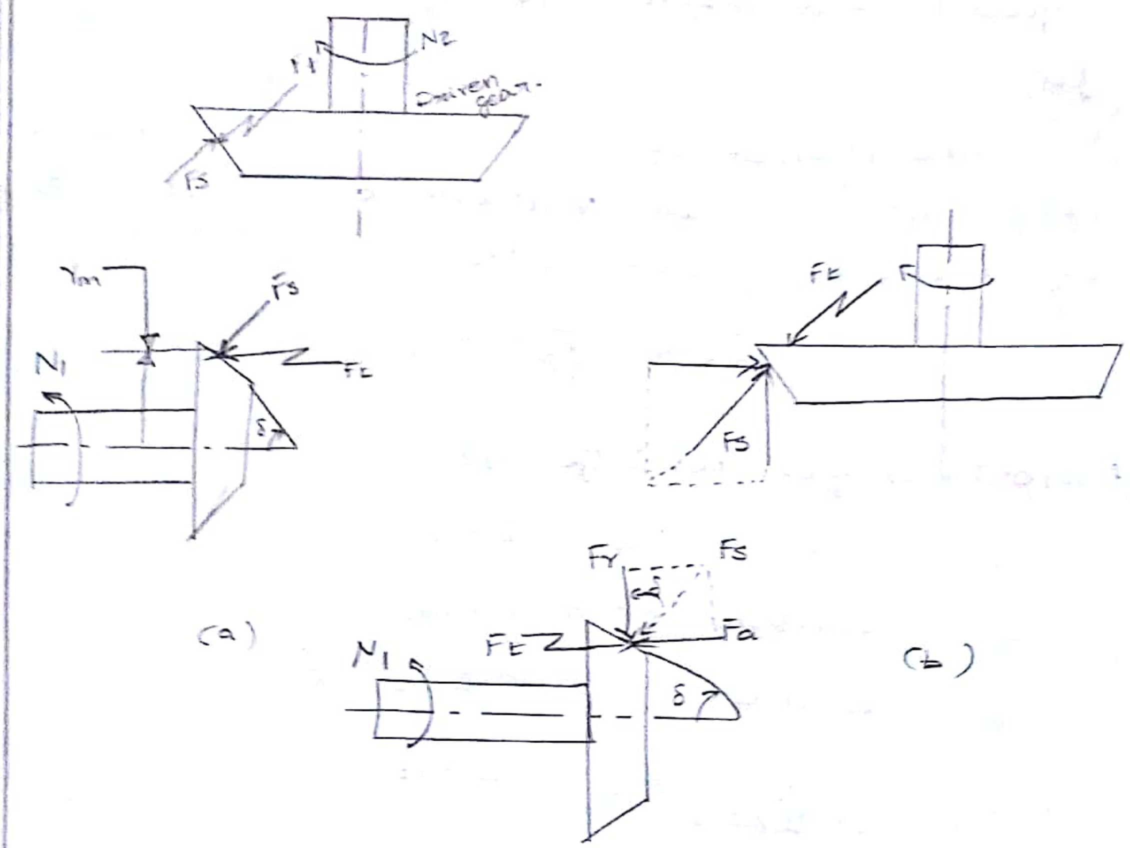
1) Tangential or useful component (F_t) and

2) Seperating force (F_s):-

It is resolved into two components. They are

i) Axial force (F_a) and

ii) Radial force (F_r).



(a) (b)

i) Components of the tooth force on the Pinion:-

To find F_t:-

$$F_t = \frac{2M_t}{d_{1av}} = \frac{M_t}{r_m}.$$

$M_t \rightarrow$ Transmitted Torque $= \frac{60 \times P}{2\pi N}$

$P \rightarrow$ Power Transmitted.

$N \rightarrow$ Speed of the gear

$$\Rightarrow z_1 . m_{av} = z_1\left(M_t - \frac{b\sin\delta}{z_1}\right), \text{ and}$$

$$r_m = \left(\frac{d_1}{2} - \frac{b\sin\delta_1}{2}\right).$$

DESIGN OF BEVEL GEAR:-

1) Beam strength of bevel gears (or Lewis equation):

$$F_S = \pi \times m_t \times b \times [\sigma_b] \times y' \left(\frac{R-b}{R}\right)$$

$M_t \Rightarrow$ Transverse module

$b \Rightarrow$ Face width $= 10 M_t$ or $0.3R$.

$[\sigma_b] \Rightarrow$ Permissible (or) allowable static stress

$y' \Rightarrow$ Lewis form factor based on virtual no. of teeth

$R \Rightarrow$ Cone distance $= 0.5 M_t \sqrt{z_1^2 + z_2^2}$.

Dynamic load on Bevel Gear tooth (effective Load on Gear tooth)

1) calculation of initial dynamic load:- (F_D):

Approximate value of dynamic load, using the velocity factor, which is used in the initial stages of design, is given by the relation

$$F_d = \frac{F_t}{C_v}$$

$F_t \rightarrow$ Tangential load considering service factor $= P/V \times K_o$

C_v = velocity factor

$$\Rightarrow \frac{3.5}{3.5 + \sqrt{V}}$$

$$\Rightarrow \frac{5.6}{5.6 + \sqrt{V}}$$

2) Buckingham's equation for dynamic load:-

$$\text{Dynamic load, } F_d \Rightarrow F_t + \frac{21V(bc+F_t)}{21V + \sqrt{bc+F_t}}.$$

Wear strength of Bevel gears (wear tooth load):-

$$\text{wear load, } F_w \Rightarrow \frac{0.75 d_1 \times b \times Q' \times k_w}{\cos \delta_1}.$$

Design Procedure:-

The design procedure for bevel gears are same as for spur gears

1) Select the materials
2) calculate z_1 and z_2. If not given, assume $z_1 \geq 17$
3) Calculate the pitch angles (δ_1 and δ_2) and the virtual no. of teeth (ie., z_{v1} and z_{v2}) using following relations.

✓ Pitch angles: $\tan \delta_2 = i$ and $\delta_1 = 90° - \delta_2$, for right angle bevel gear

$$z_{v1} = \frac{z_1}{\cos \delta_1} \text{ and } z_{v2} = \frac{z_2}{\cos \delta_2}.$$

4) calculate the tangential load on tooth using the relation $F_t = \frac{P}{V} \times k_o$

5) calculate the preliminary value of dynamic load using the relation $F_d = \frac{F_t}{C_v}$.

6) calculate the beam strength F_s in terms of traverse module using the relation:,

$$F_s = \pi \times m_t \times b \times [\sigma_b] \times y' \times \left(\frac{R-b}{R}\right).$$

(4)

initially assume $b = 10\ m_t$.

7) calculate the transverse module m_t by equating F_s and F_d

8) Calculate the values of b, d_1 and v using the following relations:

✓ Face width : $b = 10 m_t$

✓ Pitch circle diameter : $d_1 = m_t \times z_1$

✓ Pitch line velocity : $V = \frac{\pi d_1 N_1}{60}$.

9) Recalculate the beam strength using the relation,

$$F_s = \pi \times m_t \times b \times [\sigma_b] \times y' \times \left(\frac{R-b}{R}\right).$$

10) calculate the dynamic load more accurately using Buckingham's equation,

$$F_d = F_t + \frac{21 V (bc + F_t)}{21 V + (\sqrt{bc + F_t})}$$

11) check for beam strength (or tooth breakage). If $F_d \leq F_s$, the gear tooth has adequate beam strength and will not fail by breakage. Thus the design is satisfactory.

12) Calculate the maximum wear load using the relation $F_w = \frac{0.75 \times d_1 \times b \times Q' \times k_v}{\cos \delta_1}$

13) check for wear strength. If $F_d < F_w$, the gear tooth has adequate wear capacity and will not wear out. Thus the design is safe and satisfactory.

14) calculate the basic dimensions of pinion and gear using Table 7.1.