Kinematics & Dynamics of Linkages

Lecture 7: Belts

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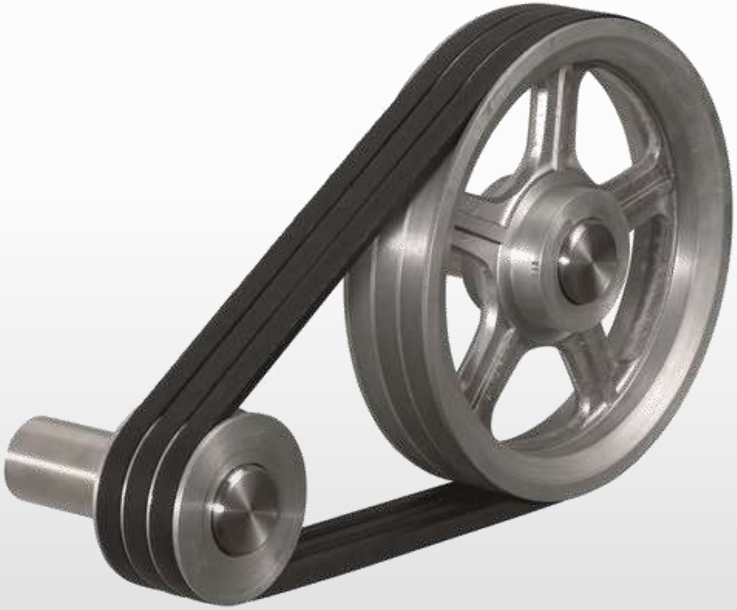
Belts advantages

- Inexpensive
- Flexible shaft center distances
- Smooth and quiet at high speeds
- Possibility of slip
- Require no lubrication, and little maintenance
- Can be used in more than one plane
- Easy to assemble
- Absorb shock loading

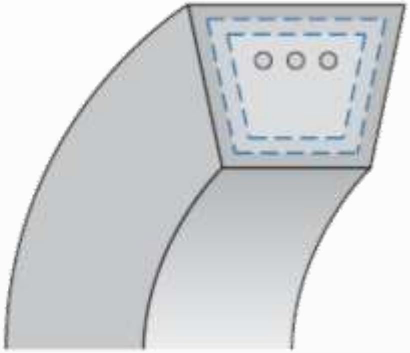


Types of belts

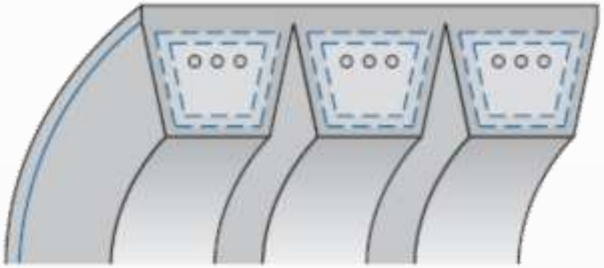
- **Flat belt:** Basic belt, limited to low-torque applications because of friction between the belt and the pulley
- **V-belt**: Minimal slipping, increased friction allowing higher operating torque
- **Timing Belt**: has gear-like teeth that engage with mating teeth on the pulley. This combines a Positive gear drive with no slip

Types of belts

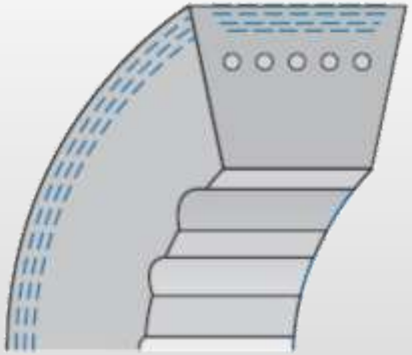
(a) Flat belt



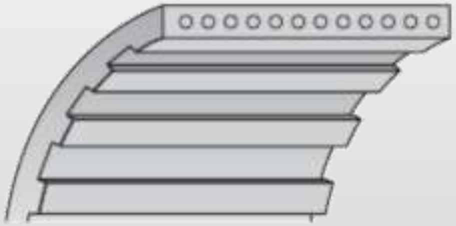
(b) V-belt



(c) Multi-V-belt

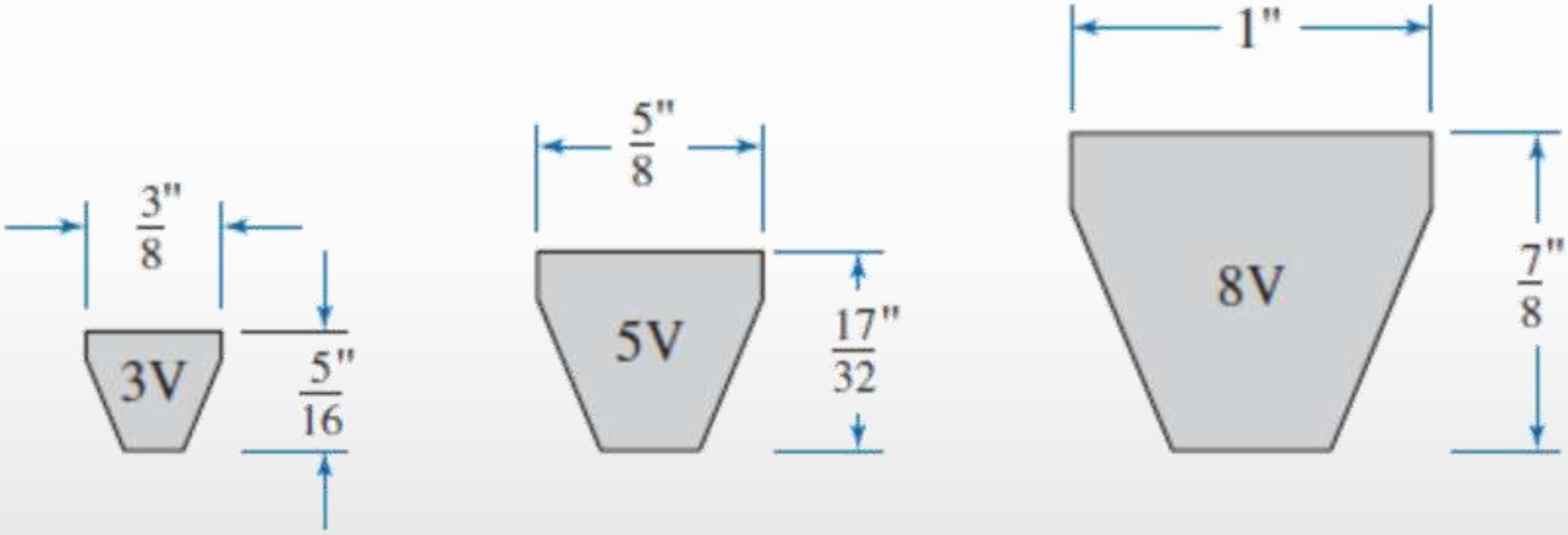


(d) Cog belt



(e) Timing belt

Conventional V-Belt sizes



V-Belt Pulley sizes

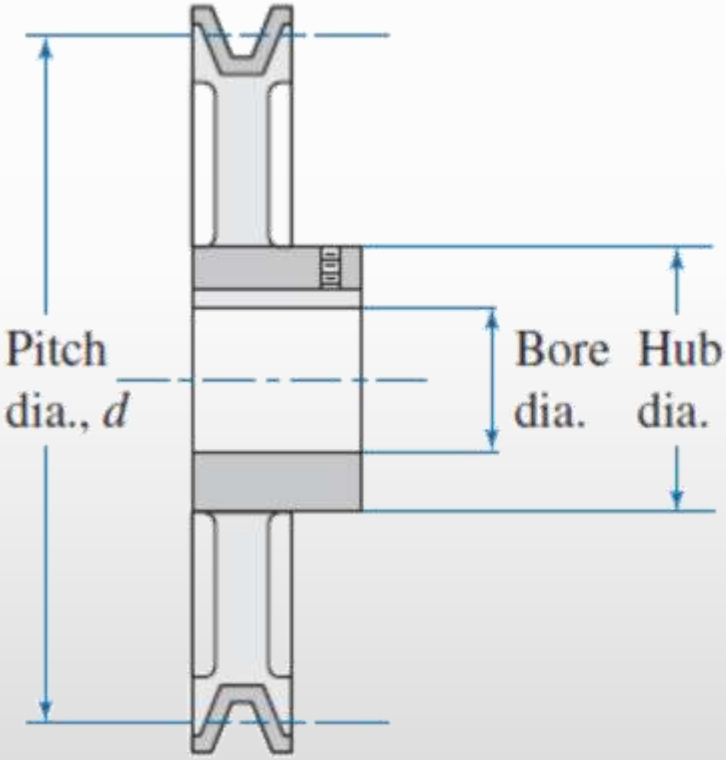
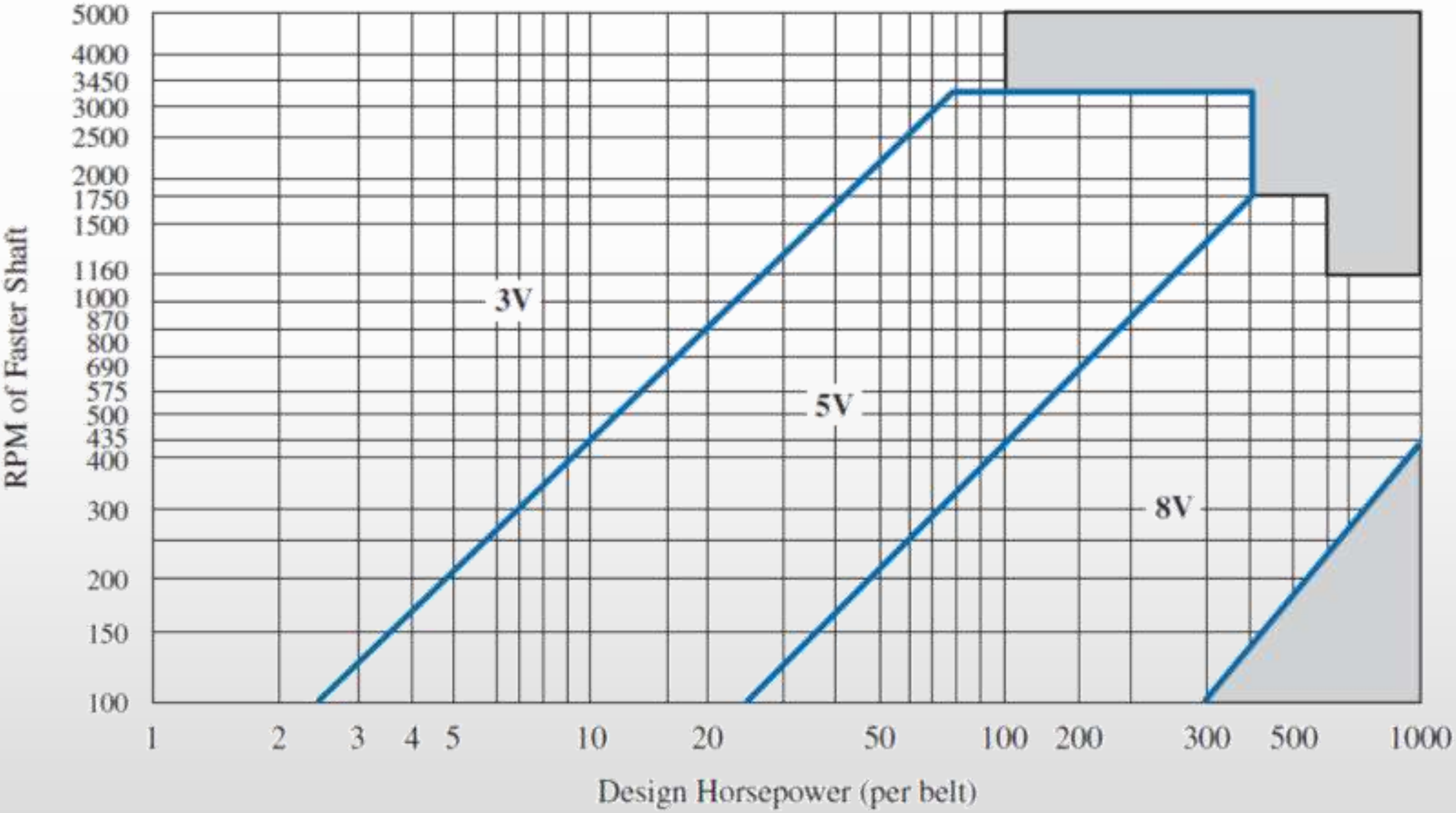


TABLE 11.1 Commercially Available Sheaves

Sheave Pitch Diameters (in.)

3V Belt		5V Belt		8V Belt
2.2	5.3	4.3	8.4	12.3
2.3	5.6	4.5	8.9	13.0
2.5	6.0	4.8	9.2	13.8
2.6	6.5	4.9	9.7	14.8
2.8	6.9	5.1	10.2	15.8
3.0	8.0	5.4	11.1	16.8
3.1	10.6	5.5	12.5	17.8
3.3	14.0	5.8	13.9	18.8
3.6	19.0	5.9	15.5	19.8
4.1	25.0	6.2	16.1	21.0
4.5	33.5	6.3	18.5	22.2
4.7		6.6	20.1	29.8
5.0		6.7	23.5	39.8
		7.0	25.1	47.8
		7.1	27.9	52.8
		7.5		57.8
		8.1		63.8

V-Belt selection chart



V-Belt lengths

TABLE 11.2 Commercially Available V-Belt Lengths (in.)

3V Belt Lengths				5V Belt Lengths				8V Belt Lengths			
25.0	40.0	63.0	100.0	50.0	90.0	160.0	280.0	100.0	160.0	236.0	355.0
26.5	42.5	67.0	106.0	53.0	95.0	170.0	300.0	112.0	170.0	250.0	400.0
28.0	45.0	71.0	112.0	56.0	100.0	180.0	315.0	118.0	180.0	265.0	450.0
30.0	47.5	75.0	118.0	60.0	106.0	190.0	335.0	125.0	190.0	280.0	
31.5	50.0	80.0	125.0	63.0	112.0	200.0	355.0	132.0	200.0	300.0	
33.5	53.0	85.0	132.0	67.0	118.0	212.0		140.0	212.0	315.0	
35.5	56.0	90.0	140.0	71.0	125.0	224.0		150.0	224.0	335.0	
37.5	60.0	95.0		75.0	132.0	236.0					
				80.0	140.0	250.0					
				85.0	150.0	265.0					

V-Belt useful Data

ENGINEERS EDGE
Solutions By Design

https://www.engineersedge.com/vee_flat_belt_menu.shtml

V-Belt and Flat Belt Design and Engineering Formulas

V-Belt Suppliers

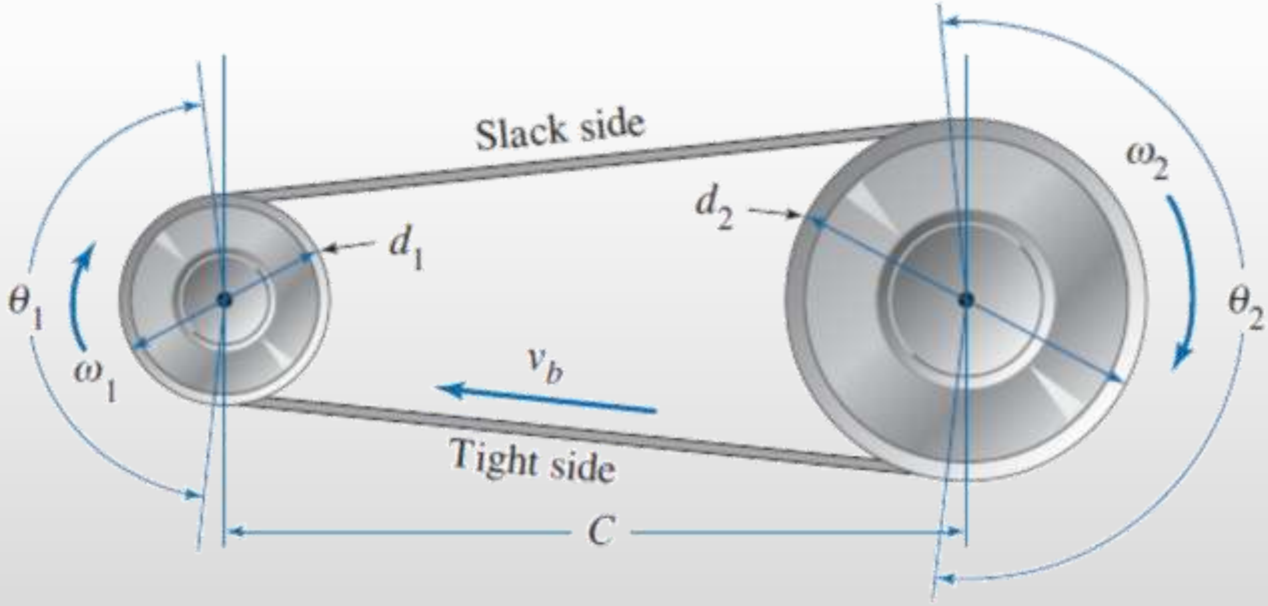
- The following are to links of mechanical V-Belt Applications and Design and other useful data.
- Should you find any errors omissions broken links, please let us know - Feedback
- Do you want to contribute to this section? See Premium Publisher Program

- Electric Motor Shaft Load Due to Belt Loading Equations and Calculator
- Flat Belt Design Equations
- V Belt Conventional Sizes
- V Belt Application
- V Belt Pulley Groove (Sheave) Sizes
- V Belt Rated Horsepower Equations
- Belt Tensions, Torques and Power
- Standard, Sizes and Sheave Diameters
- Toothed Pulley Center Distance Calculator
- Tension Relation of V Belt
- Service Factors
- Design Horsepower Vs Service Factor

Belt Drive Geometry

To avoid belt fatigue and vibrations, the center distance should be:

$$d_2 < C < 3(d_1 + d_2)$$



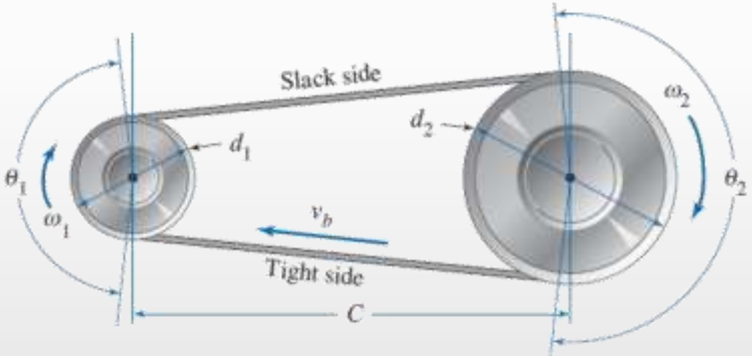
Belt Drive Geometry – Length

Belts are available in standard lengths

$$L = 2C + \frac{\pi}{2}(d_2 + d_1) + \frac{(d_2 - d_1)^2}{4C}$$

$$C = \frac{B + \sqrt{B^2 - 32(d_2 - d_1)^2}}{16}$$

$$B = 4L - 2\pi(d_2 + d_1)$$

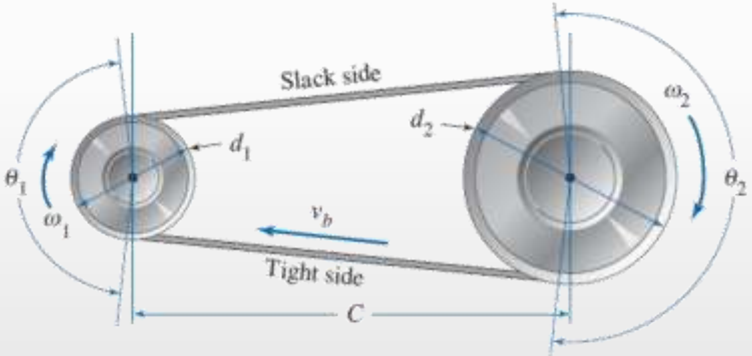


Belt Drive Geometry – Contact angle

The angle of contact, θ, is a measure of the angular engagement of the belt on each sheave:

$$\theta_1 = 180° - 2\sin^{-1}\left\{\frac{d_2 - d_1}{2C}\right\}$$

$$\theta_2 = 180° + 2\sin^{-1}\left\{\frac{d_2 - d_1}{2C}\right\}$$



Belt Drive Geometry – Contact angle

The power rating for the belts shown on slides 6 and 7 are for drives with sheaves of the same size (180° contact angle).
For smaller angles, the amount of friction that can be developed around the sheave is reduced, and therefore, the amount of power that a belt can transfer is reduced

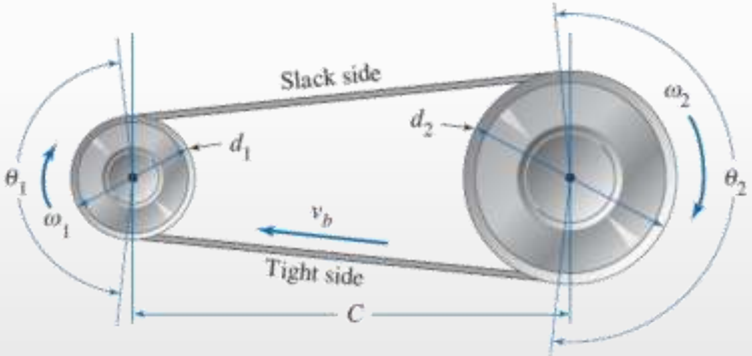
TABLE 11.3 Reduced Power Capability with Contact Angle

Angle of Contact, θ	180°	160°	140°	120°	100°	80°
Actual Capability (% of rated power)	100	95	89	82	74	63

Belt Drive Geometry – Velocity Ratio

A belt transfers maximum power at speeds of **4000 to 5000 fpm**. Therefore, it is best to design a belt drive to operate in this range.

Velocity ratio:



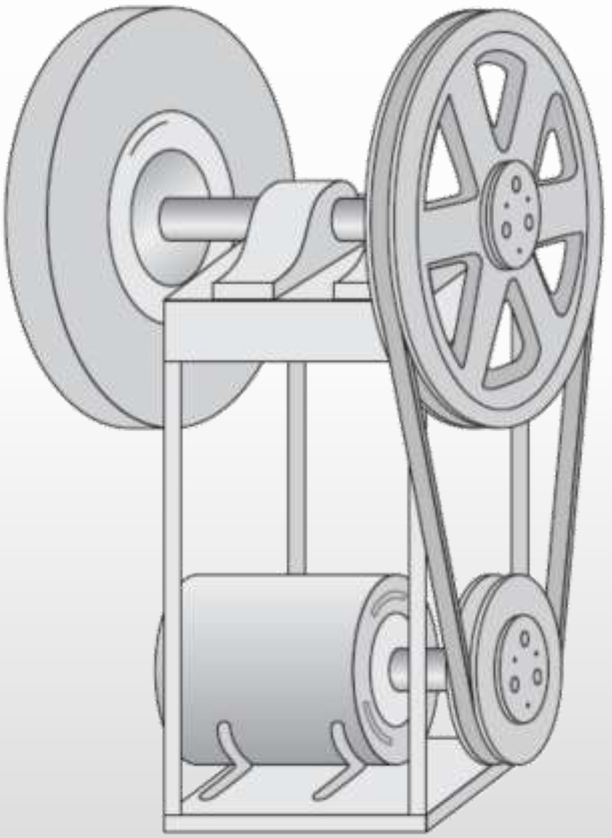
$$VR = \frac{\omega_1}{\omega_2} = \frac{r_2}{r_1} = \frac{d_2}{d_1}$$

Belt speed:

$$v_b = r_1\omega_2 = \frac{d_1}{2}\omega_1 = r_2\omega = \frac{d_2}{2}\omega_2$$

Example 1

A belt drive is required to reduce the speed of an electric motor for a grinding wheel. The 50-hp electric motor is rated at 1725rpm, and a grinding wheel of approximately 600rpm is desired. Determine an appropriate belt size and find suitable sheave diameters of stock pulleys listed in **Table 11.1**. also select a suitable belt length from **Table 11.2** and calculate the corresponding center distance C.



Example 1 – Solution

1. *Determine Appropriate Belt Size*

   With a 50-hp motor driving at 1725 rpm, Figure 11.4 suggests using a 5V belt.

2. *Determine Ideal Diameter for Driver Sheave*

   The respective shaft speeds are as follows:

$$\omega_1 = 1725 \text{ rev/min}\left(\frac{2\pi \text{ rad}}{1 \text{ rev}}\right) = 10{,}838 \text{ rad/min}$$

$$\omega_2 = 600 \text{ rev/min}\left(\frac{2\pi \text{ rad}}{1 \text{ rev}}\right) = 3770 \text{ rad/min}$$

Example 1 – Solution

$$d_1 = 2\left(\frac{v_b}{\omega_1}\right) = 2\left(\frac{4500 \text{ ft/min}}{10{,}838 \text{ rad/min}}\right)$$

$$= 0.83 \text{ ft} = 9.96 \text{ in.}$$

3. ***Select Available Sheave***

Selecting a driver sheave of 10.20 in. from Table 11.1 yields a belt speed of

$$v_b = \frac{d_1}{2}\omega_1 = \frac{10.20 \text{ in.}}{2}(10{,}838 \text{ rad/min}) = 55{,}274 \text{ in./min} = 4606 \text{ fpm}$$

Example 1 – Solution

4. *Select Available Driven Sheave*

From equation (11.8), the desired velocity ratio is determined by

$$VR = \frac{\omega_1}{\omega_2} = \frac{10{,}838 \text{ rad/min}}{3770 \text{ rad/min}} = 2.87$$

And the resulting driven sheave diameter is calculated as follows:

$$d_2 = (VR)(d_1) = 2.87(10.2 \text{ in.}) = 29.3 \text{ in.}$$

The actual grinding wheel speed is

$$\omega_2 = \frac{\omega_1 d_1}{d_2} = \frac{(1725 \text{ rpm})(10.2 \text{ in.})}{27.9 \text{ in.}} = 630 \text{ rpm}$$

Example 1 – Solution

5. ***Select an Available Belt***

The suggested center distance for belt drives is within the following range

$$d_2 < C < 3(d_1 + d_2)$$

$$27.9\,\text{in.} < C < 114.3\,\text{in.}$$

A mid-value of 72 in. is tentatively selected. Substituting into equation (11.1) gives

$$L = 2C + \frac{\pi}{2}(d_2 + d_1) + \frac{(d_2 - d_1)^2}{4C}$$

$$= 2(72\,\text{in.}) + \frac{\pi}{2}(27.9 + 10.2) + \frac{(27.9 - 10.2)^2}{4(72)} = 204.9\,\text{in.}$$

Example 1 – Solution

Because a standard length of belt is desired, a 212-in. belt will be selected from Table 11.2. Equations (11.3) and (11.4) are used to calculate the required, actual center distance.

$$C = \frac{B + \sqrt{B^2 - 32(d_2 - d_1)^2}}{16}$$

$$= \frac{580.2 + \sqrt{(580.2)^2 - 32(27.9 - 10.2)^2}}{16} = 71.98 \text{ in.}$$

where

$$B = 4L - 2\pi(d_2 + d_1)$$

$$= 4(204.9) - 2\pi(27.9 + 10.2) = 580.2 \text{ in.}$$

Example 2

Two sheaves have diameters of 3.5 in. and 8 in. and their center distance is 23 in. Compare the center distance to the ideal range and determine the associated belt length. Also determine the angle of contact over the smaller sheave.

$$8 < C_{ideal} < 3\left(3.5+8\right) = 34.5 \Rightarrow Acceptable\ C_{actual}$$

$$L = 2\left(23\right) + \frac{\pi}{2}\left(8+3.5\right) + \frac{\left(8-3.5\right)^2}{4\left(23\right)} = 64.28''$$

$$\theta_1 = 180 - 2\sin^{-1}\left(\frac{8-3.5}{2\left(23\right)}\right) = 168.8^\circ$$