8.3 Unit Guide

Since this unit is quite extensive, I will give you a clear guide for sizing each type of component, independent of one another, despite there being alot of repetition. In each guide, I will explain in a way that even a child will understand. This is to make your life easier.

I hope you can tell for yourself that all these guides are for 2 pulley systems. For systems of 3 or more pulleys, solve for 2 pulleys at a time, and you should be Gucci.

Also, when it comes to both textbooks, they do things considerably differently. In this case, Shigley is a bit more complicated with a fuck-load of correction factors and what not, so I will primarily use Mott. It does however have a lot of good figures. It is very much possible that some homework questions in this section will require one textbook or the other, so in case I don't have it covered, I'll let you figure it out yourself.

Make sure to check out this unit's calculators (here), they're useful! Here's the list of calculators available within the Mlx file:

- Flat-Belt Calculator
- Automatic Standard Belt Length Calculator (for V-belt)
- Chain Drive Calculator[8]
- Wire Rope Calculators (Mine Hoist[9] and Shigley's Design Guide)

For force calculations, check the excel as well.

[8] Very Good
[9] Spectacular

8.3.1 Flat Belts

**This guide follows Shigley and so should you.*

1. **In case of a flat belt, you will need the following specifications to start the question/design:**

    - C [in.], the centre to centre distance between each pulley
    - Pulley diameters d (driving) and D (driven) [in.], or at least a velocity ratio
    - n [rpm], rotational speed
    - H_{nom} [hp], nominal horsepower
    - b [in.], belt width
    - t [in.], belt thickness
    - Belt Material: Leather, Polyamide, or Urethane (most common)
    - w [lbf/ft], weight of a foot of belt
    - f, Coefficient of Friction

    If the question requires you to DESIGN a flat belt drive, you will only be given the first 4 specifications, and you'll have to choose a belt yourself. Use the figures below to do so.

Table 17–2 **Properties of Some Flat- and Round-Belt Materials. (Diameter = d, thickness = t, width = w)**

Material	Specification	Size, in	Minimum Pulley Diameter, in	Allowable Tension per Unit Width at 600 ft/min, lbf/in	Specific Weight, lbf/in^3	Coefficient of Friction
Leather	1 ply	$t = \frac{11}{64}$	3	30	0.035–0.045	0.4
		$t = \frac{13}{64}$	$3\frac{1}{2}$	33	0.035–0.045	0.4
	2 ply	$t = \frac{18}{64}$	$4\frac{1}{2}$	41	0.035–0.045	0.4
		$t = \frac{20}{64}$	6[a]	50	0.035–0.045	0.4
		$t = \frac{23}{64}$	9[a]	60	0.035–0.045	0.4
Polyamide[b]	F–0[c]	$t = 0.03$	0.60	10	0.035	0.5
	F–1[c]	$t = 0.05$	1.0	35	0.035	0.5
	F–2[c]	$t = 0.07$	2.4	60	0.051	0.5
	A–2[c]	$t = 0.11$	2.4	60	0.037	0.8
	A–3[c]	$t = 0.13$	4.3	100	0.042	0.8
	A–4[c]	$t = 0.20$	9.5	175	0.039	0.8
	A–5[c]	$t = 0.25$	13.5	275	0.039	0.8
Urethane[d]	$w = 0.50$ in	$t = 0.062$	See Table 17–3	5.2[e]	0.038–0.045	0.7
	$w = 0.75$ in	$t = 0.078$		9.8[e]	0.038–0.045	0.7
	$w = 1.25$ in	$t = 0.090$		18.9[e]	0.038–0.045	0.7
	Round	$d = \frac{1}{4}$	See Table 17–3	8.3[e]	0.038–0.045	0.7
		$d = \frac{3}{8}$		18.6[e]	0.038–0.045	0.7
		$d = \frac{1}{2}$		33.0[e]	0.038–0.045	0.7
		$d = \frac{3}{4}$		74.3[e]	0.038–0.045	0.7

Some things to clarify:

- Velocity Ratio:

$$Velocity\ Ratio = \frac{V_{driver}}{V_{driven}} = \frac{D}{d}$$

- Belt Speed [ft/min]:

$$V = \frac{\pi d n}{12}$$

where d [in.] is pulley diameter, and n [rpm] is rotational speed

- w [lbf/ft], weight per foot:

$$w = 12\gamma bt$$

where γ [lbf/in^3] is weight density[10]*, b [in.] is belt width, and t [in.] is belt thickness*

2. **Next, you may want to find some of these parameters, based on the question being asked [11]:**

- Wrap Angles[12] [rad]:

$$\phi_d = \pi - 2sin^{-1}(\frac{D-d}{2C})$$

$$\phi_D = \pi + 2sin^{-1}(\frac{D-d}{2C})$$

- Belt Length[13] [in.]:

$$L = \sqrt{4C^2 - (D-d)^2} + \frac{1}{2}(D\phi_D + d\phi_d)$$

- H_d [hp], Design Horsepower:

$$H_d = H_{nom} K_s n_d$$

where K_s is a service factor and n_d is a design factor (also called safety factor at times). For flat belts, they are usually given to you

3. **After this, you will want to find Torques and Forces:**

- T [lbf · in], required torque:

$$T = \frac{63025 H_d}{n}$$

[10] or specific weight in the figure above

[11] If it's "design" question, find all to be safe

[12] These equations are for open belts. for crossed belts, $\phi = \pi + 2sin^{-1}(\frac{D+d}{2C})$ and both pulleys have the same angle of wrap

[13] For crossed belts, $L = \sqrt{4C^2 - (D+d)^2} + \frac{1}{2}(D+d)\phi$

- F_c [lbf], centrifugal force:

$$F_c = \frac{w}{g}(\frac{V}{60})^2$$

where w [lbf/ft] is weight per foot, g is 32.2 ft/s^2, and V [ft/min] is belt speed

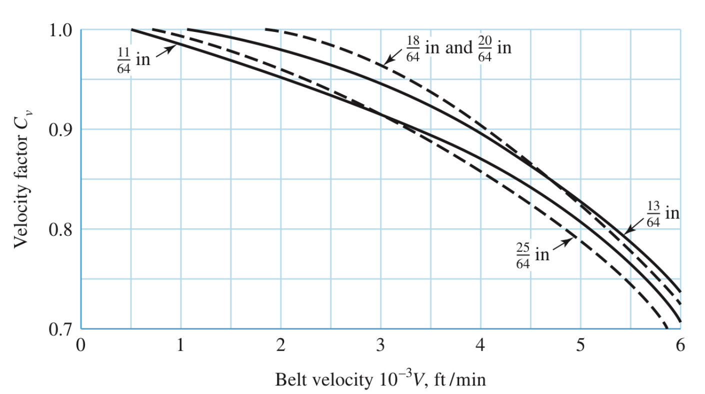
- F_{1a} [lbf] allowable largest tension (tight side tension):

$$F_{1a} = bF_aC_pC_v$$

where b [in] is belt width, F_a [lbf/in] is manufacturer's allowed tension (see figure above), C_p is the pulley correction factor (1 for urethane belts; see figure below for others), and C_v is the velocity correction factor (1 for urethane and polyamide belts; see figure below for leather belts of different thicknesses)

Table 17–4 Pulley Correction Factor C_P for Flat Belts*

	Small-Pulley Diameter, in					
Material	**1.6 to 4**	**4.5 to 8**	**9 to 12.5**	**14, 16**	**18 to 31.5**	**Over 31.5**
Leather	0.5	0.6	0.7	0.8	0.9	1.0
Polyamide, F–0	0.95	1.0	1.0	1.0	1.0	1.0
F–1	0.70	0.92	0.95	1.0	1.0	1.0
F–2	0.73	0.86	0.96	1.0	1.0	1.0
A–2	0.73	0.86	0.96	1.0	1.0	1.0
A–3	—	0.70	0.87	0.94	0.96	1.0
A–4	—	—	0.71	0.80	0.85	0.92
A–5	—	—	—	0.72	0.77	0.91



- $F_{1a} - F_2$ [lbf]:

$$F_{1a} - F_2 = \frac{2T}{d}$$

where T [lbf ·in] is Torque, and d [in.] is the driver pulley diameter

- F_2 [lbf], slack side tension:

$$F_2 = F_{1a} - (F_{1a} - F_2) = F_{1a} - \frac{2T}{d}$$

- F_i [lbf], initial tension:

$$F_i = \frac{F_{1a} + F_2}{2} - F_c$$

4. **Finally, wrap up with a few concluding calculations:**

- H_a [hp], Transmitted Power:

$$H_a = \frac{(F_{1a} - F_2)V}{33000}$$

This should equal to your design horsepower...

- n_{fs}, Safety Factor:

$$n_{fs} = \frac{H_a}{H_{nom}K_s}$$

- Check friction development:

$$f' = \frac{1}{\phi_d} ln(\frac{F_{1a} - F_c}{F_2 - F_c})$$

make sure f' < f or else you will need to change the design!!!!!

- dip [in.]:

$$dip = \frac{12(C/12)^2 w}{8F_i}$$

where C [in.] is the centre to centre distance of the pulleys, w [lbf/ft] is the weight per foot of the belt, and F_i *[lbf] is initial tension*

Check out the Matlab Live script calculator to make life easier!