Unit-I

Design of Flexible Elements

- Design of flat belts and pulleys:
  - i) Using Basic Equations
  - ii) Using Data Book

- Design of V-belt and pulleys:
  - i) Using data book
  - ii) Using Equations

- Design of wire ropes and pulleys:
  - i) Using Equations
  - ii) Using Data Book

Design of flat belt and pulley

(i) Using basic equation
(ii) Using data book

Using basic equations:

1. Two shafts whose centers are 1m apart are connected by a flat-belt drive. The driving pulley is supplied with 100 kW power and has an effective diameter of 500 mm. It runs at 1000 rpm while the driven pulley runs at 375 rpm. The angle of groove on the pulley is 40°. Permissible tension in 400 mm² cross-sectional area of the belt is 2.1 MPa. The material of the belt has a density of 1100 kg/m³. The distance of the center from the nearest bearing is 200 mm. The coefficient of friction is 0.28. Estimate the number of belts required. Design the flexible drive.

Solution:

\[ C = 1 \text{m} = 1000 \text{ mm} \]

Power, \( P = 100 \text{ kW} \)

Diameter, \( d = 500 \text{ mm} \) (driving pulley)
Speed, \( N = 1000 \) mm/min. (driven pulley)

\[ n = 375 \text{ rpm} \]

Area, \( A = 400 \text{ mm}^2 \)

Permissible stress = 8.1 N/mm²

Density, \( \rho = 1100 \text{ kg/m}^3 \)

\( \mu = 0.28 \)

Step I: Calculation of diameter of driven pulley:

\[ \frac{D}{d} = \frac{N}{n} \]

\[ \frac{D}{500} = \frac{1000}{375} \]

\[ D = 1333.33 \text{ mm} \]

Step II: Calculation of mass per meter of length

\[ \rho = \text{density} \times \text{volume} \]

\[ = \rho \times A \times \ell \]

\[ = 1100 \times 400 \times 10 \times 1 \]

\[ \text{mass} = 0.444 \text{ kg/m} \]
Step 5: Calculation of Centrifugal Tension ($T_c$)

$$T_c = \frac{mv^2}{2}$$

$$v = \frac{\pi DN}{60}$$

$$v = \frac{\pi \times 0.5 \times 1000}{60}$$

$$v = 26.17 \text{ m/s}$$

$$T_c = 0.441 \times (26.17)^2$$

$$T_c = 301.57 \text{ N}$$

Step 6: Calculation of Max. Tension ($T_i$)

$$T_i = T - T_c$$

$$T = Sbren \times Area$$

$$= 2.1 \times 400$$

$$[T = 840 \text{ N}]$$

$$T_i = 840 - 301.57$$

$$T_i = 538.43 \text{ N}$$

Step 7: Calculation of Min. Tension ($T_2$)

$$\frac{T_i}{T_2} = e^{\mu x}$$

$$\frac{538.43}{T_2} = e^{(0.28 \times 0.5)}$$
\[ \alpha' = 180 - \left( \frac{1333.33 - 500}{1000} \right) \times 60 \]

\[ \alpha' = 130 \text{ degrees} \]

\[ \alpha' = 130 \times \frac{\pi}{180} \]

\[ \alpha' = 2.26 \text{ radians} \]

\[ \frac{538.43}{1.883} = T_2 \]

\[ T_2 = 285.96 \text{ N} \]

**Step V:** Power transmitted per belt.

\[ \text{Power per belt} = (T_1 - T_2) N \]

\[ = (538.43 - 285.96) \times 26.11 \]

\[ = 660.7 \times 10^3 \text{ watts} \]

**Step VI:** No. of belts

\[ n_b = \frac{\text{Total power}}{\text{Power per belt}} = \frac{100 \times 10^3}{660.7 \times 10^3} = 15.13 \text{ belts} \]
An open flat drive connects two shafts 1.2 m apart. The driving and driven shafts rotate at 350 rpm and 140 rpm. The driven pulley is 400 mm in diameter. The power to be transmitted is 1.1 kw. Design the drive.

\[ c = 1200 \text{ mm} \]
\[ N = 350 \text{ rpm} \quad \text{(driving pulley)} \]
\[ n = 140 \text{ rpm} \quad \text{(driven pulley)} \]
\[ D = \text{driven pulley diameter} = 400 \text{ mm} \]

Power = \[ 1.1 \times 10^3 \text{ Watts} \]

Step I: Selection of belt

From DB. PG 7.52

Dunlop "HI-speed" 878 G fabric belt is selected.
Step II: Selection of Pulley System

\[ \frac{D}{d} = \frac{N}{n} \]

\[ \frac{450}{d} = \frac{350}{140} \]

\[ d = 160 \text{ mm} \]

Step III: Calculation of Belt Length

From DB pg 7.53

\[ L = 2C + \frac{\pi}{2} (D+d) + \frac{(D-d)^2}{4C} \]

\[ L = 2(1200) + \frac{\pi}{2} (400+160) + \frac{(400-160)^2}{4 \times 1200} \]

\[ L = 3285.64 \text{ mm} \]

Step IV: Calculation of Load Rating

From DB pg 7.54

Load rating at 1 m/s = load rating at 10 m/s \( \times \frac{1}{5} \)

\[ = 0.023 \times \frac{\pi \times 1000 \times 1}{60} \times \frac{1}{10} \]

\[ = 0.023 \times \frac{\pi \times 0.16 \times 350}{60} \times \frac{1}{10} \]

Load rating = 6.74 x 10^-3 kN mm per ply
(ii) Design of V-belts and pulleys

Using (i) Basic Equations
(ii) Using database.

**Using Basic Equations:**

3. It is required to design a cross-V-belt drive to connect a 7.5 kW @ 1440 rpm motor to a compressor running at 480 rpm. The distance between the centres of the pulleys is twice the diameter of the bigger pulley. The belt is operated at 20 m/s and its thickness is 5 mm. Density of belt = 950 kg/m³ and $t_{b} = 5.6$ MPa, $h = 0.3$.

Power $= 7.5 \text{ kW} = 7.5 \times 10^3 \text{ Watts}$

$v = \frac{N \times \pi}{60}$

$n = 1440 \text{ rpm} \quad (\text{driving pulley})$

$n = 480 \text{ rpm} \quad (\text{driven pulley})$

$c = 2D, \quad v = 20 \text{ m/s}$

$f = 950 \text{ kg/m}^3, \quad h = 0.3$

$\sigma_{b} = 5.6 \text{ MPa}, \quad t = 5 \text{ mm}$
Step 5: Calculation of \( d, D, C \):

\[
\text{Given: } v = 20 \text{ m/s}
\]

\[
v = \frac{\text{rad} \times \text{m}}{60}
\]

\[
d = \frac{r \times \text{d} \times \text{m} \times \text{rad}}{60}
\]

\[
d = 0.265 \text{ m}
\]

\[
\begin{align*}
\text{d} &= 265 \text{ mm} \\
\frac{D}{d} &= \frac{N}{n} \\
\frac{D}{265} &= \frac{1440}{180} \\
D &= 795 \text{ mm} \\
C &= 2D = 2 \times 795 = 1590 \text{ mm}
\end{align*}
\]

\[
C = 1590 \text{ mm}
\]
Step II: Calculation of mass per meter length

\[
\text{mass} = \text{density} \times \text{volume} = 8 \times A \times l = 8 \times 5 \times 5 \times 10^{-6} \times 1
\]

\[
\text{mass} = 4.75 \times 10^{-3} \text{ b kg/m}
\]

Step III: Calculation of centrifugal tension (Tc)

\[
T_c = m \cdot V^2 = 4.75 \times 10^{-3} \text{ b} \times (20)^2
\]

\[
T_c = 1.95 \text{ b}
\]

Step IV: Calculation of max. tension (T1)

\[
T_1 = T - T_c
\]

\[
T = \text{stress} \times \text{area} = 5.6 \times 5.6
\]

\[
T = 31.36 \text{ b}
\]

\[
T_1 = 31.36 - 1.95 = 29.41 \text{ b}
\]

\[
\frac{T_1}{T_2} = \lambda
\]

Step V: Calculation of Min. tension (T2)
\[ \theta = 180 - \left( \frac{D \cdot d}{c} \right) \times 60 \]

\[ \theta = 180 - \left( \frac{745 - 260}{7590} \right) \times 60 \]

\[ \theta = 160 \text{ degrees} \]

\[ \alpha = 160 \times \frac{\pi}{180} = 2.79 \text{ radians} \]

\[ \alpha = 2.79 \text{ radians} \]

\[ \frac{T_1}{T_2} = e \]

\[ 2 \beta = 40^\circ \text{ for } v_{boy} \]

\[ \beta = 20^\circ \]

\[ \frac{26.1 \text{ b}}{T_2} = 0.32 \times 2.79 \times 2.423 \]

\[ \text{case } n_0 = \frac{1}{\sin n_0} \]

\[ \text{case } n_0 = 2.923 \]

\[ \frac{26.1 \text{ b}}{T_2} = 11.554 \]

\[ T_2 = \frac{26.1 \text{ b}}{11.554} \]

\[ T_2 = 2.258 \text{ b} \]
Step 2: Power for breaking

\[ \text{Power} = (T_1 - T_0) \text{ N per foot} \]
\[ = (26.15 - 2.25 \times 15.728) \times 20 \]
\[ = 23.842 \times 20 \]
\[ \text{Power per foot} = 476.845 \]

\[ 7500 = 476.845 \times b \]
\[ b = 15.728 \text{ mm} \]

Now the results are as follows

\[ \text{mom} = 4.75 \times 10^{-3} \times 5 = 4.75 \times 10^{-3} \times 15.728 = 0.0747 \text{ kgs/m} \]

\[ T_0 = 1.9 \times b = 1.9 \times 15.728 = 29.88 \text{ N} \]
\[ T_1 = 26.15 \times b = 26.15 \times 15.728 = 410.5 \text{ N} \]
\[ T_2 = 2.255 \times b = 2.255 \times 15.728 = 35.51 \text{ N} \]
(2) A V-belt is required to transmit 16 kW power to a compressor. The motor speed is 1440 rpm and speed reduction ratio is 3.6. Design the drive.

\[ \text{Power, } P = 16 \times 10^3 \text{ Watts} \]

\[ \text{driving speed, } \omega_D = 1440 \text{ rpm} \]

\[ \text{speed reduction ratio, } i = 3.6 \]

\[ i = \frac{\omega_D}{\omega_I} = 3.6 \]

\[ \omega_I = \frac{\omega_D}{i} = 400 \text{ rpm} \]

\[ n_I = 400 \text{ rpm} \]

\[ n_I = \text{driven speed} = 400 \text{ rpm} \]

Step 1: Selection of belt:

From DB pg 7.58

For 16 kW power,

C-section of V-belt can be selected.
**Step II**: Selection of diameters

Recommended minimum driving shaft diameter.

d = 2(3.6d) = 720 mm

**Step III**: Calculation of nominal pitch length (L)

From DB pg 7-6, \( L = 2C + \frac{\pi}{2} \left( d + d \right) + \frac{(D - d)}{4C} \)

\[
\frac{D}{d} = \frac{3.6}{2} = 1.8
\]

\[ \frac{L}{d} = \frac{0.98}{1.8} = 0.98 \]

\[ C = 0.98 \times 720 \]

\[ C = 705.6 \text{ mm} \]

Now,

\[ L = 2 \left( 705.6 \right) + \frac{\pi}{2} \left( 700 + 200 \right) + \frac{(720 - 200)^2}{4(705-6)} \]

\[ L = 2952.13 \text{ mm} \]
DB pg 7.59 and 7.60

nominal pitch length, \( L = 3104 \text{ mm} \)

Step IX: Calculation of maximum power capacity

From DB pg 7.62

for C-section of V-belt

\[
1cw = \left[ 1.147 (s - 0.09) \right] \left[ 142.7 - \frac{142.7 - 2.34 \times 10^{-4} s^2}{\text{de}} \right] \text{s}
\]

\( s = \text{speed of belt in m/s} \)

\[
8 = \left( \frac{F}{b} \right) \times \text{de}
\]

\( \text{de} = \frac{800 \times 1.14}{2.82} \)

\( \text{de} = 228 \text{ mm} \)

Now

\[
1cw = \left[ 1.147 (15.02) \right] \left[ 142.7 - \frac{142.7 - 2.34 \times 10^{-4} (15.02)^2}{2.82} \right] \text{s}
\]

\( 1cw = 9.128 \)
Max. Power Capacity of a Substation

\( P = 7.128 \text{ kW} \)

Step 4: Calculation of arc of contact and various factors

From DB PG 7.68

\[ \alpha = 180^\circ - \left( \frac{2\pi}{c} \right) \times 60 \]

\[ \alpha = 180^\circ - \left( \frac{2 \times 3.14}{705.6} \right) \times 60 \]

\[ \alpha = 125.78 \text{ degrees} \]

\[ \alpha = 125.78 \times \frac{\pi}{180} = 2.21 \text{ radians} \]

DB PG 7.68

\[ F_d = \text{Correction factor at } \alpha = 186 \text{ degrees} \]

\[ F_d = 0.88 \]

DB PG 7.69

Over 16 hrs in Continuous Service.

\[ F_a = \text{Correction factor for Included Service (Fa)} \]

\[ F_a = 1.35 \text{ for medium duty} \]
DB pg 7.60

\( F_c = \) concrete factor

\[ F_c = 0.97 \]

Step VI: Calculation of No. of belts (N_b)

From DB pg 7.70

\[ \frac{\text{No. of belts}}{(N_b)} = \frac{P \times E_a}{I_{CW} \times F_c F_d} \]

\[ = \frac{16 \times 1.3}{7.128 \times 0.97 \times 0.88} \]

\[ N_b = 3.41 \]

\[ N_b = 4 \] belts

Step VII: Calculation of actual length

From DB pg 7.61

\[ A = \frac{L}{4} - \pi \left( \frac{D + d}{8} \right) \]

\[ B = \frac{\pi \times d \times l^2}{8} \]

\[ C = A + \sqrt{A^2 - B} \]
\[ A = \frac{3104}{4} - \frac{\pi}{8} \left( \frac{720 + 200}{8} \right) \]
\[ A = 414.71 \text{ mm} \]

\[ B = \frac{(D-d)^2}{8} = \frac{(720-200)^2}{8} \]
\[ B = 33800 \text{ mm} \]

\[ C = 414.71 + \sqrt{(414.71)^2 - 33800} \]
\[ C = 786.4 \text{ mm} \]  
\( \Rightarrow \) final centre distance.

Then
\[ L = 2C + \frac{\pi}{2} \left( D+d \right) + \frac{(D-d)^2}{4C} \]
\[ = 2(786.4) + \frac{\pi}{2} (720+200) + \frac{(720-200)^2}{4(786.4)} \]
\[ L = 3103.8 \text{ mm} \]
If 40 m/s.

pull the sheet. If it is made by sheet with a mass of

the pull is 0.5m. Suggest suitable size here.

Test number. Has no weight required. At the evening:

and both the force and pulleys are

per metre length and each note has a maximum of

50 mm in diameter. The mass of the note is 13kg.

and angle of 22.5°. The note to be noticed

the second leg may be taken as in medicine

A scope above in the frame and 30 km from

Uns.

V瘦身

(1) Pitch Pool

(1) Test equation

(1) Examination
Using (i) Basic Equations,

(ii) Data Book.

**USING BASIC EQUATIONS:**

5. A rope drive is to transmit 250 kW from a pulley of 1.2 m diameter, running at 3000 rpm. The angle of lap may be taken as $\pi$ radians. The groove half angle is $22.5^\circ$. The ropes to be used are 50 mm in diameter. The mass of the rope is 1.3 kg per metre length and each rope has a maximum pull of 22 kN. The coefficient of friction for rope and pulley is 0.3. Determine the number of ropes required; if the overhang of the pulley is 0.5 m. Suggest suitable size for the pulley shaft if it is made of steel with a shear stress of 400 MPa.

**Answer:**
\[ d = 1.2 \text{ m} \]

\[ N = 300 \text{ mm} \]

\[ \theta = \pi \text{ radians} = 3.14 \text{ radians} \]

\[ \beta = 22.5 \text{ degrees} \]

Pull tension, \( T_0 = 2.2 \text{ kN} = 2.2 \times 10^3 \text{ N} \)

 mass, \( m = 1.2 \text{ kg/m} \)

rope diameter, \( d_r = 50 \text{ mm} \)

\[ \mu = 0.3 \]

\[ T = 40 \text{ N/mm}^2 \]

\[ V = \frac{9 \pi d N}{60} = \frac{9 \pi \times 1.2 \times 300}{60} = 18.65 \text{ m/s} \]

\[ V = 18.65 \text{ m/s} \]

Centrifugal tension:

\[ T_c = mV^2 = 1.2 \times (18.65)^2 \]

\[ T_c = 462 \text{ N} \]

Max Tension

\[ T_1 = T - T_c = 2200 - 462 \]

\[ T_1 = 1738 \text{ N} \]
\[
\frac{T_1}{T_2} = e^{0.3 \times 3.14 \times \frac{1}{6.22 \times 5}}
\]
\[
= 2.46
\]
\[
\frac{1738}{T_2} = e^{2.46}
\]
\[
T_2 = 148.25 \text{ N}
\]

**No. of ropes:**

\[
(\text{No}) = \frac{\text{Total power}}{\text{power per rope}}
\]

\[
(\text{No}) = \frac{(1738 - 148.25) \times 18.85}{29.9 \times 10^3}
\]
\[
= 8.36 \text{ ropes}
\]

\[
(\text{No}) = \frac{280 \times 10^3}{29.9 \times 10^3}
\]
\[
\approx 9 \text{ ropes}
\]
Diameter of driven pulley: \( D \)

\[
D = \, ?
\]

\[
\text{Torque} = \frac{\text{Power} \times 60}{2\pi \text{N} \cdot \text{m}} = \frac{250 \times 10^3 \times 60}{2\pi \times 300}
\]

\[
\text{Torque} = 7957 \text{ Nm}
\]

Since overhanging of the pulley is 0.5 m.

Bending moment:

\[
M = \left( T_1 + T_2 + 2T_c \right) \times \text{overhang} \times \text{no. of }
\]

\[
= \left( 1738 + 14 \times 0.15 + 2(1462) \right) \times 0.5 \times 9
\]

\[
\therefore M = 12646 \text{ Nm.}
\]

Equivalent Torque

\[
T_e = \sqrt{(\text{Torque})^2 + (\text{Bending moment})^2}
\]

\[
T_e = \frac{\pi}{16} \pi D^3
\]

\[
T_e = \sqrt{(7957)^2 + (12646)^2} \times 10^3
\]

\[
= \frac{\pi}{16} \times 40 \times 70^3
\]
$$T_e = 14941.05 \text{ Nm}$$

$$= 14941.05 \times 10^3 \text{ Nmm}$$

$$\frac{T_e}{\pi} = \frac{7}{16} D^3$$

$$14941.05 \times 10^3 = \frac{7}{16} (40)^2 D^3$$

$$D = 123.9 \text{ mm}$$

$$\sqrt{D} = 124 \text{ mm}$$
Select a wire rope for a vertical mine host to lift a load of 55 kN from a depth of 200 m. A rope speed of 500 m/min is to be attained in 10 seconds.

**Solution:**

\[ W = 55 \times 10^3 \text{ N} \]

\[ h = 300 \text{ m} \]

\[ v = 500 \text{ m/min} \]

\[ t = 10 \text{ seconds} \]

**Step I:** Selection of type of wire rope

From DB PG 9.5

Select the group 6x19.

**Step II:** Selection of factor of safety

From DB PG 9.1

For the depth of 300 m,

Factor of safety = 5

**Step III:** Calculation of design load

For design load, factor of safety can be 2.5 to 2.8 times.

\[ \text{Factor of safety} = 5 \times 2.5 = 12.5 \]
Design load = 12.5 x 55 x 10^3

Design load = 687.5 x 10^3 N

Step IV: Calculation of diameter of rope (d)

From DB pg 9.5

Net design load = 687.5 x 10^3 N

constant \cdot 59.5 \cdot d^2 = 687.5 x 10^3

\frac{d}{2} = 0.99 mm

\Rightarrow d = 1.99 mm

\[ \underline{d = 35 mm} \]

Step V: Weight of rope

From DB pg 9.5

W = A \cdot 5.5 \cdot \log b / m.

\Rightarrow W = 4.55 \times 9.61 N/m

\Rightarrow W = 4.55 \times 9.61 \times 300

\Rightarrow W = 13890.65 N

Weight = 13890.65 N

\Rightarrow W = 13891 N
Step VI: Diameter of sheave (D)

\[ D = 60 \text{ to } 100 \text{ times } (d) \]

\[ D = 100 \times d \]

\[ = 100 \times 25 = 3500 \text{ mm} \]

\[ \sqrt{D} = 3500 \text{ mm} \]

Step VII: Bending stress

\[ \sigma_b = \frac{84 \times w^3 \times (0.063 \times 0)}{3500} \]

\[ = \frac{84 \times w^3 \times 0.063 \times 35}{3500} \]

\[ \sigma_b = 52.92 \text{ N/mm}^2 \]

Step VIII: Equivalent bending load

\[ W_b = \sigma_b \times \text{Area} \]

\[ = 52.92 \times (0.38 \times b^2) \]

\[ W_b = 52.92 \times 0.38 \times (35)^2 \]

\[ W_b = 24634.26 \text{ N} \]
Given:

\[ a = \frac{\text{velocity}}{\text{time}} = \frac{50 \text{ m}}{10 \text{ s}} = 5 \text{ m/s}^2 \]

\[ a = 0.8 \text{ m/s}^2 \]

Additional load due to acceleration:

Total load = weight + \((W_a = W + W) \times a\) g

\[ = 55 \times 10^3 + 133.91 \]

\[ = 5786.39 \text{ N} \]

Step 2: Check for factor of safety

Under normal working

Factor of safety = \( \frac{\text{benton load}}{\text{load on rope during normal working}} \)

\[ = 12.5 \]
Note: Tensile safety margin must be less than 1.5.

Load on rope during normal working

\[ = W + W_d + W_b \]

\[ = 55 \times 10^3 + 13.29 + 211.34 \times 9.26 \]

\[ = 93025 \text{ N} \]

\[ \therefore \text{Fos} = \frac{687.5 \times 10^3}{93025} \]

\[ \text{Fos} = 7.39 < 12.5 \]

Hence design is safe.

Load on rope during acceleration

\[ \text{Fos} = \frac{\text{Design load}}{\text{Load on rope during acceleration}} \]

Load on rope during acceleration:

\[ = 93025 + W_a = 93025 + 5786.9 \]

\[ = 98811.39 \text{ N} \]

\[ \text{Fos} = \frac{687.5 \times 10^3}{98811.39} = 6.95 \]

\[ \leq 12.5 \]

Hence design is safe.
During starting

\[ F_{os} = \frac{\text{design load}}{\text{load on rope during starting}} \]

\[ \text{load on rope during starting} \]

\[ = W_{st} + W_b \]

\[ W_{st} = 2(W + w) \]

\[ = 2(51xW^3 + 1339) \]

\[ W_{st} = 13678^2 \text{ N} \]

\[ \text{load on rope during starting} \]

\[ = 136782 + 24634.06 \]

\[ = 161416.26 \text{ N} \]

\[ F_{os} = \frac{687.05 \times W^3}{161416.26} = 4.25 \]

\[ P_{os} = 4.25 < 12.5 \]

Hence design is safe
IV: Design of chain drives using data book

Using data book:

7. Design a chain drive to run a compressor from a 11 kW motor running at 970 rpm. The compressor speed is 330 rpm, the centre distance is approximately 500 mm. The compressor operates 16 hrs/day.

**Solution:**

Power, \( N = 11 \text{ kW} \)

Driving speed, \( N_1 = 970 \text{ rpm} \)

Driven speed, \( N_2 = 330 \text{ rpm} \)

Centre distance, \( a = 500 \text{ mm} \)

Working hrs = 16 hrs/day

Step 2: Selection of transmission ratio:

\[
\rho = \frac{N_2}{N_1} = \frac{N}{N} = \frac{330}{970} = 0.337
\]

\[
\rho = \frac{Z_2}{Z_1} = \frac{330}{970} = 0.337
\]

**Further step:**

Calculate...

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Step II: Selecting the number of teeth on spur pinion.

From DB Pg. 7.74 for \( \phi = 2.93\% \)

\[ z_1 = 25 \text{ teeth} \]

Step III: Calculation of number of teeth in the spur gear.

From DB Pg. 7.74

\[ z_2 = 0.25 z_1 \]

\[ z_2 = 2.939 \times 25 \]

\[ z_2 = 73.48 \text{ teeth} \]

\[ z_2 = 74 \text{ teeth} \]

Step IV: Calculation of pitch

From DB Pg. 7.74

\[ \alpha = \left( \frac{30}{50} \frac{\text{km}}{\text{sec}} \right) P \]

\[ P_{\text{max}} = \frac{\alpha}{30} \]

\[ P_{\text{min}} = \frac{\alpha}{50} \]

\[ P_{\text{max}} = \frac{500}{30} = 16.67 \text{ mm} \]

\[ P_{\text{min}} = \frac{500}{50} = 10 \text{ mm} \]

\[ \text{Pitch} = 15.875 \text{ mm} \]
\[ p = \frac{\rho_0}{p} \]

\[ \rho_0 = 2p + 2\pi z_2 + \left( \frac{2x + 74}{\pi} \right) \left( \frac{174 - 25}{2\pi} \right) \]

\[ 3.1496 \]

\[ \rho = 1816.4 \text{ mm} \]

\[ 1.114 \times 1.575 = 1.814 \times 1.575 \]

\[ \frac{1816.4}{1.814} \]

\[ \frac{1816.4}{1.814} = 2.718 \]
Step 51: Calculation of Centre distance

\[ a = e + \sqrt{e^2 - 8m} \times p \]

\[ e = l_0 - \left( \frac{\frac{z_2 + z_2}{2}}{n} \right) \]

\[ m = \left( \frac{2 \times 2}{2} \right) \]

\[ e = 114.42 - 49.5 \, \text{mm} = 64.92 \, \text{mm} \]

\[ m = \left( \frac{2 \times 2}{2} \right) = 60.81 \]

\[ a = 64.92 + \sqrt{64.92^2 - 8(60.81)^2} \times 4 \]

\[ a = 499.9 \, \text{mm} \, \text{satisfied} \]
Step vii: Calculation of source factor

From PB pg 7.76,

\[ I_{S} = I_{1} \times I_{2} \times I_{3} \times I_{4} \times I_{5} \times I_{6} = 1.25 \times 1 \times 1 \times 1 \times 1 \times 1.25 \]

\[ I_{S} = 1.5625 \]

Step viii: Calculation of bending stress

From DB pg 7.77

\[ N = \frac{\sigma A V}{V_{bc} \times 102 l_{s}} \] (kW)

\[ \sigma \] is obtained from DB pg 7.72

10 A-2 D250 chain.

\[ A = 1.410 \text{ cm}^2 \]

\[ m = 1.78 \text{ kg/m} \]

\[ V = \frac{21 P N}{60} \text{ mm} \]

\[ V = 25 \times 15 \times 875 \times 970 \times 10^{-3} \]

\[ V = 6.1416 \text{ m/s} \]

\[ \text{Power} = 6.1416 \text{ m/s} \times 10^{-3} \]
\[ 11 = \sigma \times 1.40 \times 6.416 \]
\[ 10.2 \times 1.5925 \]
\[ \sigma = 19.5178 \text{ kN/m}^2 \]

**Step 1:** Calculation of Total Load

From page 7.76

\[ \sum P = P_k + P_c + P_s \]

\[ P_c = \frac{102 \times 10^3}{11} \times 10 \text{ (N)} \]

\[ P_c = \frac{wv^2}{g} = \frac{\mu v^2}{g} \text{ (N)} \]

\[ P_s = k \times W_a \times 10 \text{ (N)} \]

\[ \mu = 0.07 \quad s = 6 \]

\[ P_c = \frac{102 \times 10^3}{11} = 1748.75 \text{ N} \]

\[ P_s = 1 \times W_a \times 10 = 6 \times 1.78 \times 10^3 \times 10 \]

\[ P_s = 53.4 \text{ N} \]
\[ \Sigma P = 1348.75 + 73.27 + 83.14 \]

\[ \Sigma P = 1875.15 \text{ N} \]

Step 4: Calculation of pitch diameter of the gear.

From reference pg 7.78

\[ d_1 = \frac{P}{\sin\left(\frac{180}{21}\right)} = \frac{15.875}{\sin\left(\frac{180}{21}\right)} \]

\[ d_1 = 126.66 \text{ mm} \]

\[ d_2 = \frac{P}{\sin\left(\frac{180}{28}\right)} = \frac{15.875}{\sin\left(\frac{180}{74}\right)} \]

\[ d_2 = 374.04 \text{ mm} \]
$$\Sigma P = 1714.75 + 73.27 + 53.4 \quad \sqrt{\Sigma P} = 1875.42 \text{ N}$$

**Step 3:** Calculation of pitch diameter of spur gear.

From AS pg 7.78

$$d_1 = \frac{P}{\sin\left(\frac{180}{2z_1}\right)} = \frac{15.875}{\sin\left(\frac{180}{26}\right)}$$

$$d_1 = 126.66 \text{ mm}$$

$$d_2 = \frac{P}{\sin\left(\frac{180}{2z_2}\right)} = \frac{15.875}{\sin\left(\frac{180}{74}\right)}$$

$$d_2 = 374.04 \text{ mm}$$