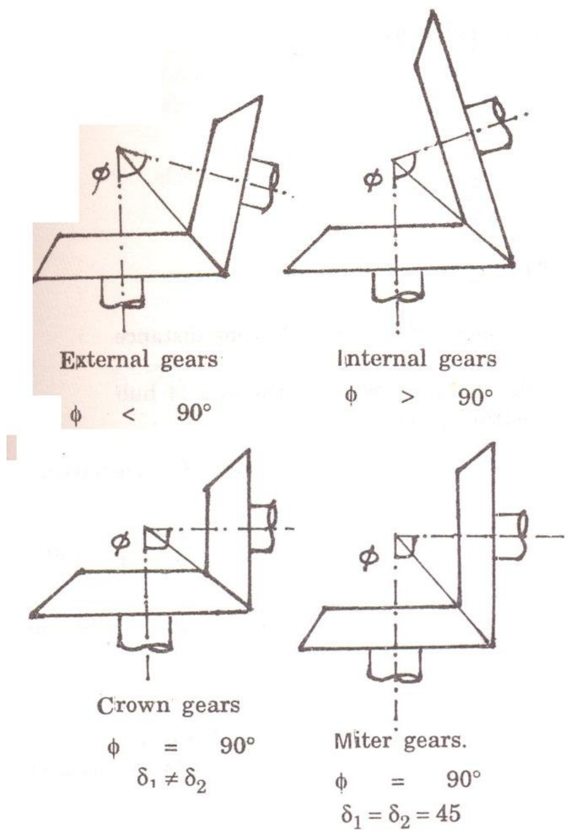
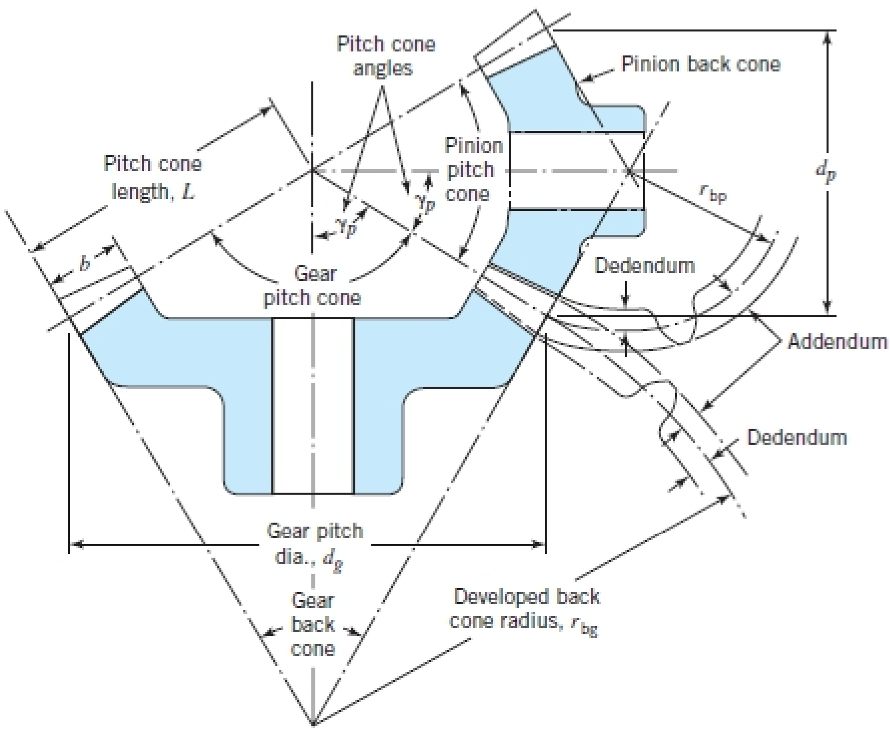
3 BEVEL, WORM AND CROSS HELICAL GEARS

3.1 BEVEL GEAR

Bevel gears are used to transmit power between the shafts whose axes are intersecting at an angle. In bevel gears, teeth are cut on conical surface in contrast with spur and helical gears, for which the teeth are cut on a cylindrical surfaces.The structure of the helical gear is similarly to an uniformly serrated frustum of a cone.



3.1.1 BEVEL GEAR TERMINOLOGY



CLASSIFICATION

1. Based on the shape of teeth such as
   a. Straight teeth bevel gears
   b. Curved teeth bevel gears
2. Based on the angle between the shafts
   a. External gear drive ,if shaft angle <90°
   b. Internal gear drive ,if shaft angle >90°
   c. Mitre gear, if shaft angle = 90°

Example.Design a bevel gear drive to transmit 7 kW at 1600 rpm for the following data

Gear ratio = 3

Material for pinion and gear = C45 Steel

Life = 10,000 hours

Since the pinion and gear are made of same material, pinion is weaker than gear and its teeth are subjected to more number of cycles.

STEP-1-MINIMUM CONE DISTANCE

Minimum cone distance based on surface compressive strength

$$R \geq \psi_y \sqrt{i^2+1} \sqrt[3]{\left\{\frac{0.72}{(\psi_y - 0.5)[\sigma_c]}\right\}^2 \frac{E[M_t]}{i}}$$ **(PSG 8.13)**

Design torque $[M_t] = M_t.k.k_d$ **(PSG 8.15)**

$[M_t] = 97420 x \frac{7}{1600} x 1.5 = 640$ kgf-cm ; $k.k_d = 1.5$ (assumed)

Equivalent young's modulus = $2.15 x 10^6 kgf/cm^2$ **(PSG 8.14)**

$[\sigma_c] = 5000 kgf/cm^2$ **(PSG 8.5)**

$\psi_y = R/b = 3$ (for i=3) **(PSG 8.15)**

$$R \geq 3\sqrt{3^2+1} \sqrt[3]{\left\{\frac{0.72}{(3-0.5)5000}\right\}^2 \frac{2.15x10^6 x640}{3}} \geq 10.95 \text{ cm}$$

STEP-2-AVERAGE MODULE

$$m_{av} \geq 1.26 \; x \sqrt[3]{\frac{[M_t]}{y_v[\sigma_b]\psi_m z_1}}$$ **(PSG 8.15)**

$\sigma_b = 1400 kgf/cm^2$ **(PSG 8.5)**

$\psi_m = \frac{b}{m_{av}} = 10$ (initially assumed)

y_v= form factor

$z_v = z_1 / \cos \delta_1$ for pinion **(PSG 8.39)**

$\tan \delta_2 = i = 3$; $\delta_2 = \tan^{-1} i = \tan^{-1} 3 = 71.66$

$\delta_1 = 90 - 71.56 = 18.43°$

$z_v = z_1 / \cos \delta_1 = 20/\cos 18.43 = 21$

$y_v = 0.396$ **(PSG 8.18)**

$$m_{av} \geq 1.26 \; x \sqrt[3]{\frac{640}{0.396x1400x10x20}} = 0.226 \text{ cm} \quad = 2.3 \text{ mm}$$

STEP-3-TRANSVERSE MODULE

$m_t = m_{av} x \frac{\psi_y}{(\psi_y - 0.5)} = 2.3 x \frac{3}{(3-0.5)} = 2.76$ mm

next standard module = 3 mm =0.3cm

STEP-4-CORRECTED CONE DISTANCE

$R = 0.5 m_t z_1 \sqrt{(i^2+1)}$ **(PSG 8.38)**

$10.95 = 0.5 x 0.3 x z_1 x \sqrt{(3^2+1)}$; $z_1 = 23.08 \approx 24$

$z_1 = 24$ and $z_2 = i x z_1 = 3x24 = 72$

Final cone distance R= $0.5x0.3x24\sqrt{(3^2+1)}$ = 11.4 cm

Since the final cone distance is greater than initial distance our design is safe.

STEP-5-FACE WIDTH

$b = \frac{R}{\psi_y} = \frac{11.4}{3} = 3.8$ cm ≈ 4 cm

STEP-6-CHECKING THE INDUCED STRESSES

$\sigma_C = \frac{0.72}{(R-0.5b)} \sqrt{\frac{\sqrt{(i^2+1)^3} E[M_t]}{ib}}$ **(PSG 8.13)**

$$= \frac{0.72}{(11.4 - 0.5x4)} \sqrt{\frac{\sqrt{(3^2+1)^3} 2.15x10^6 x640}{3x4}}$$

$= 4638$ kgf/cm$^2 < [\sigma_c] = 5000$ kgf/cm^2

Our design if safe.

$\sigma_b = \frac{R\sqrt{(I^2+1)[M_t]}}{(R-0.5b)^2 . b . m_t . y_v} x \frac{1}{cos\alpha} \leq [\sigma_b]$ **(PSG 8.13a)**

A =20° usually **(PSG 8.38)**

$= \frac{11.4\sqrt{(3^2+1)640}}{(11.4-0.5x4)^2 x4x0.3x0.396} x \frac{1}{cos20}$ =591 kgf/cm$^2 \leq [\sigma_b]$ =1400 kgf/cm^2

STEP-7-PITCH CIRCLE DIAMETER

For pinion $d_1 = m_t z_1$=3x24=72 mm

For gear d_2=$m_t z_2$=3x72 = 216 mm

STEP-8-TIP CIRCLE DIAMETER

$d_{a1} = m_t(z_1+2\cos\delta_1) = 3(24+2\cos18.43) = 77.7 \approx 78$ mm **(PSG 8.38)**

$d_{a2} = m_t(z_2+2\cos\delta_2) = 3(72+2\cos71.56) = 218$ mm

STEP-9-ADDENDUM ANGLE θ_a

$\theta_{a1} = \theta_{a2} = \tan^{-1}\left(\frac{m_t f_o}{R}\right) = \tan^{-1}\left(\frac{0.3x1}{11.4}\right) = 1.5°$

STEP-10-DEDENDUM ANGLE θ_f

$\theta_{f1} = \theta_{f2} = \tan^{-1}\left(\frac{m_t(f_o+c)}{R}\right) = \tan^{-1}\left(\frac{0.3x(1+0.2)}{11.4}\right) = 1.8°$

STEP-11-TIP ANGLE

For pinion $\delta_{a1}=\delta_1+\theta_{a1}$=18.43+1.5=19.93°

For gear $\delta_{a2}=\delta_2+\theta_{a2}$=71.56+1.5=73.06°

STEP-12-ROOT ANGLE

For pinion $\delta_{f1}=\delta_1-\theta f_1$=18.43-1.5=16.63°

For gear $\delta_{f2}=\delta_2-\theta_{f2}$=71.56-1.5=69.76°

STEP-13-OTHER PARAMETERS

Addendum $h_a=m_t$=3 mm

Dedendumh_f = 1.1236 x m_t = 1.1236x3 = 3.4 mm

Tooth height $h= h_a + h_f$ = 3+ 3.4 = 6.4 mm

SPECIFICATION

SL NO	SPECIFICATION	PINION	GEAR
1.	Material	C45 steel	C45 steel
2.	Cone distance	114 mm	114 mm

3.	Module	3 mm	3mm
4.	No of teeth	24	72
5.	Face width	40 mm	40 mm
6.	Semi cone angle	18.43°	71.56°
7.	Addendum	3mm	3mm
8.	Dedendum	3.4 mm	3.4mm
9.	Pitch circle diameter	72 mm	216 mm
10.	Tip circle diameter	78 mm	218 mm
11.	Tip angle	19.93°	73.06°
12.	Root angle	16.63°	69.76°
13.	Addendum angle	1.5°	1.5°
14.	Dedendum angle	1.8°	1.8°

Two mark questions

1. When do we employ crossed helical gear?

A pair of crossed-helical gears also known as spiral gears are used to connect and transmit motion between two non-parallel and non- intersecting shafts. As the contact between the mating teeth is always a point, these gears are suitable only for transmitting a small amount of power.

2. Mention two characteristics of hypoid gear.

They are similar in appearance to spiral-bevel gears. Their pitch surfaces are hyperboloids rather than cones. Axis of pinion is offset from the axis of the gear.

3. What are the various forces acting on a bevel gear?

Tangential force, Axial force & Radial force

4. Usually worm is made of hard material and worm gear is made of softer material – justify.

A material strength is set so that an amount of wear of the worm becomes larger that of the worm wheel.

5. When is bevel gear preferred?

They are used to transmit power between two intersecting shafts.

6. Calculate the angle between the shafts of a crossed helical gears made of two right handed helical gears of 15˚ helix angle each.

Shaft angle, $\Theta = \beta 1 + \beta 2 = 2\beta = 2\,(15^\circ) = 30^\circ$

7. State the use of bevel gears.

They are used to transmit power between two intersecting shafts.

8. State the advantage of worm gear drive in weight lifting machine.

The worm gear drives are irreversible. It means that the motion cannot be transmitted from worm wheel to the worm. This property of irreversible is advantageous in load hoisting applications like cranes and lifts.

9. Why is the crossed helical gear drive not used for power transmission?

As the contact between the mating teeth of crossed helical gears is always a point, these gears are suitable only for transmitting a small amount of power. That's why mostly these gears are not used for power transmission.

10. Why is the efficiency of a worm gear drive comparatively low?

Because of power loss due to friction caused by sliding.

Ex. two straight bevel gears are used in a speed reducer with a transmission ratio of 2.The wheel is supported on both sides and the pinion is over hanging. The input is from a 20kW electric motor running at 950 rpm. Design the bevel gears.

Ex.A pair of straight bevel gears is to be designed to transmit 5 kW at a pinion speed of 800 rpm. The desired velocity ratio is 2. Choosing proper materials, find all the dimensions of gears.

PROBLEMS FROM ANNA UNIVERSITY EXAMS

Design a pair of cast iron bevel gears for a special purpose machine tool to transmit 3.5 kW from a shaft at 500 rpm to another at 800 rpm. The gears overhang in their shafts, Life required is 8000 hours. [April/may2010]

A 25 kW motor running at 1200 rpm drives a compressor at 780 rpm through 90^0 bevel gearing arrangement. The pinion has 30 teeth.The pressure angle of the teeth is 20^0.Both the pinion and gear are made of heat treated cast iron grade 35.Determin the cone distance, average module and face width of gears. [April/may2008]

Design a bevel gear drive to transmit 10 kW at 140 rpm.Gear ratio is 3, material for pinion and gear is C45 steel. Minimum number of teeth is to be 20.[April/may2009]

A pair of 20^0 full depth involute teeth bevel gears are to be designed to connect two shafts at right angles having velocity ratio 4:1.The gear is made of cast steel and pinion is made of C40 material. The pinion transmits 40 kW at 720 rpm.Design the gears completely. Expected gear life is 10000 hrs. [April/may2012]

A pair of cast iron bevel gears connect two shafts at right angles.The pitch diameters of the pinion and gear are 80 mm and 100 mm respectively.The tooth profiles of the gears are of 14.5^0 composite form.The allowable static stress for both the gears is 55 Mpa.If the pinion transmits 2.75 kW at 1100 rpm, find the module and number of teeth on each gear and check the design.Take surface endurance limit as 630 Mpa and modulus of elasticity for cast iron as 84 kN/mm^2[April/may2009]

Design a cast iron bevel gear drive for a pillar drilling machine to transmit 1.5kW at 800 rpm to a spindle at 400 rpm. The gear is to work for 40 hours/per week for 3 years. Pressure angle is 20^0.check the design and calculate the basic dimension. [April/may2010]

A pair of bevel gears is to be used to transmit 8 kW from a pinion rotating at 240 rpm to a gear mounted on a shaft which intersects the pinion shaft at an angle of 70^0.Assuming that the pinion is to have an outside pitch diameter of 180 mm, a pressure angle of 20^0, a face width of 30 mm, and the gear shaft is to rotate at 80 rpm, determine the forces on the gears and the torque produced about the shaft axis.[Nov/Dec2012]

Design a bevel gear drive to transmit 10 kW power at 1440 rpm.Gear ratio is 4 and life of gears 10,000 hrs. Pinion and gear are made of C45 steel and minimum no. of teeth is 20.[May/june2014]

Design a bevel gear drive to transmit 7 kW at 1600 rpm for the following data: Gear ratio = 3; Material for pinion and gear = C45 Steel; Life = 10,000 hours. [AU, M/J 2013]

Design a bevel gear drive to transmit 7.5 kW at 150 rpm. Gear ratio is 3.5. Material for pinion and gear is C45 Steel. Minimum no of teeth is to be 25. [AU, M/J 2012]

Design a bevel gear drive to transmit 7.5 kW; Speed ratio is 4. Driving shaft speed is 400 rpm. [AU, N/D 2012]

Design a bevel gear drive to transmit 7.36 kW at 1440 rpm for the following data: Gear ratio = 3; Material for pinion and gear = C45 surface hardened. [AU, M/J 2011]

Design a bevel gear drive to transmit 3.5 kW. Speed ratio = 4; Driving shaft speed = 200 rpm. The drive is non-reversible pinion is of steel and wheel of CI. Assume a life of 25,000 hours. [AU, N/D 2011]