SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
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DEPARTMENT OF MECHANICAL ENGINEERING

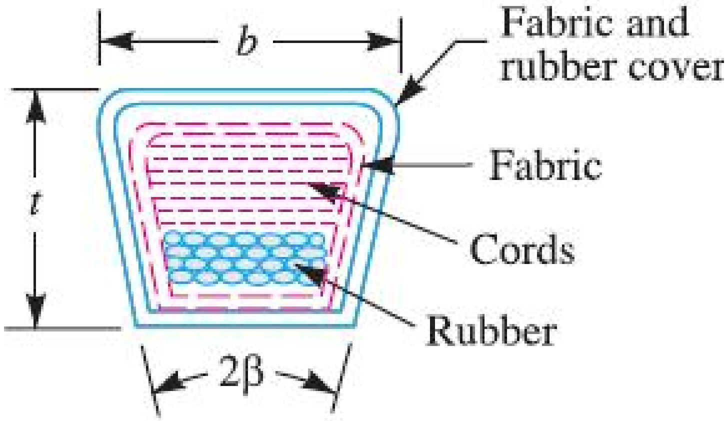
DESIGN OF Transmission System

III YEAR VISEM

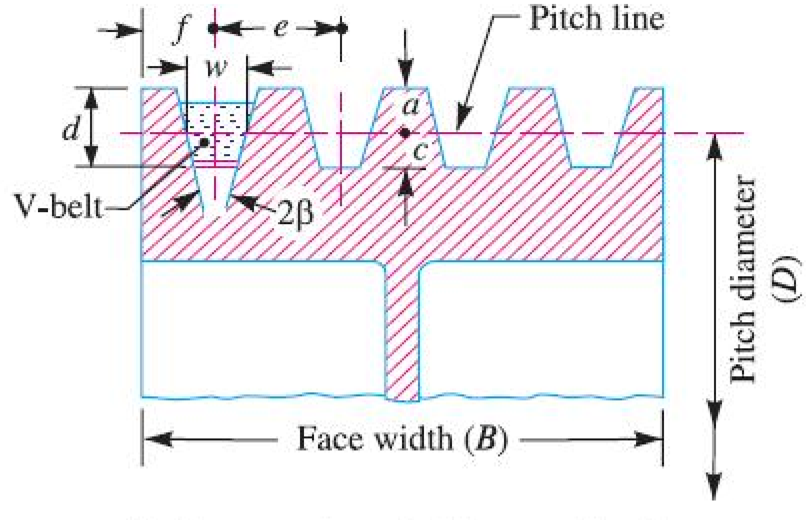
UNIT 1– Design of Flexible Transmission Element

TOPIC :V Belt

Cross-section of v-belt



Cross section of a V Belt



Cross section of a V Grooved Pulley

MATERIALS USED :-

Usually V-belts are made of cord and fabric, impregnated with rubber, the cord material being cotton or rayon. Some of the companies, where V-belts are manufactured, are Goodyear India Ltd., and Fenner India Ltd.

ADVANTAGES AND DISADVANTAGES OF V-BELTS :-

Advantages :-

1. V-Belts can be employed for higher velocity ratio (upto 10)
2. They are used to employ with small centre distance.
3. They can be operated at any position of the drive (i.e., horizontal, vertical or inclined) and even with vertical shaft.
4. In this drive, the tight side of the belt need not compulsorily be at the bottom side of the pulley, like in flat belt drive.
5. They can take up shocks especially at starting.
6. High smoothness of operation is obtained owing to the absence of laced joints and other belt fasteners which may produce noise as in the case of flat belts.
7. The space required for this drive will be comparatively less.
8. During operation, the belt will not come out from pulley at any cost which may sometimes happened in flat belt drive if the shaft's parallelism is slightly changed.

Disadvantages:-

1. V-belts are not so durable as flat ones, because of formation of high bending stresses in V-belts due to higher ratio of belt section height to the pulley diameter comparing to flat belts.
2. The design of pulleys for V-belts are more complicated than the design of pulleys for flat belts.
3. The power transmitting capacity of V-belts is in lower range than flat belt.
4. V-belts cannot be used with large centre distance.
5. They can not be used for cross-belt drive (or) Quarter-turn drive.

DESIGNATION OF V-BELTS:-

V-belt of cross-section D and of

nominal inside length 3048 mm shall be designated as D 3048 - IS: 2494 : 1964 or simply D 3048. Some times the belt length may be represented in inches as D 120. (i.e., 120 inches = 3048mm).

A belt of designation D 3048 having actual pitch length of 3127 mm should be represented as D 3048-50.

If the actual pitch length is 3122 mm, then it may be marked as D 3048-48.

If the actual pitch length is 3132 mm, then it is denoted as D 3048 - 52.

DESIGN OF V-BELTS :-

V-belts are also designed based on 1) fundamental formulas

2) manufactures catalogues.

DESIGN OF V-BELTS USING MANUFACTURES' TABLES :-

The manufacturers produce V-belts in different grades as A, B, C, D, E which can be used to transmit different ranges of power, the range being in increasing order from A to E because of increasing order of area of cross-section in the same series.

Here also, the design of V-belt depends on two concepts.

1. Design Power (i.e., Total power after considering safety factors or correction factors)
2. Belt Rating (i.e., Power transmitting capacity of one belt)

Procedure

1. At first based on amount of power to be transmitted, select the type of belt from A to E grades (Table 4.1) (PSG 7.58)

2. Calculate design power using the relation as

$$\text{Design Power} = \frac{\text{Rated Power x Service Factor}}{\text{Arc of contact factor x Belts's pitch length factor}}$$

For obtaining the above correction factors, find out the service conditions, arc of contact and pitch length and then choose suitable factors from tables 4.2, 4.3, 4.4 respectively. Since the V-belt can be operated as open-belt type we can make use of the following formula for finding pitch length and arc of contact, i.e., The pitch length

$L = 2C + \frac{\pi}{2}(D + d) + \frac{(D - d)^2}{4\,C}$ The arc of contact $\theta = 180° - \left(\frac{D - d}{C}\right)60°$

3. Note the inside length corresponding to pitch length from table 4.4 for belt specification.
4. Determine the belt rating (i.e., power transmitting capacity of one belt) using suitable formula adopted by the manufacturers given in table 4.5 or from table 4.6 (a) to 4.6 (e)
5. Obtain number of belts required to transmit the entire design power as

$$\text{Number of belts} = \frac{\text{Design Power}}{\text{Belt rating}}$$

6. Correct the centre distance according to the selected pitch length Using the formulas (A) which have been given below of table 4.7 and give initial tension to belt. (Refer condition B, below of table 4.7.)

7. Also determine parameters of V-groove pulleys using table 4.8

V belt Drive : Problem :1

A motor driven blower is to run at 650 rpm driven by an electric motor of 7.5 k.W at 1800 rpm. Design V belt drive :

Since the diameters of driving pulley and driven pulley are not given, they may be assumed.

Let d = Diameter of smaller pulley (i.e. driving pulley)

D = Diameter of bigger pulley (i.e. driven pulley)

C = Centre distance.

For the power of 7.5 k.W, 'B' type belt may be selected. For 'B' type belt; d_{min} = 125 mm and d_{max} is calculated as follows.

Equivalent pitch diameter $d_{e\ max} = d_{p\ max} \times F_{b\ max}$

i.e., $d_{p\ max} = \frac{d_{e\ max}}{F_{b\ max}} = \frac{175}{1.14} = 153.5$ mm (Table 4.5) (PSG 7.62)

Hence "d" should be in between 125 to 153.5 mm

Let diameter of driving pulley d = 140 mm

$$\therefore D = \frac{n_1}{n_2} d \cdot \eta = \frac{1800}{650} \times 140 \times 0.98 = 380 \text{ mm}$$

$i = \frac{D}{d} = \frac{n_1}{n_2} = 2.8$ (Table 4.7) (PSG 7.61)

Hence $\frac{C}{D} = 1$ for $\frac{D}{d} = 2.8$

$$\therefore C = D = 380 \text{ mm}$$

$C_{min} = 0.55\,(D + d) + T$ (T from table 4.1) (PSG 7.58)

$= 0.55\,(380 + 140) + 11$

$= 297$ mm

$C_{max} = 2\,(D + d) = 2\,(380 + 140)$

$= 1040$ mm

Since, the calculated centre distance is in between C_{min} and C_{max}; our selection is correct.

$$\text{Design power} = \frac{\text{Rated power} \times \text{Service Factor}}{\text{Length factor} \times \text{Arc of contact factor}}$$

Service factor= 1.3 (Table 4.2) (PSG 7.69)

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

$$= (2 \times 380) + \frac{\pi}{2}(380 + 140) + \frac{(380 - 140)^2}{4 \times 380}$$

$$= 1615 \text{ mm}$$

Standard length = 1694 mm; Inside length = 1651 mm

$\therefore$ Length factor $= 0.94$ (Table 4.4) (PSG 7.59)

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

$$= 180^\circ - \left(\frac{380 - 140}{380} \right) 60^\circ$$

$$= 142^\circ$$

Arc of contact factor $= 0.9$ (Table 4.3) (PSG 7.68)

$$\therefore \text{Design power} = \frac{7.5 \times 1.3}{0.94 \times 0.9} = 11.52 \text{ k.W}$$

Now Belt Rating for 'B' type belt (Refer table 4.5) (PSG 7.62)

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

Now $d_e = d_p \times F_b$

$$= 140 \times 1.13 = 158.2 \text{ mm} < d_{e\,(max)}$$

$$S = \frac{\pi\, dn}{60 \times 1000} = \frac{\pi \times 140 \times 1800}{60 \times 1000} = 13.2 \text{ m/s}$$

By substituting in the above equation; (or) from table (4.6 (b)) (PSG 7.64)

Belt rating $= 3.75$ k.W at 180° arc of contact for $d_e = 160$ mm

and $S = 13$ m/s

(i.e., Power transmitting capacity of one belt)

$$= 3.75 \times \frac{142}{180} = 3.0 \text{ k.W at } 142° \text{ arc of contact.}$$

Number of belts required $= \dfrac{\text{Design power}}{\text{Belt rating}}$

$$= \frac{11.52}{3.0} = 3.84 \text{ belts}$$

$$= 4 \text{ belts}$$

Now, the new centre distance

$$C' = A + \sqrt{A^2 - B}$$

Where $A = \dfrac{L}{4} - \dfrac{\pi (D + d)}{8}$; $B = \dfrac{(D - d)^2}{8}$

Substituting D = 380 mm; d = 140 mm; L = 1694 mm

We get $C' = 421$ mm

Giving initial tension of 1% of L; the final centre

distance = 421 + 17 = 438 mm = 440 mm (say)

Width of pulley = (n − 1) e + 2 f

= (4 − 1) 19 + (2 × 12.5) = 82 mm

Specifications :

Type of drive	—	V-Belt drive
Belt used	—	B1651 - IS2494
Number of belts used	—	4 belts
Diameter of smaller pulley	—	140 mm
Diameter of bigger pulley	—	380 mm
Centre distance	—	440 mm

V belt Drive : Problem : 2

Design a V-belt drive to the following specifications.

Power to be transmitted	=	75 k.W
Speed of driving wheel	=	1440 rpm
Speed of driven wheel	=	400 rpm
Diameter of driving wheel	=	300 mm
Centre distance	=	2500 mm
Service	=	16 hours/day

Solution :

For the given power of 75 k.W, 'D' type (or) 'E' type belts are suited. Let us select 'D' type belt. (From Table 4.1) (PSG 7.58)

$$\text{Design power} = \frac{\text{Rated power} \times \text{Service factor}}{\text{Length factor} \times \text{Arc of contact factor}}$$

Service factor $= 1.5$ (for heavy duty and 16 hours/day with A.C. motor high torque) (Table 4.2) (PSG 7.69)

Pitch length of the belt, $L = 2C + \frac{\pi}{2}(D + d) + \frac{(D-d)^2}{4C}$

Now $d = 300$ mm

$$\therefore\ D = \frac{n_1}{n_2} \times d = \frac{1440}{400} \times 300 = 3.6 \times 300 = 1080 \text{ mm}$$

$C = 2500$ mm

Now $L = (2 \times 2500) + \frac{\pi}{2}(1080 + 300) + \frac{(1080 - 300)^2}{4 \times 2500} = 7229$ mm.

The next standard pitch length $= 7648$ mm

Corresponding inside length $= 7569$ mm (Table 4.4) (PSG 7.60)

Length factor $= 1.05$

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

$$= 180° - \left\{\frac{1080 - 300}{2500}\right\} 60° = 161.3°$$

Arc of contact factor $= 0.955$ (Table 4.3) (PSG 7.68)

Now

$$\text{Design factor} = \frac{75 \times 1.5}{1.05 \times 0.955} = 112.0 \text{ k.W}$$

Power rating for 'D' type belt (Refer table 4.5) (PSG 7.62)

Power transmitting capacity of one belt

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

$$d_e = d_p \times F_b = 300 \times 1.14 = 342 \text{ mm} < d_{e\,(max)} \; (= 425 \text{ mm})$$

$$S = \frac{\pi\, d\, n}{60 \times 1000} = \frac{\pi \times 300 \times 1440}{60 \times 1000} = 22.6 \text{ m/s}$$

$$\therefore \text{ Belt capacity } = \left(3.22 \times 22.6^{-0.09} - \frac{506.7}{342} - 4.78 \times 10^{-4} \times 22.6^2\right) 22.6$$

$$= 15.96 \text{ k.W at } 180^\circ \text{ arc of contact}$$

Power rating for 'D' type belt (Refer table 4.5) (PSG 7.62)

Power transmitting capacity of one belt

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

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$$S = \frac{\pi\, d\, n}{60 \times 1000} = \frac{\pi \times 300 \times 1440}{60 \times 1000} = 22.6 \text{ m/s}$$

$$\therefore \text{ Belt capacity } = \left(3.22 \times 22.6^{-0.09} - \frac{506.7}{342} - 4.78 \times 10^{-4} \times 22.6^2\right) 22.6$$

$$= 15.96 \text{ k.W at } 180^\circ \text{ arc of contact}$$

$\therefore$ Required Belt capacity for 161.3° arc of contact $= 15.96 \times \frac{161.3}{180}$

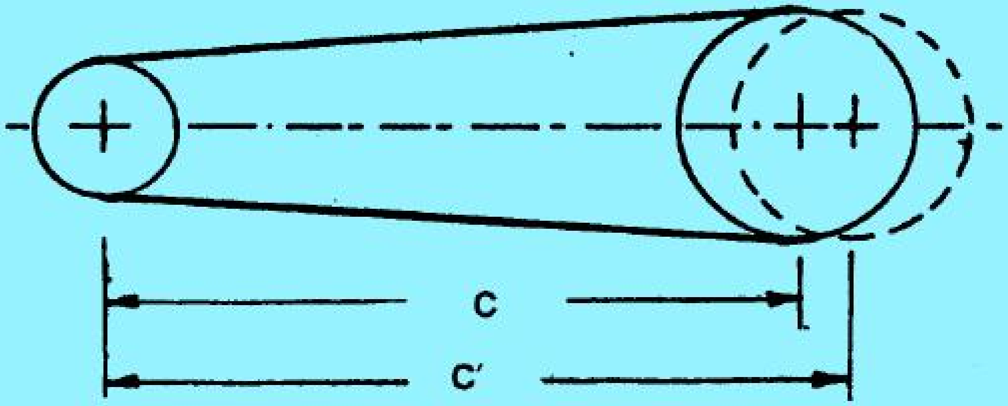
$= 14.3$ k.W

Number of belts required $= \frac{\text{Design power}}{\text{Belt rating}}$

$= \frac{112.0}{14.3} = 7.82$ belts

Total Number of belts $= 8$

Since the pitch length is changed from 7229 mm to 7648 mm, the centre distance should also be increased in order to place the belt property over the pulley (Refer figure 4.4)



C – Given centre distance
C′ – Corrected centre distance.

New centre distance

$$C' = A + \sqrt{A^2 - B}$$

Where $$A = \frac{L}{4} - \frac{\pi}{8}(D + d)$$

$$= \frac{7648}{4} - \frac{\pi}{8}(1080 + 300) = 1370$$

$$B = \frac{(D - d)^2}{8} = \frac{(1080 - 300)^2}{8} = 76050$$

$$\therefore C' = 1370 + \sqrt{1370^2 - 76050} = 2712 \text{ mm}$$

Initial tension $= 0.75$ to 1% of L

Take 1% of $L = 7648 \times \frac{1}{100} = 76$ mm

$\therefore$ Final centre distance $= 2712 + 76 = 2788$ mm.

Width of pulley $= (n - 1)\, e + 2\, f$ where n = total no. of belts

$= (8 - 1)\, 37 + (2 \times 24) = 307$ mm (Table 4.8) (PSG 7.70)

Specifications :

Type of Belt	=	D 7569 50 IS2494 (V-Belt)
Number of belts	=	8
Pitch diameter of smaller pulley	=	300 mm
Pitch diameter of bigger pulley	=	1080 mm
Centre distance	=	2788 mm

V belt Drive : Problem :3

Select a suitable V-Belt and design the drive for a wet grinder. Power is available from a 0.5 k.W motor running at 750 rpm. Drum speed is to be about 100 rpm. Drive is to be compact.

Solution :

Given :-	Power	=	0.5 k.W.
	Motor speed n	=	750 rpm
	Drum speed N	=	100 rpm

For the power 0.5 k.W 'A' type belt may be selected. For this belt, the minimum pulley pitch diameter is

$$d_{min} = 75 \text{ mm} \qquad \text{(Table 4.1)}$$

d_{max} can be calculated from the relation

$$d_{e\,max} = d_{p\,max} \times F_{b\,max}$$

$$125 = d_{p\,max} \times 1.14 \qquad \text{(Table 4.5)}$$

$$\therefore\ d_{p\,max} = \frac{125}{1.14} = 109.6 \text{ mm} = 110 \text{ mm}$$

Hence we should select the diameter of smaller pulley (d) between 75 mm and 110 mm.

Let us select $d = 100$ mm

Diameter of Drum $D = \frac{n}{N} \eta \cdot d$

$$= \frac{750}{100} \times 0.98 \times 100 = 735 \text{ mm}$$

Centre distance :

$$\frac{C}{D} = 0.85 \text{ for } \frac{D}{d} = 7.35 \quad \text{(Table4.7)}$$

$$\therefore C = 0.85 \times D = 0.85 \times 735 = 625 \text{ mm}$$

$$C_{min} = 0.55\,(D + d) + T \qquad \text{(T is from table 4.1)}$$

$$= 0.55\,(735 + 100) + 8 = 467 \text{ mm}$$

$$C_{max} = 2\,(D + d)$$

$$= 2\,(735 + 100) = 1670 \text{ mm}$$

Since 'C' value is in between C_{min} and C_{max} our selection is correct.

$$\text{Design power} = \frac{\text{Rated power} \times \text{Service factor}}{\text{Arc of contact factor} \times \text{Length factor}}$$

Rated power $= 0.5$ k.W

Service factor $= 1.2$ (for light duty)

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

$$= 180 - \left(\frac{735-100}{625}\right) \times 60 = 119^\circ$$

Arc of contact factor $= 0.82$ (Table 4.3)

$$\text{Pitch length} = 2C + \frac{\pi}{2}(D+d) + \frac{(D-d)^2}{4C}$$

$$= (2 \times 625) + \frac{\pi}{2}(735+100) + \frac{(735-100)^2}{4 \times 625}$$

$= 2723$ mm

Next standard pitch length $= 2880$ mm

$\therefore$ Length factor $= 1.11$

Inside length $= 2845$ mm (Table 4.4)

$$\therefore \text{Design power} = \frac{0.5 \times 1.2}{0.82 \times 1.11} = 0.659 \text{ k.W} = 0.7 \text{ k.W}$$

Belt capacity :

$$\text{Belt speed} = \frac{\pi d n}{60 \times 1000} = \frac{\pi \times 100 \times 750}{60 \times 1000} = 3.93 \text{ m/sec}$$

Equivalent pitch diameter $d_e = d_p \times F_b$

$$d_e = 100 \times 1.14 = 114 \text{ mm}$$

$\therefore$ Belt capacity $= 0.9$ k.W (Table 4.6 (a))

$$\therefore \text{No. of belts} = \frac{\text{Design power}}{\text{Belt rating}}$$

$$= \frac{0.7}{0.9} = 0.8 = 1 \text{ belt (say)}$$

Corrected centre distance

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

$$A = \frac{L}{4} - \frac{\pi}{8}(D + d) = \frac{2880}{4} - \frac{\pi}{8}(735 + 100) = 392$$

$$B = \frac{(D-d)^2}{8} = \frac{(735-100)^2}{8} = 50403$$

$$\therefore C = 392 + \sqrt{392^2 - 50403} = 713 \text{ mm}$$

Distance for initial tension = 0.5 % of L

$$\therefore \text{Actual centre distance} = 713 + \frac{0.5}{100} \times 2880 = 727.4 \text{ mm}$$

$$= 730 \text{ mm (say)}$$

$$\text{Width of pulley} = (n-1)\,e + 2\,f = 2 \times 10 = 20 \text{ mm}$$

(e value is zero)

Specifications :

1.	Type of belt	=	A2845 – IS2494
2.	Diameter of motor pulley	=	100 mm
3.	Diameter of Drum pulley	=	735 mm
4.	Centre distance	=	730 mm
5.	Width of pulley	=	20 mm
6.	No. of belts	=	1

USING FUNDAMENTAL FORMULAS

A compressor, requiring 90 kW, is to run at about 250 r.p.m. The drive is by V-belts from an electric motor running at 750 r.p.m. The diameter of the pulley on the compressor shaft must not be greater than 1 metre while the centre distance between the pulleys is limited to 1.75 metre. The belt speed should not exceed 1600 m / min.

Determine the number of V-belts required to transmit the power if each belt has a cross-sectional area of 375 mm^2, density 1000 kg / m^3 and an allowable tensile stress of 2.5 MPa. The groove angle of the pulleys is 35°. The coefficient of friction between the belt and the pulley is 0.25. Calculate also the length required of each belt.

Solution. Given : $P = 90$ kW $= 90 \times 10^3$ W ; $N_2 = 250$ r.p.m. ; $N_1 = 750$ r.p.m. ; $d_2 = 1$ m ; $x = 1.75$ m ; $v = 1600$ m/min $= 26.67$ m/s ; $a = 375$ mm$^2 = 375 \times 10^{-6}$ m^2 ; $\rho = 1000$ kg / m^3 ; $\sigma = 2.5$ MPa $= 2.5$ N/mm^2 ; $2\beta = 35°$ or $\beta = 17.5°$; $\mu = 0.25$

First of all, let us find the diameter of pulley on the motor shaft (d_1). We know that

$$\frac{N_1}{N_2} = \frac{d_2}{d_1} \quad \text{or} \quad d_1 = \frac{d_2 N_2}{N_1} = \frac{1 \times 250}{750} = 0.33 \text{ m}$$

For an open belt drive, as shown in Fig. 20.4,

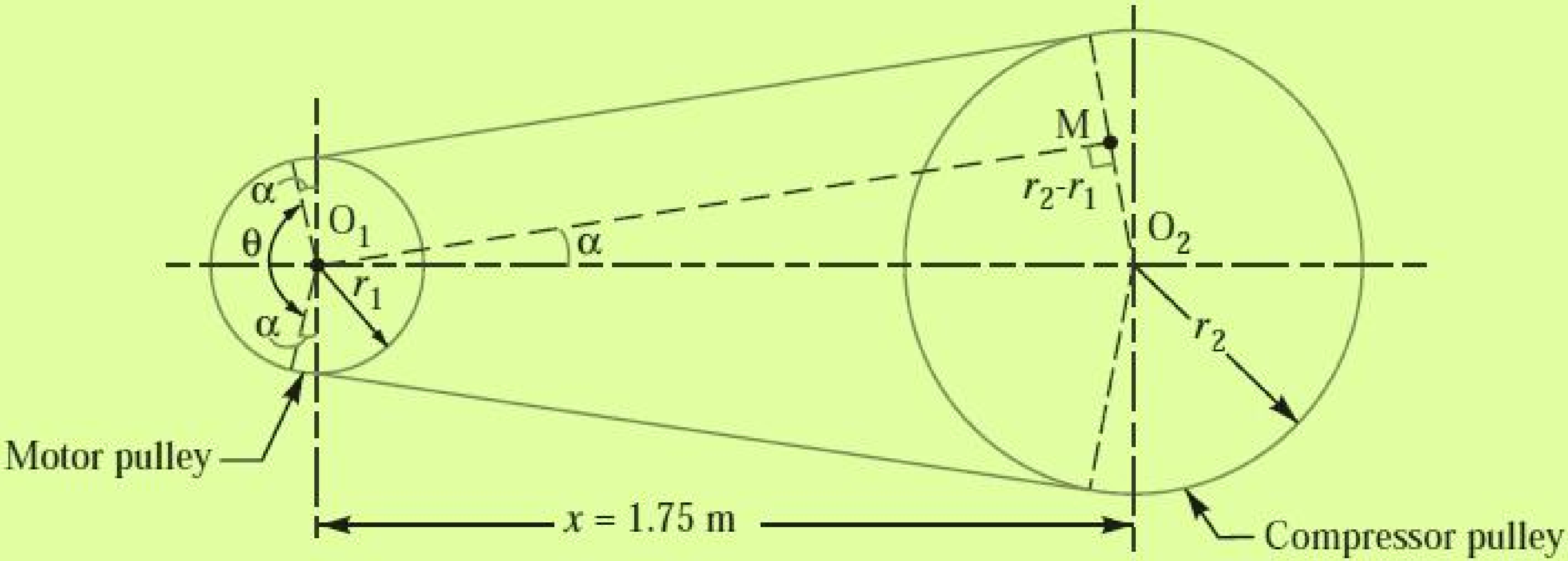
$$\sin \alpha = \frac{O_2 M}{O_1 O_2} = \frac{r_2 - r_1}{x} = \frac{d_2 - d_1}{2x} = \frac{1 - 0.33}{2 \times 1.75} = 0.1914$$

$$\therefore \quad \alpha = 11.04°$$

and angle of lap on the smaller pulley (*i.e.* pulley on the motor shaft),

$$\theta = 180° - 2\alpha = 180 - 2 \times 11.04 = 157.92°$$

$$= 157.92 \times \frac{\pi}{180} = 2.76 \text{ rad}$$



We know that mass of the belt per metre length,

$$m = \text{Area} \times \text{length} \times \text{density} = 375 \times 10^{-6} \times 1 \times 1000 = 0.375 \text{ kg / m}$$

∴ Centrifugal tension,

$$T_C = m.v^2 = 0.375\,(26.67)^2 = 267 \text{ N}$$

and maximum tension in the belt,

$$T = \sigma \times a = 2.5 \times 375 = 937.5 \text{ N}$$

∴ Tension in the tight side of the belt,

$$T_1 = T - T_C = 937.5 - 267 = 670.5 \text{ N}$$

Let T_2 = Tension in the slack side of the belt.

We know that

$$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu.\theta \operatorname{cosec} \beta = 0.25 \times 2.76 \times \operatorname{cosec} 17.5^\circ$$

$$= 0.69 \times 3.3255 = 2.295$$

$$\therefore \quad \log\left(\frac{T_1}{T_2}\right) = \frac{2.295}{2.3} = 0.9976 \quad \text{or} \quad \frac{T_1}{T_2} = 9.95$$ ...(Taking antilog of 0.9976)

and $T_2 = T_1 / 9.95 = 670.5 / 9.95 = 67.4$ N

Number of V-belts

We know that the power transmitted per belt,

$$= (T_1 - T_2)\, v = (670.5 - 67.4)\, 26.67 = 16\,085 \text{ W} = 16.085 \text{ kW}$$

∴ Number of *V*-belts

$$= \frac{\text{Total power transmitted}}{\text{Power transmitted per belt}} = \frac{90}{16.085} = 5.6 \text{ say } 6$$ **Ans.**

Length of each belt

We know that radius of pulley on motor shaft,

$$r_1 = d_1 / 2 = 0.33 / 2 = 0.165 \text{ m}$$

and radius of pulley on compressor shaft,

$$r_2 = d_2 / 2 = 1 / 2 = 0.5 \text{ m}$$

We know that length of each belt,

$$L = \pi (r_2 + r_1) + 2x + \frac{(r_2 - r_1)^2}{x}$$

$$= \pi (0.5 + 0.165) + 2 \times 1.75 + \frac{(0.5 - 0.165)^2}{1.75}$$

$$= 2.09 + 3.5 + 0.064 = 5.654 \text{ m } \textbf{Ans.}$$


Thank You