LECTURE FIVE

V-BELT DRIVES

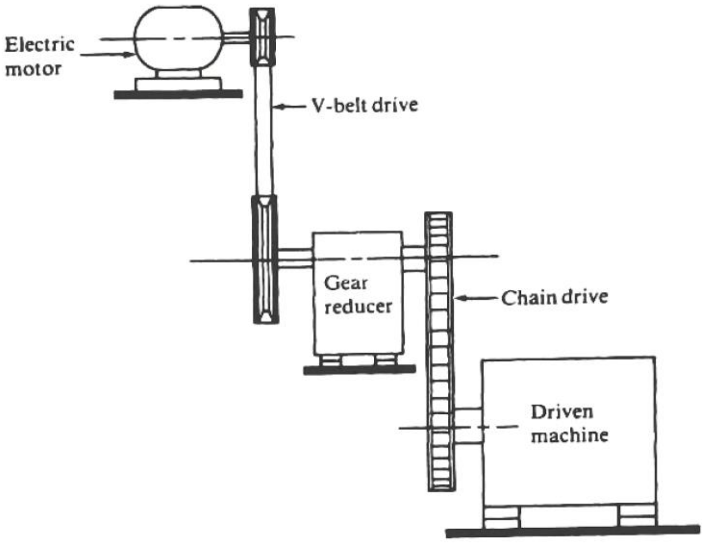
References:

Machine Elements in Mechanical Design by Robert L. Mott, P.E. (Chapter 7)

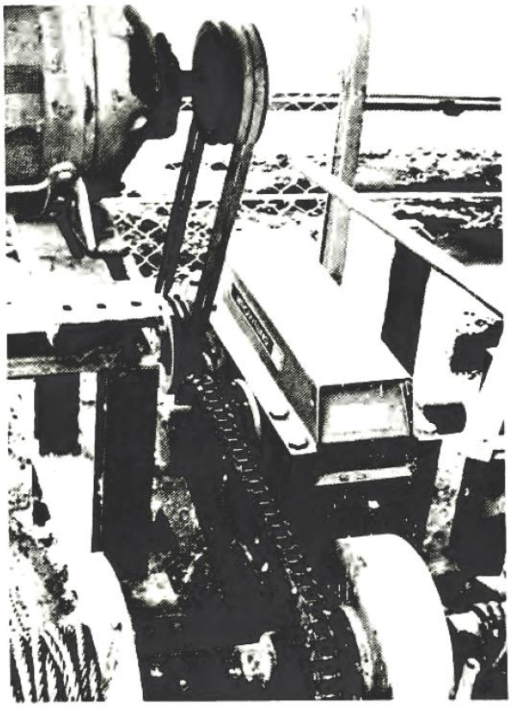
Introduction:

Belts represent the major types of flexible power transmission elements. Figure (7-1) shows a typical industrial application of this element.

FIGURE 7–1
Combination drive employing V-belts, a gear reducer, and a chain drive [Source for Part (*b*): Browning Mfg. Division, Emerson Electric Co., Maysville, KY]



(*a*) Sketch of combination drive



(*b*) Photograph of an actual drive installation. Note that guards have been removed from the belt and chain drives to show detail.

Basic belt drive:

FIGURE 7–2 Basic belt drive geometry

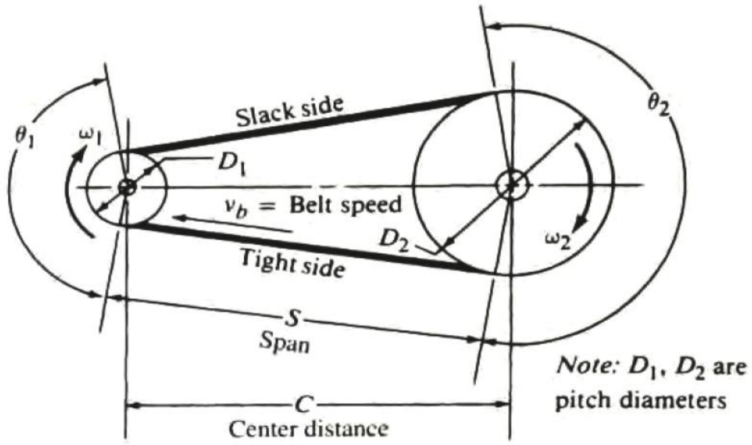
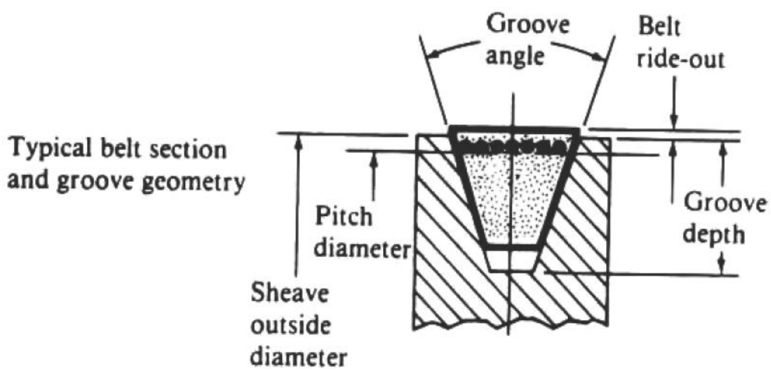


FIGURE 7–4 Cross section of V-belt and sheave groove



$$V_b = R_1W_1 = R_2W_2 \quad \text{Or} \quad V_b = \frac{D_1W_1}{2} = \frac{D_2W_2}{2} \quad \text{.......... (7-1)}$$

$$\text{And} \quad \frac{W_1}{W_2} = \frac{D_2}{D_1} \quad \text{.......... (7-2)}$$

$$L = \text{Pitch length} = 2C + 1.57\,(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C} \quad \text{.......... (7-3)}$$

$$C = \text{Center distance} = \frac{B + \sqrt{B^2 - 32\,(D_2 - D_1)^2}}{16} \quad \text{....... (7-4)} \quad \text{Where } B = 4L - 6.28\,(D_2 + D_1)$$

$$\theta_1 = Angle\ of\ contact\ of\ belt\ on\ sheave\ 1 = 180^o - 2\sin^{-1}\left|\frac{D_2 - D_1}{2C}\right| \quad \text{......... (7-5)}$$

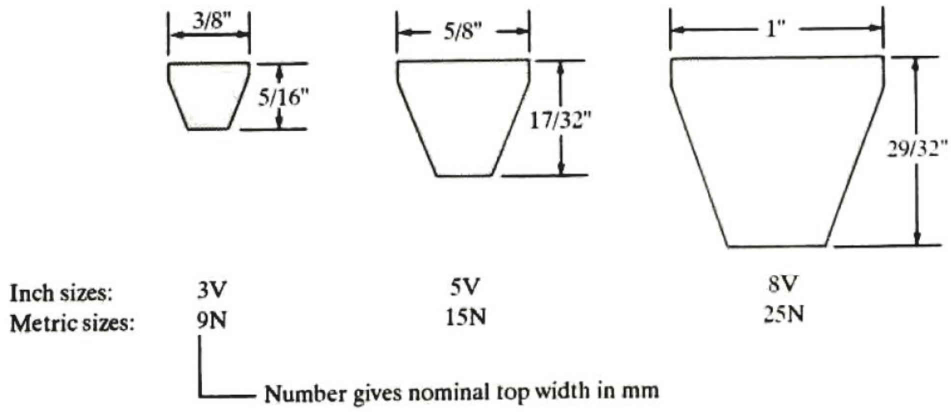
$$\theta_2 = Angle\ of\ contact\ of\ belt\ on\ sheave\ 2 = 180^o - 2\sin^{-1}\left|\frac{D_2 - D_1}{C}\right| \quad \text{......... (7-6)}$$

$$S = \text{Length of span} = \sqrt{C^2 - \left|\frac{D_2 - D_1}{2}\right|^2}$$

Note: The design value of the ratio of tight side tension to the slack side tension $\cong 5.0$, the actual value may be range as high as 10.

Standard Belt cross sections (Page 271)

FIGURE 7–6
Industrial narrow-section V-belts



Notes:

1. The basic data required for drive selection are as mentioned in page 272 section 7-4.

- The rated power of the driving motor or other prime mover
- The service factor based on the type of driver and driven load
- The center distance
- The power rating for one belt as a function of the size and speed of the smaller sheave
- The belt length
- The size of the driving and driven sheaves
- The correction factor for belt length
- The correction factor for the angle of wrap on the smaller sheave
- The number of belts
- The initial tension on the belt

2. The nominal range of center distance should be

$$\boldsymbol{D_2 < C < 3(D_2 + D_1)} \quad \text{........ (7-8)}$$

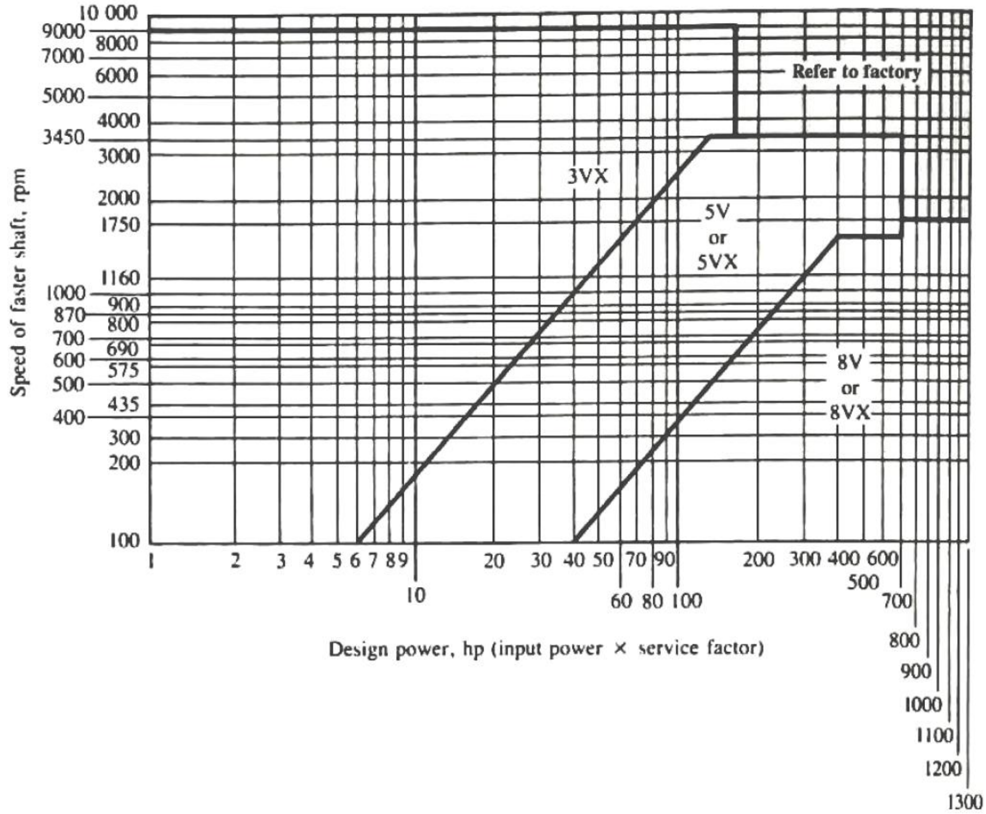
3. The angle of wrap on smaller sheave should be $> 120°$

4. Most commercially available sheaves are cast iron. This should be limited to (1981 m/min = 33 m/sec) belt speed.

5. Consider on alternative type of drive, such as a gear type or chain, if the belt speed is less than (304.8 m /min = 5 m/sec).

6. Figure (7-9) page 274 can be used to choose the basic size for belt cross section.

FIGURE 7–9
Selection chart for narrow-section industrial V-belts (Dayco Corp., Dayton, OH)



7. The service factor can be taken from table (7-1) page 274.

TABLE 7–1 V-belt service factors

Driven machine type	AC motors: Normal torque[a] DC motors: Shunt-wound Engines: Multiple-cylinder <6 h per day	6–15 h per day	>15 h per day	AC motors: High torque[b] DC motors: Series-wound, compound-wound Engines: 4-cylinder or less <6 h per day	6–15 h per day	>15 h per day
Agitators, blowers, fans, centrifugal pumps, light conveyors	1.0	1.1	1.2	1.1	1.2	1.3
Generators, machine tools, mixers, gravel conveyors	1.1	1.2	1.3	1.2	1.3	1.4
Bucket elevators, textile machines, hammer mills, heavy conveyors	1.2	1.3	1.4	1.4	1.5	1.6
Crushers, ball mills, hoists, rubber extruders	1.3	1.4	1.5	1.5	1.6	1.8
Any machine that can choke	2.0	2.0	2.0	2.0	2.0	2.0

Driver type columns: first three under "AC motors: Normal torque[a], DC motors: Shunt-wound, Engines: Multiple-cylinder"; last three under "AC motors: High torque[b], DC motors: Series-wound, compound-wound, Engines: 4-cylinder or less".

[a]Synchronous, split-phase, three-phase with starting torque or breakdown torque less than 175% of full-load torque.
[b]Single-phase, three-phase with starting torque or breakdown torque greater than 175% of full-load torque.

8. Figures (7-10), (7-11) and (7-12) give rated power per belt for three cross sections.

FIGURE 7–10
Power rating: 3V belts

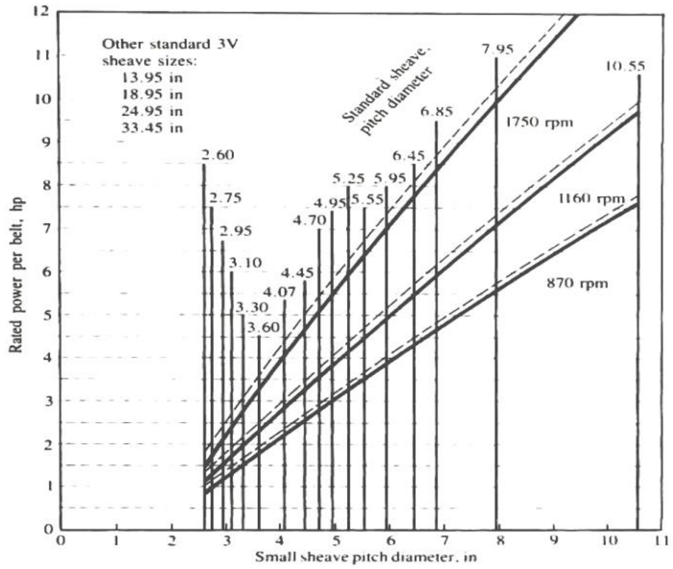


FIGURE 7–11
Power rating: 5V belts

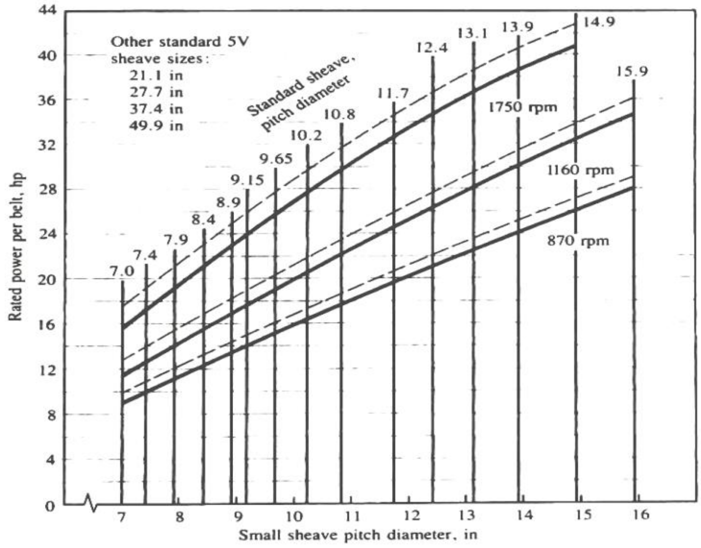
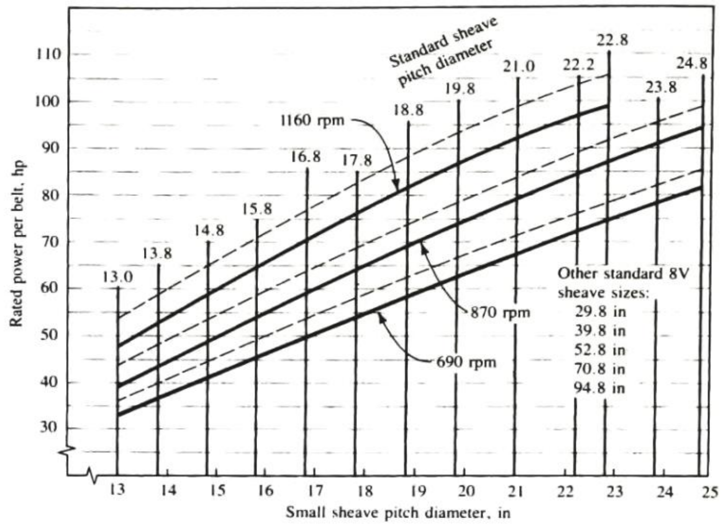
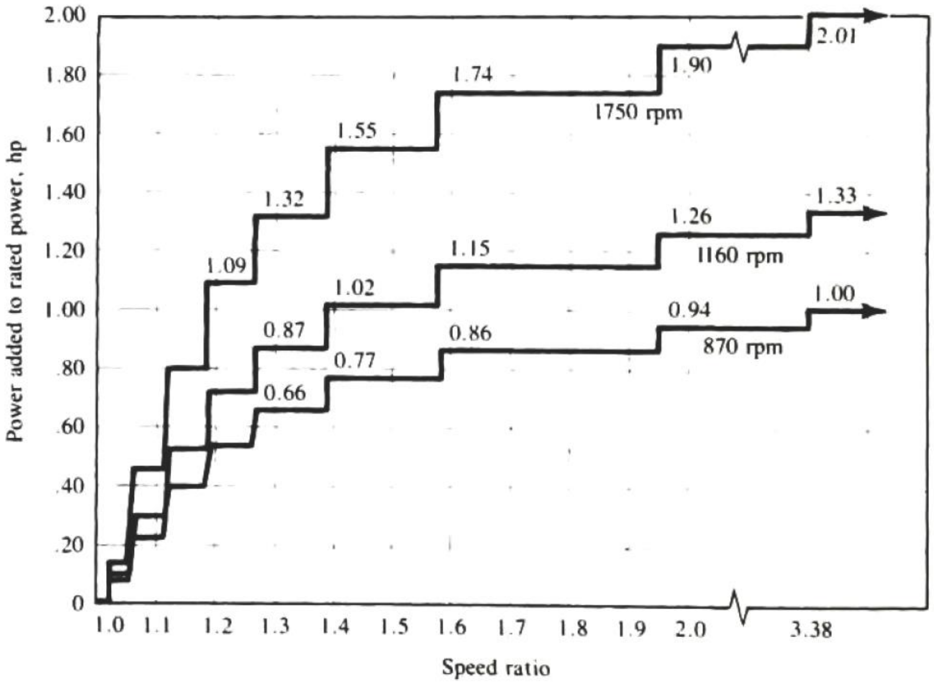


FIGURE 7–12
Power rating: 8V belts



9. The basic power rating for a speed ratio of 1 is given as solid curve; figure (7-13) is a plot of the added power to basic rating as a function of speed ration for SV belt size.

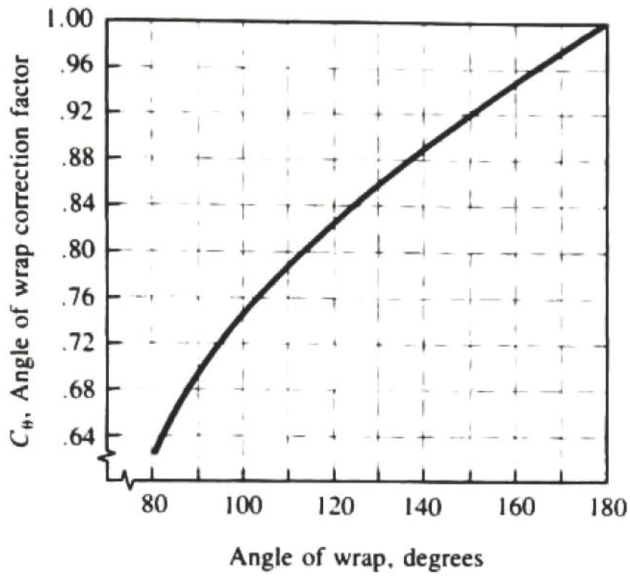
FIGURE 7–13
Power added versus speed ratio: 5V belts



10. For ratio above 3.38 was used. Draw dashed curves in fig. (7-10) , (7-11) & (7-12) (Make interpolation if possible).

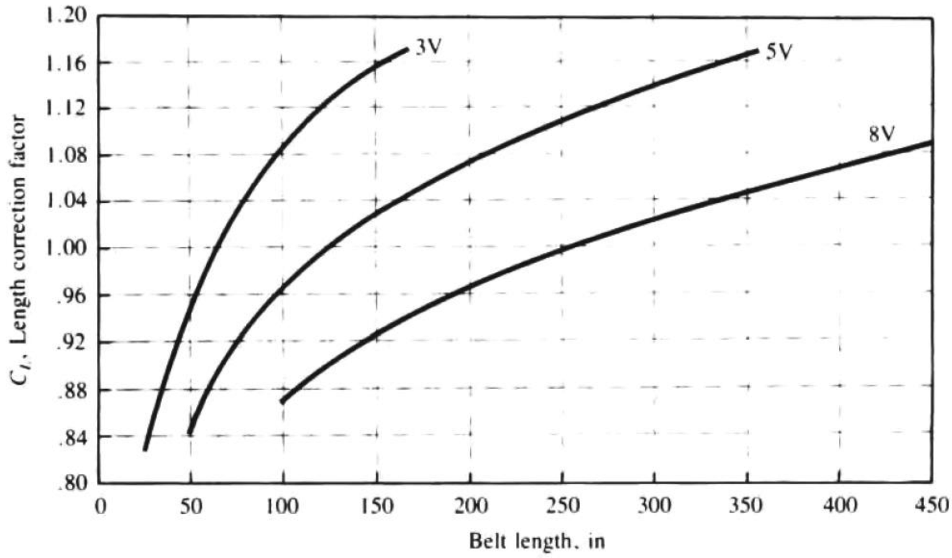
11. Figure (7-14) page 277 give value of correction factor C_θ as a function of angle of wrap of the belt on the small sheave.

FIGURE 7–14 Angle of wrap correction factor, C_θ



12. Figure (7-15) gives the value of correction factor C_L.

FIGURE 7–15 Belt length correction factor, C_L



13. Table (7-2) gives certain standard lengths are available.

TABLE 7–2 Standard belt lengths for 3V, 5V, and 8V belts (in)

3V only	3V and 5V	3V, 5V, and 8V	5V and 8V	8V only
25	50	100	150	375
26.5	53	106	160	400
28	56	112	170	425
30	60	118	180	450
31.5	63	125	190	475
33.5	67	132	200	500
35.5	71	140	212	
37.5	75		224	
40	80		236	
42.5	85		250	
45	90		265	
47.5	95		280	
			300	
165			315	
			335	
			355	

Example Problem 7–1 Design a V-belt drive that has the input sheave on the shaft of an electric motor (normal torque) rated at 50.0 hp at 1160-rpm, full-load speed. The drive is to a bucket elevator in a potash plant that is to be used 12 hours (h) daily at approximately 675 rpm.

Solution

Objective: Design the V-belt drive.

Given:

Power transmitted = 50 hp to bucket elevator

Speed of motor = 1160 rpm; output speed = 675 rpm

Analysis: Use the design data presented in this section. The solution procedure is developed within the Results section of the problem solution.

Results

Step 1. Compute the design power. From Table 7–1, for a normal torque electric motor running 12 h daily driving a bucket elevator, the service factor is 1.30. Then the design power is 1.30(50.0 hp) = 65.0 hp.

Step 2. Select the belt section. From Figure 7–9, a 5V belt is recommended for 70.0 hp at 1160-rpm input speed.

Step 3. Compute the nominal speed ratio:

$$\text{Ratio} = 1160/675 = 1.72$$

Step 4. Compute the driving sheave size that would produce a belt speed of 4000 ft/min, as a guide to selecting a standard sheave:

$$\text{Belt speed} = v_b = \frac{\pi D_1 n_1}{12}\text{ft/min}$$

Then the required diameter to give v_b = 4000 ft/min is

$$D_1 = \frac{12\,v_b}{\pi n_1} = \frac{12(4000)}{\pi n_1} = \frac{15\,279}{n_1} = \frac{15\,279}{1160} = 13.17\text{ in}$$

Step 5. Select trial sizes for the input sheave, and compute the desired size of the output sheave. Select a standard size for the output sheave, and compute the actual ratio and output speed.

For this problem, the trials are given in Table 7–3 (diameters are in inches).

The two trials in **boldface** in Table 7–3 give only about 1% variation from the desired output speed of 675 rpm, and the speed of a bucket elevator is not critical. Because no space limitations were given, let's choose the larger size.

Step 6. Determine the rated power from Figure 7–10, 7–11, or 7–12.

For the 5V belt that we have selected, Figure 7–11 is appropriate. For a 12.4-in sheave at 1160 rpm, the basic rated power is 26.4 hp. Multiple belts will be required. The ratio is relatively high, indicating that some added power rating can be used. This value can be estimated from Figure 7–11 or taken directly from Figure 7–13 for the 5V belt. Power added is 1.15 hp. Then the actual rated power is 26.4 + 1.15 = 27.55 hp.

Step 7. Specify a trial center distance.

We can use Equation (7–8) to determine a nominal acceptable range for C:

$$D_2 < C < 3(D_2 + D_1)$$
$$21.1 < C < 3(21.1 + 12.4)$$
$$21.1 < C < 100.5\text{ in}$$

In the interest of conserving space, let's try C = 24.0 in.

TABLE 7–3 Trial sheave sizes for Example Problem 7–1

Standard driving sheave size, D_1	Approximate driven sheave size ($1.72D_1$)	Nearest standard sheave, D_2	Actual output speed (rpm)
13.10	22.5	21.1	720
12.4	**21.3**	**21.1**	**682**
11.7	20.1	21.1	643
10.8	18.6	21.1	594
10.2	17.5	15.9	744
9.65	16.6	15.9	704
9.15	**15.7**	**15.9**	**668**
8.9	15.3	14.9	693

Step 8. Compute the required belt length from Equation (7–3):

$$L = 2C + 1.57(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C}$$

$$L = 2(24.0) + 1.57(21.1 + 12.4) + \frac{(21.1 - 12.4)^2}{4(24.0)} = 101.4 \text{ in}$$

Step 9. Select a standard belt length from Table 7–2, and compute the resulting actual center distance from Equation (7–4).

In this problem, the nearest standard length is 100.0 in. Then, from Equation (7–4),

$$B = 4L - 6.28(D_2 + D_1) = 4(100) - 6.28\,(21.1 + 12.4) = 189.6$$

$$C = \frac{189.6 + \sqrt{(189.6)^2 - 32(21.1 - 12.4)^2}}{16} = 23.30 \text{ in}$$

Step 10. Compute the angle of wrap of the belt on the small sheave from Equation (7–5):

$$\theta_1 = 180^\circ - 2\sin^{-1}\left[\frac{D_2 - D_1}{2C}\right] = 180^\circ - 2\sin^{-1}\left[\frac{21.1 - 12.4}{2(23.30)}\right] = 158^\circ$$

Step 11. Determine the correction factors from Figures 7–14 and 7–15. For $\theta = 158^\circ$, $C_\theta = 0.94$. For $L = 100$ in, $C_L = 0.96$.

Step 12. Compute the corrected rated power per belt and the number of belts required to carry the design power:

$$\text{Corrected power} = C_\theta C_L P = (0.94)(0.96)(27.55 \text{ hp}) = 24.86 \text{ hp}$$

$$\text{Number of belts} = 65.0/24.86 = 2.61 \text{ belts (Use 3 belts.)}$$

Comments

Summary of Design

Input: Electric motor, 50.0 hp at 1160 rpm

Service factor: 1.4

Design power: 70.0 hp

Belt: 5V cross section, 100-in length, 3 belts

Sheaves: Driver, 12.4-in pitch diameter, 3 grooves, 5V. Driven, 21.1-in pitch diameter, 3 grooves, 5V

Actual output speed: 682 rpm

Center distance: 23.30 in