A compressor running at 360 r.p.m is driven by a 140 kW, 1440 r.p.m motor through a pair of 20° full depth helical gears having helix angle of 25°. The centre distance is approximately 400 mm. The Motor pinion is to be forged steel and the driven gear is to be cast steel. Assume medium shock conditions. Design the gear pair.

Given Data:-

$N_2 = 360$ rpm, $P = 40$ kW, $N_1 = 1440$ rpm $\phi = 20°$, $\beta = 25°$, $a = 400$ mm.

To find:-

Design the helical gear pair.

Solution :-

Gear ratio $i = \frac{N_1}{N_2} = \frac{1440}{360} = 4.$

Assume $z_1 = 20$

$z_2 = i \times z_1 = 4 \times 20 = 80.$

$z_{v_1} = \frac{z_1}{\cos^3 \beta} = \frac{20}{\cos^3 25^\circ} \approx 27$ and

$z_{v_2} = \frac{80}{\cos^3 25^\circ} \approx 108.$

Pinion - forged steel.

Gear - Grade 1 ie., CS65 steel.

For Pinion .., From table 5.4

$\sigma_{b_1} = 112 N/mm^2$

$[\sigma_{b_1}] y_1' = 112 \times 0.1202 = 13.465 N/mm^2.$

For gear ..., From table 5.4.,

$[\sigma_{b_2}] = 105 N/mm^2$ for cast steel;

$[\sigma_{b_2}] y_2' = 105 \times 0.1455$

$= 15.28 N/mm^2.$

$[\sigma_{b_1}] y_1' < [\sigma_{b_2}] y_2'$ Pinion is weaker.

Material selection :-

1) Pinion - 40Ni 2 Cr1 Mo 28; and Gear-Grade1 Cast steel.

2) $z_1 = 20$ and $z_2 = 80$

3) Calculation of Module :

$$a = \left(\frac{m_n}{\cos\beta}\right) \times \left(\frac{z_1 + z_2}{2}\right).$$

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$M_n = 7.25\,mm.$

4) calculation of b, d, and v :-

Face width (b) = $10 m_n = 10 \times 8 = 80\,mm.$

Pitch circle dia $(d_1) = \frac{m_n}{\cos\beta} \times z_1$

$\Rightarrow 176.54\,mm.$

Pitch line velocity $(v) = \frac{\pi d_1 N_1}{60}$

$\Rightarrow \frac{\pi \times 176.54 \times 10^{-3} \times 1440}{60}$

$\Rightarrow 13.31\,m/s.$

5) Calculation of beam strength (Fs) :-

$F = \pi \cdot m_n \cdot b \cdot [\sigma_b] \cdot y'$

$\Rightarrow 27067.76\,N.$

6) calculation of accurate dynamic load : (Fa) :-

$$F_d = F_t + \frac{21v\,(C_b \cdot \cos^2\beta + F_t)\cos\beta}{21v + \sqrt{C_b \cos^2\beta + F_t}}$$

$F_t = \frac{P}{v} = \frac{140 \times 10^3}{13.31} = 10518.4\,N.$

$$F_d = 10518.4 + \frac{21 \times 13.31 \times 10^3 (450.68 \times 80 \times \cos^2 25^\circ + 10518.4)\cos 25^\circ}{21 \times 13.31 \times 10^3 + \sqrt{450.68 \times 80 \times \cos^2 25^\circ + 10518.4}}$$

$\Rightarrow 46865.44\,N.$

7) Check for beam strength (or tooth breakage) :-

Face width, $b = 10 m_n = 10 \times 9 = 90\,mm.$

Pitch circle dia $d_1 = \frac{m_n}{\cos\beta} \times z_1 = \frac{9}{\cos 25^\circ}$

$\Rightarrow 198.61$ mm.

Pitch line velocity $V = \frac{\pi d_1 N_1}{60} = \frac{\pi \times 198.61 \times 10^{-3} \times 1440}{60}$

$\Rightarrow 14.97$ m/s.

$F_s = \pi \times 9 \times 90 \times 11Q \times 0.1Q02 \Rightarrow 34257.64N$

$$F_d = 9352 + \frac{21 \times 1497 \times 10^3 (243.13 \times 90 \times \cos^2 25^\circ + 9352) \cos 25^\circ}{21 \times 14.97 \times 10^3 \sqrt{243.13 \times 90 \times \cos^2 25^\circ + 9352}}$$

$\Rightarrow 34104.29N$

8) calculation of limited wear load (F_w):-

$$F_w \Rightarrow \frac{d_1 \times b \times Q \times k_w}{\cos^2\beta}$$

Q = Ratio factor $= \frac{2i}{i+1} = 1.6$ and

K_w = Load stress factor $= 2.553$ N/mm^2

$$F_w = \frac{198.61 \times 90 \times 1.6 \times 2.553}{\cos^2 25^\circ} = 88892.66N$$

9) Check for wear :-

We find $F_w > F_s$. It means the gear tooth has adequate wear capacity and will not wear out.

The design is safe and satisfactory.

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1a) calculations of basic dimensions of Pinion and gear:-

Normal Module $M_n = 9mm.$

Face width $b = 90mm.$

No. of teeth $z_1 = 20$ and $z_2 = 80.$

Pitch circle dia $d_1 = 198.61$ mm and

$$d_2 = \frac{m_n}{\cos\beta} \times z_2 = \frac{9}{\cos 25^\circ} \times 80$$

$$\Rightarrow 794.43mm.$$

Centre distance $a = \left(\frac{m_n}{\cos\beta}\right) \times \left(\frac{z_1+z_2}{2}\right)$

$$\Rightarrow \frac{9}{\cos 25^\circ} \times \left(\frac{20+80}{2}\right)$$

$$\Rightarrow 496.52mm.$$

Height factor $f_o = 1$

Bottom clearence $c = 0.25 m_n = 0.25 \times 9$

$$\Rightarrow 2.25mm.$$

$$h = 2.25 m_n = 2.25 \times 9 = 20.25mm.$$

Tip dia $da_1 = \left(\frac{z_1}{\cos\beta} + 2f_o\right) m_n$

$$\Rightarrow \left(\frac{20}{\cos 25^\circ} + 2\times 1\right) 9$$

$$\Rightarrow 216.61mm.$$

$$da_2 = \left(\frac{z_2}{\cos\beta} + 2f_o\right) m_n$$

$$\Rightarrow 812.43mm.$$

Root dia $d_{f_1} = \left(\frac{z_1}{\cos\beta} - 2f_0\right) m_n - 2c$

$\Rightarrow$ 176.11 mm.

$d_{f_2} = \left(\frac{z_2}{\cos\beta} + - 2f_0\right) m_n - 2c$

$\Rightarrow$ 771.93 mm.

Virtual no. of teeth $z_{v1} = 27$ and $z_{v2} = 108$.