Example 2.2 *Design a V-belt drive to the following specifications :*

Power to be transmitted	=	*7.5 kW*
Speed of driving wheel	=	*1440 r.p.m.*
Speed of driven wheel	=	*400 r.p.m.*
Diameter of driving wheel	=	*300 mm*
Centre distance	=	*1000 mm*
Service	=	*16 hours / day*

Given Data : P = 7.5 kW ; N_1 = 1440 r.p.m. ; N_2 = 400 r.p.m. ;

d = 300 mm = 0.3 m ; C = 1000 mm = 1 m.

To find : Design a V-belt drive.

Solution :

1. *Selection of the belt section :*

Consulting Table 2.3, for power 7.5 kW ***B section*** is selected.

2. *Selection of pulley diameters (d and D) :*

$$\text{Speed ratio} = \frac{D}{d} = \frac{N_1}{N_2} = \frac{1440}{400} = 3.6$$

Smaller pulley diameter, d = 300 mm ... (Given)

Referring Table 1.5, the preferred smaller pulley diameter, d = **315 mm.**

∴ Larger pulley diameter, $D = 3.6\,d = 3.6 \times 315 = 1134$ mm

Referring Table 1.5, the preferred larger pulley diameter, D = **1250 mm.**

3. *Selection of centre distance (C) :*

Centre distance, C = **1000 mm** ... (Given)

4. *Determination of nominal pitch length :*

$$\text{Nominal inside length, } L = 2C + \left(\frac{\pi}{2}\right)(D + d) + \frac{(D - d)^2}{4C}$$

$$= (2 \times 1000) + \left(\frac{\pi}{2}\right)(1250 + 315) + \frac{(1250 - 315)^2}{4 \times 1000}$$

$$= 4676.85 \text{ mm}$$

For this nominal inside length and B section, consulting Table 2.5, the next standard pitch length is selected as **4996 mm.**

5. *Selection of various modification factors :*

(i) *Length correction factor (F_c) :* For B section, referring Table 2.5,

length correction factor, F_c = 1.18

(ii) *Correction factor for arc of contact (F_d):*

$$\text{Arc of contact} = 180° - \left(\frac{D - d}{C}\right) \times 60°$$

$$= 180° - \left(\frac{1250 - 315}{1000}\right) \times 60° = 123.9°$$

For this arc of contact, consulting Table 2.6, correction factor for arc of contact is selected as $F_d = 0.83$.

(iii) ***Service factor*** (F_a): Consulting Table 2.7, for light duty 16 hours continuous service, for driving machines of type II, service factor is selected as $F_a = 1.3$.

6. *Calculation of maximum power capacity :*

Consulting Table 2.8, for B section, power capacity formula is given as

$$kW = \left(0.79\, S^{-0.09} - \frac{50.8}{d_e} - 1.32 \times 10^{-4}\, S^2\right) S$$

where S = Belt speed = $\dfrac{\pi d N_1}{60} = \dfrac{\pi \times 0.315 \times 1440}{60}$ = 23.75 m/s

d_e = Equivalent pitch diameter = $d_p \times F_b$

d_p = Pitch diameter of the smaller pulley = 315 mm

F_b = Small diameter factor for speed ratio of 3.6 = 1.14 ... [From Table 2.9]

$\therefore$ d_e = 315 × 1.14 = 359.1 mm

But from Table 2.8, maximum value of d_e in the formula should be 175 mm.

$$\text{Power, kW} = \left(0.79 \times 23.75^{-0.09} - \frac{50.8}{175} - 1.32 \times 10^{-4} \times 23.75^2\right) 23.75 = 5.445 \text{ kW}$$

7. *Determination of number of belts* (n_b):

We know that

$$n_b = \frac{P \times F_a}{kW \times F_c \times F_d}$$

$$= \frac{7.5 \times 1.3}{5.445 \times 1.18 \times 0.83} = 1.828 \approx \mathbf{2\ belts} \quad \textbf{Ans.}$$

8. *Calculation of actual centre distance :*

Actual centre distance is given by

$$C_{actual} = A + \sqrt{A^2 - B}$$

where

$$A = \frac{L}{4} - \pi\left[\frac{D+d}{8}\right] = \frac{4996}{4} - \pi\left[\frac{1250 + 315}{8}\right]$$

$$= 634.42$$

and

$$B = \frac{(D-d)^2}{8} = \frac{(1250 - 315)^2}{8} = 109278$$

$$\therefore \quad C_{actual} = 634.42 + \sqrt{(634.42)^2 - 109278}$$

$$= \mathbf{1175.92\ mm} \quad \textbf{Ans.}$$

Example 2.3 *A centrifugal pump running at 340 r.p.m. is to be driven by a 100 kW motor running at 1440 r.p.m. The drive is to work for atleast 20 hours every day. The centre distance between the motor shaft and the pump shaft is 1200 mm. Suggest a suitable multiple V-belt drive for this application. Also calculate the actual belt tensions and stress induced.*

speed (driven) Power speed (driving) Center distance

Given Data : N_2 = 340 r.p.m. ; P = 100 kW ; N_1 = 1440 r.p.m. ; C = 1200 mm = 1.2 m

To find : (i) Design a V-belt drive, and Service = 20 Hours / day

(ii) Actual belt tensions and stress induced.

☺ Solution :

1. Selection of the belt section : 7.58

Consulting Table 2.3, for power 100 kW, ***D section*** is selected.

2. Selection of pulley diameters (d and D) :

Since diameters of both pulleys are not given, therefore first select the smaller pulley diameter from Table 2.3. 7.58

∴ Consulting Table 2.3, for power 100 kW, smaller pulley diameter, d = **355 mm** 7.58

$$\text{Speed ratio} = \frac{D}{d} = \frac{N_1}{N_2} = \frac{1440}{340} = 4.235$$

∴ Larger pulley diameter, $D = 4.235 \times d = 4.235 \times 355 = 1503.53$ mm

Consulting Table 1.5, the preferred larger pulley diameter, **D = 1600 mm.** 7.54

3. Selection of centre distance (C) :

Centre distance, **C = 1200 mm** ... (Given)

4. Determination of nominal pitch length : 7.53

$$\text{Nominal inside length, } L = 2C + \frac{\pi}{2}(D+d) + \frac{(D-d)^2}{4C}$$

$$= 2 \times 1200 + \frac{\pi}{2}(1600+355) + \frac{(1600-355)^2}{4 \times 1200}$$

$$= 5793.83 \text{ mm}$$

For this nominal inside length and D section, consulting Table 2.5, the next standard pitch length is selected as **6124 mm.** (L) 7.60

5. Selection of various modification factors :

(i) Length correction factor : For D section, referring Table 2.5, length correction factor, F_c = 1.00. 7.60

Correction factor for Industrial service	Fa	7.69
Small dia factor	Fb	7.62
Correction factor	Fc	7.60
For Arc of contact	Fd	7.68

(ii) Correction factor for arc of contact (F_d) :

$$\text{Arc of contact} = 180° - \left(\frac{D-d}{C}\right) \times 60° = 180° - \left(\frac{1600-355}{1200}\right) 60°$$

$$= 117.75°$$

For 117.75°, consulting Table 2.6, correction factor for arc of contact, $F_d = 0.81$.

(iii) Service factor (F_a) : For light duty, for over 16 hours continuous service, for driving machines of type II, consulting Table 2.7, the service factor, $F_a = 1.3$.

6. *Calculation of maximum power capacity (kW) :*

Consulting Table 2.8, for D section, power capacity formula is given as

$$kW = \left(3.22\ S^{-0.09} - \frac{506.7}{d_e} - 4.78 \times 10^{-4}\ S^2\right) S$$

where

$$S = \text{Belt speed} = \frac{\pi\, d\, N_1}{60} = \frac{\pi \times 0.355 \times 1440}{60} = 26.76 \text{ m/s}$$

$$d_e = d_p \times F_b$$

$$d_p = \text{Smaller pulley diameter} = 355 \text{ mm}$$

$$F_b = \text{Small diameter factor, for speed ratio of 4.235, from Table 2.9} = 1.14$$

$$\therefore \quad d_e = 355 \times 1.14 = 404.7$$

$$\text{Power, kW} = \left(3.22 \times 26.76^{-0.09} - \frac{506.7}{404.7} - 4.78 \times 10^{-4} \times 26.76^2\right) 26.76$$

$$kW = 21.44 \text{ kW}$$

7. *Determination of number of belts (n_b) :*

We know that

$$n_b = \frac{P \times F_a}{kW \times F_c \times F_d}$$

$$= \frac{100 \times 1.3}{21.44 \times 1 \times 0.81} = 7.486 \approx \mathbf{8\ belts} \quad \textbf{Ans.}$$

8. *Calculation of actual centre distance :*

$$\text{Actual centre distance, } C_{actual} = A + \sqrt{A^2 - B}$$

where

$$A = \frac{L}{4} - \pi\left[\frac{D+d}{8}\right] = \frac{6124}{4} - \pi\left[\frac{1600+355}{8}\right] = 763.27$$

$$B = \frac{(D-d)^2}{8} = \frac{(1600-355)^2}{8} = 193753.125$$

$$\therefore \quad C_{actual} = 763.27 + \sqrt{763.27^2 - 193753.125} = \mathbf{1386.83\ mm} \quad \textbf{Ans.}$$

9. Calculation of belt tensions (T_1 and T_2) :

We know that,

$$\text{Power transmitted per belt} = (T_1 - T_2)\, v$$

$$\frac{100 \times 10^3}{8} = (T_1 - T_2)\, 26.76 \quad \text{or} \quad T_1 - T_2 = 467.12 \qquad \ldots (i)$$

From Table 2.3, mass per metre length, $m = 0.596$ kg/m

From Table 2.2, groove angle $(2\beta) = 34°$.

Already found that arc of contact for smaller pulley, $\alpha = 117.75° \times \frac{\pi}{180°}$

$= 2.055$ radians

We know that the tension ratio for V-belts considering centrifugal tension,

$$\frac{T_1 - mv^2}{T_2 - mv^2} = e^{\mu\alpha / \sin\beta} = e^{\mu\alpha \cdot \text{cosec}\,\beta}$$

$$\frac{T_1 - 0.596\,(26.76)^2}{T_2 - 0.596\,(26.76)^2} = e^{0.3 \times 2.055 \times \text{cosec}\,17°} = 8.237$$

or $\quad T_1 - 8.237\, T_2 = -3088.68 \qquad \ldots (ii)$

Solving (i) and (ii), we get $\quad T_1 =$ **958.45 N** and $T_2 =$ **491.33 N** **Ans.**

10. Calculation of stress induced :

Consulting Table 2.3, cross-sectional area of D section $= 475\ \text{mm}^2$

$$\therefore \quad \text{Stress induced} = \frac{\text{Maximum tension}}{\text{Cross-sectional area}} = \frac{958.45}{475}$$

$=$ **2.02 N/mm²** **Ans.**