pressure angle of 20°. The material of the pinion is forged steel SAE 1030 whose σ_d = 172.375 MPa and the material for gear is cast steel 0.2% C untreated with σ_d = 137.4 MPa. The gears operate under a condition of medium shocks for a period of 10 hours per day. Check for dynamic load, if load factor 580 N/mm and also for wear load. **(16 Marks)**

June/ July 2011 (06ME61)

44. A 12 kW motor running at 1170 rpm drives a fan through a pair of spur gears (forged steel SAE 1030 pinion and CI gear) with a reduction ratio of 3.9:1. Design the gear and check for dynamic and wear loads. **(20 Marks)**

Dec. 2011 (06ME61)

45. a. Derive the Lewis equation for the beam strength of a gear tooth. Also list the assumptions. **(04 Marks)**

b. Design a pair of spur gears to transmit 20 kW of power at a pinion speed of 1000 rpm. The required velocity ratio is 3.5:1. 20° stub involute tooth profile to be used. The static design stress for the pinion is 100 MPa and for the gear is 70 MPa. The pinion has 16 teeth. Determine the module, face width, and pitch circle diameters of the gears based on a service factor of 1.25. **(16 Marks)**

June 2012 (06ME61)

46. a. Sketch and explain the different forms of involute gear tooth. **(05 Marks)**

b. A cast steel pinion with an allowable stress of 103 MPa rotating at 900 r/min is to drive a cast iron gear at 1440 r/min. the teeth are 20° stub involute and maximum power to be transmitted is 25 kW. The allowable stress for cast iron gear is 56 MPa. Determine the module, number of teeth on the gears and face width from the stand-point of strength, dynamic load and wear. **(15 Marks)**

December 2012 (06ME12)

47. a. Two spur gears are to be used for a rock crusher drive and are to be of minimum size. The gears are to be designed for the following requirements. Power to be transmitted is 20 kW; speed of pinion is 1200 rpm, velocity ratio is 3.5:1, tooth profile 20° stub involute. Determine module and face width for strength requirements only. **(10Marks)**

b. A pair of mating helical gears have 20° pressure angle in the normal plane. The normal module is 5 mm and the module in the diametral plane is 5.7735 mm. the pitch diameter of the smaller gear is 115.47 mm. if the transmission ratio is 4:1, calculate;

i. Helix angle
ii. Normal pitch
iii. Transverse pitch
iv. Number of teeth for each gear
v. Addendum
vi. Deddendum
vii. Hole depth
viii. Clearance
ix. Tooth thickness
x. Working depth
xi. outside diameters
xii. center distance
xiii. Root circle diameters
xiv. Base circle diameters.

(10 Marks)

June/ July 2013 (AU53)

48. a. Derive the expression for beam strength of a gear tooth. **(05 Marks)**

b. A pair of straight teeth spur gears, having 20° involute full depth teeth is to transmit 12 kW at 300 rpm of the pinion. The speed ratio is 3:1. The allowable

5

Bevel and Worm Gears

BEVEL GEARS

5.1 INTRODUCTION

Bevel gears are used to transfer power between intersecting shafts, whose axes are not parallel. The teeth of these gears are formed on a conical surface (frustums of cone) Bevel gears are most often mounted on shafts that are 90° apart, but can be designed to work at other angles as well **(Fig. 5.1)**.

Fig. 5.1: Bevel gear

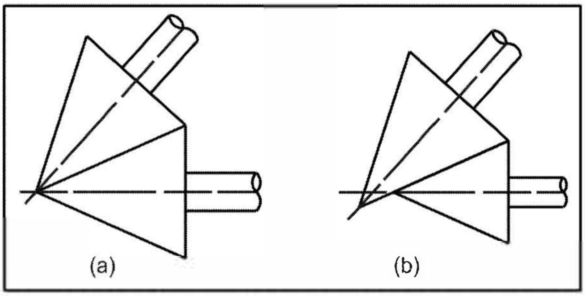

Fig. 5.2: Forms of bevel gear

Figure 5.2 shows two pairs of cone in contact. Since the cone elements **[Fig. 5.2(b)]** do not intersect at the point of intersection of the axis of rotation, these types of cones can't be used as pitch surfaces since it is impossible to have positive driving and sliding in the same direction at the same time. Thus in order to have a positive drive, the elements of the bevel gear pitch cones and shafts must intersect at the same point **[Fig. 5.2 (a)].**

5.2 CLASSIFICATION

Depending upon the angle between the shafts and pitch surfaces, bevel gears are classified as:

1. **Miter Gears:** These are bevel gears with equal numbers of teeth and with axes at right angles. These are specifically designed for operating in pairs. It has a set of tooth that is identical in number, diametral pitches.

5.17 DESIGN PROCEDURE FOR BEVEL GEAR PROBLEMS

1. **Material selection:**
   - Select suitable material if not given from **Table 12.7/ Pg 186, DHB**.
   - **Identifying weaker part (pinion/gear):**
     → If the material used for both pinion and gear is same, then the pinion is weaker.
     → If the material used for both pinion and gear are different, then the strength factor is used to determine the weaker part.
   - Design is based on weaker part.
2. **To find module:**

   a. If the diameter is known, use $m = \dfrac{F_t}{\sigma_d C_v bY}\left[\dfrac{L}{L-b}\right]$, where, $F_t = \dfrac{1000\,PC_s}{v}$

   b. If the diameter is unknown, use $m^3 = \dfrac{18 M_t}{\sigma_d . C_v . Y . z . \sqrt{z_1^2 + z_2^2}}$, where, $M_t = \dfrac{F_t d}{2}$

   c. Check for σ_d in both the cases

   d. If σ_d > permissible value, design fails. Hence adopt/change the module and repeat (2c).
3. **Calculate the dynamic load (F_d).**
4. **Calculate the endurance limit (F_{en}).**

   For safe design, $F_{en} > F_d$
5. **Calculate the wear load (F_w)**
   - For safe design, $F_w > F_d$
   - If $F_w < F_d$, then equate $F_w = F_d$

     i.e. $d_1 bQK = F_d$

   Find the value of K and choose suitable material for gear and pinion using **Table 12.16/ Pg 193, DHB**

Note:

- **If in the problem, diameter is known and z is unknown, calculate m assuming suitable value of z. After obtaining m, find the value of z again.**

1. **Two shafts intersect at right angles and connected by a pair of bevel gears of gear ratio 2.5:1. The module for 20° full depth involute teeth at outer radius is 5 mm and the number of teeth on pinion is 30. If 10 kW of power is to be transmitted at 400 rpm of pinion and face width is 67 mm, determine:**

   a. tangential force at mean radius **c. axial thrust on pinion**
   d. axial thrust on gear.

Solution: $\theta = 90°$, $i = 2.5{:}1$, $\alpha = 20°$ FDI, $m = 5$ mm, $z_1 = z_p = 30$ teeth, $P = 10$ kW, $N_1 = N_p = 400$ rpm, $b = 67$ mm

a. Axial thrust at mean radius, $F_t = ?$
b. Axial thrust on pinion, $F_r = ?$
c. Axial thrust on gear, $F_a = ?$

c. To find dynamic tooth load (F_d):

We know that, $F_d = F_t + \frac{K_3 v (Cb + F_t)}{K_3 v + \sqrt{Cb + F_t}}$ ...Eq. (*iii*) **12.88/ Pg 174, DHB**

here $K_3 = 20.67$

@ $v = 5$ m/s	Error, $e = 0.0640$ mm	**...Tb. 12.14/ Pg 191, DHB**
For $\alpha = 14.5°$ system and CI – CI combination		
@ $e = 0.06$ mm	$C = 331.3$ N/mm	**...Tb. 12.12/ Pg 190, DHB**
$e = 0.0640$ mm	$C = ?$	

$\therefore$ at $v = 5.03$ m/s, $C = \frac{0.064 \times 331.3}{0.06} = 353.39$ N/mm

$\therefore$ Eq. (*iii*) yields... $F_d = 994.04 + \frac{(20.67 \times 5.03) \times [(353.39 \times 50) + 994.04]}{(20.67 \times 5.03) + \sqrt{[(353.39 \times 50) + 994.04}}$

$F_d = 9060$ N

d. To find wear load (F_w):

We know that, $F_w = \frac{d_1 b Q_e K}{\cos \delta_1}$ ...Eq. (*iv*) **12.89/ Pg 174, DHB**

- Diameter of pinion, $\delta_1 = 80$ mm
- Ratio factor, $Q_e = \frac{2 z_{e_2}}{z_{e_2} + z_{e_1}}$ **...12.89/ Pg 174, DHB**

$= \frac{2 \times 254.73}{254.73 + 20.80}$

$Q = 1.849$

- Since *BHN* is unknown, referring to the material of the weaker part i.e. CI pinion whose value of $\sigma_d \leq 55$ MPa, we have *BHN* = 220 **...Tb.12.7/ Pg 186, DHB**
- @ *BHN* = 220, σ_{en} value is not available in the **Tb.12.15/ Pg 192, DHB.**
- Referring to **Tb 12.16/ Pg 193, DHB**, the value of *BHN* for CI is 180 (maximum).
- For $\alpha = 14.5°$ and CI – CI combination of $BHN_1 = BHN_2 = 180$, we have

$\sigma_{en} = 617.8$ MPa and $K = 1.324$ **...Tb.12.16/ Pg 193, DHB**

$\therefore$ Eq. (*iv*) yields... $F_w = \frac{80 \times 50 \times 1.849 \times 1.324}{\cos 15.95}$

$F_w = 10.18$ kN

For safety against wear, $F_w \geq F_d$

i.e. 10.18 kN $\geq$ 9.06 kN ...hence safe.

5. A pair of straight bevel gears transmits 15 kW at 1250 rpm of 120 mm diameter pinion. The speed reduction is 3.5. Use 14.5° involute tooth system. The angle between the shaft axes is 90°. The pinion is made of case hardened alloy steel