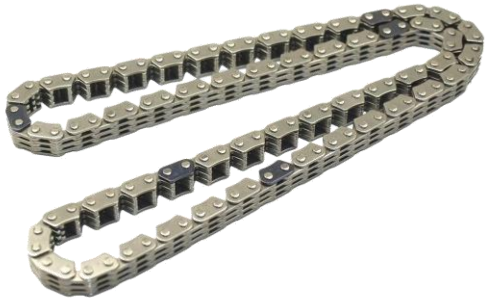
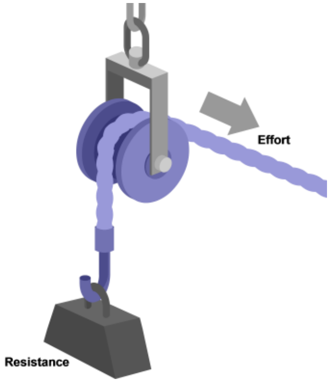
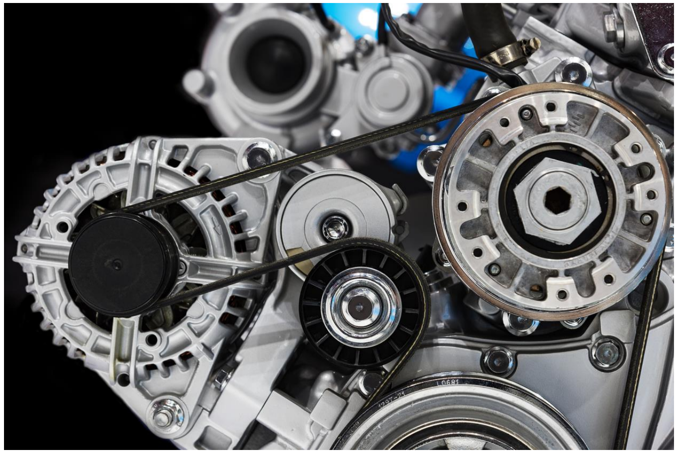
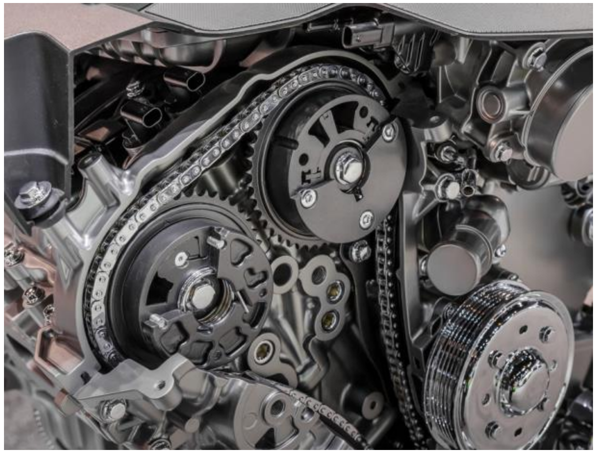
# Belt – Chain  - Rope







# Belt – Chain - Rope

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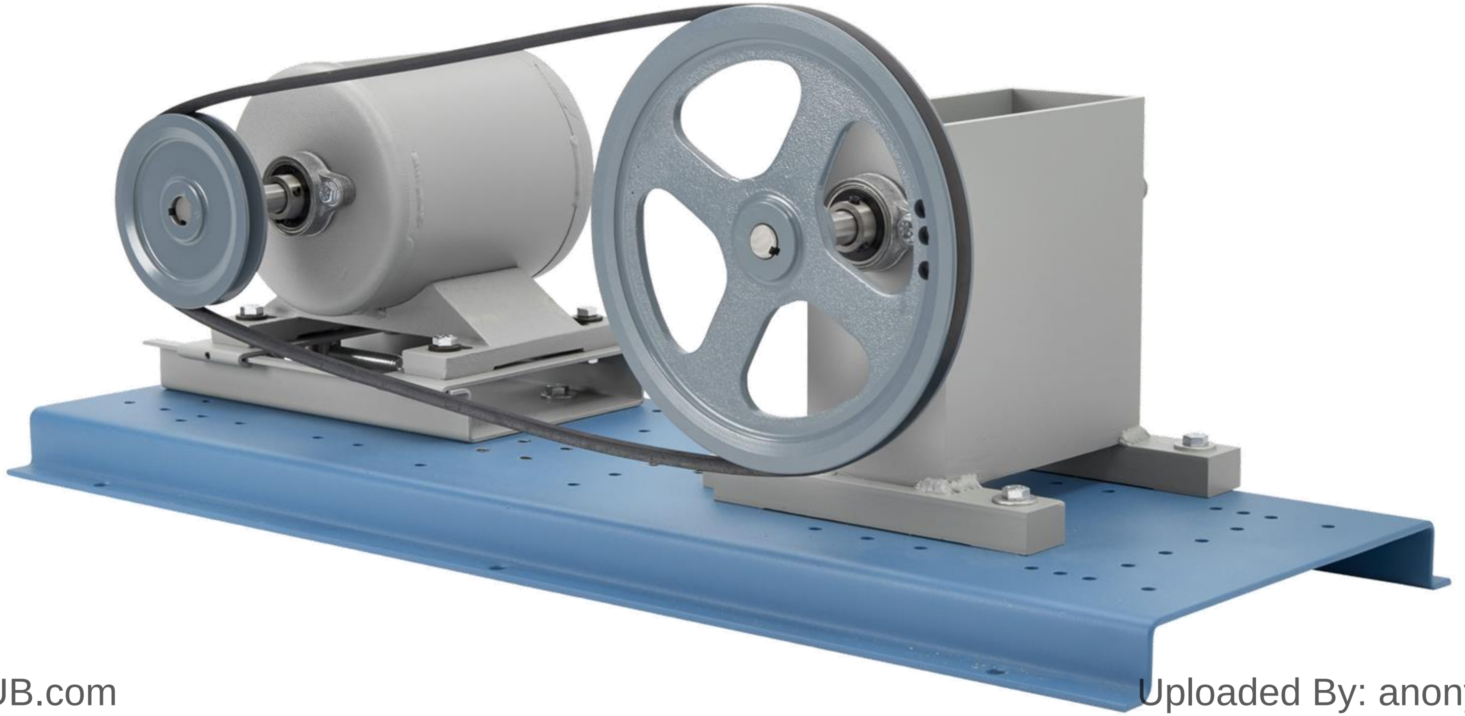
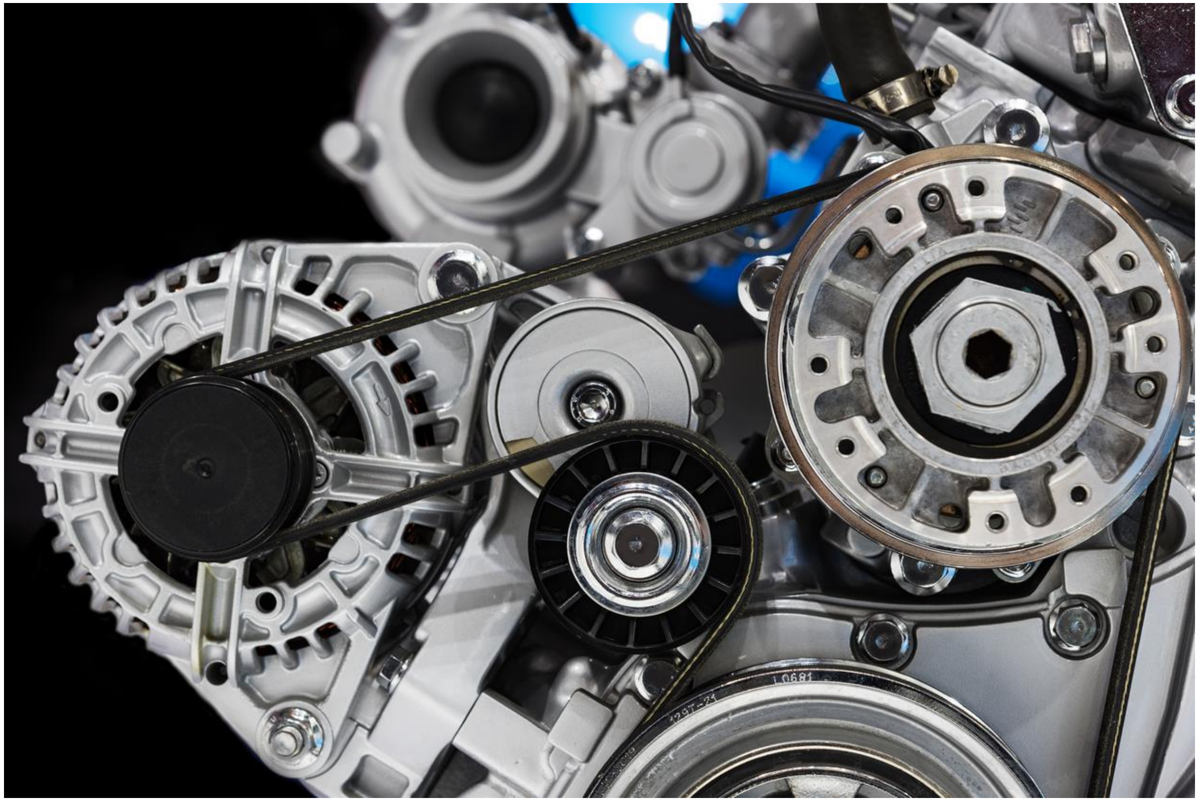
Flexible machine elements are used in conveying systems and in the **transmission of power over comparatively long distances**. These elements can be used as a replacement for gears, shafts, bearings, and other relatively rigid power-transmission devices. In many cases their use simplifies the design of a machine and substantially **reduces the cost.**



# Belt – Chain - Rope



Since these elements are elastic and usually quite long, they play an important part in **absorbing shock** loads and in damping out and isolating the effects of vibration. This is an important advantage as far as machine life is concerned.



# Belt – Chain  - Rope

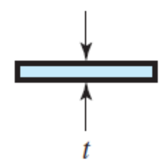
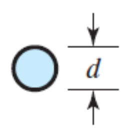
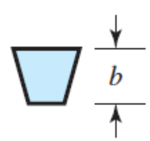
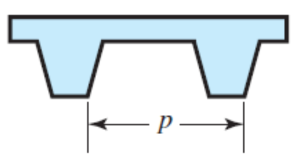
Most flexible elements do **not have an infinite life**. When they are used, it is important to establish an inspection schedule to guard against wear, aging, and loss of elasticity.

# 17.1 Belts - Characteristics

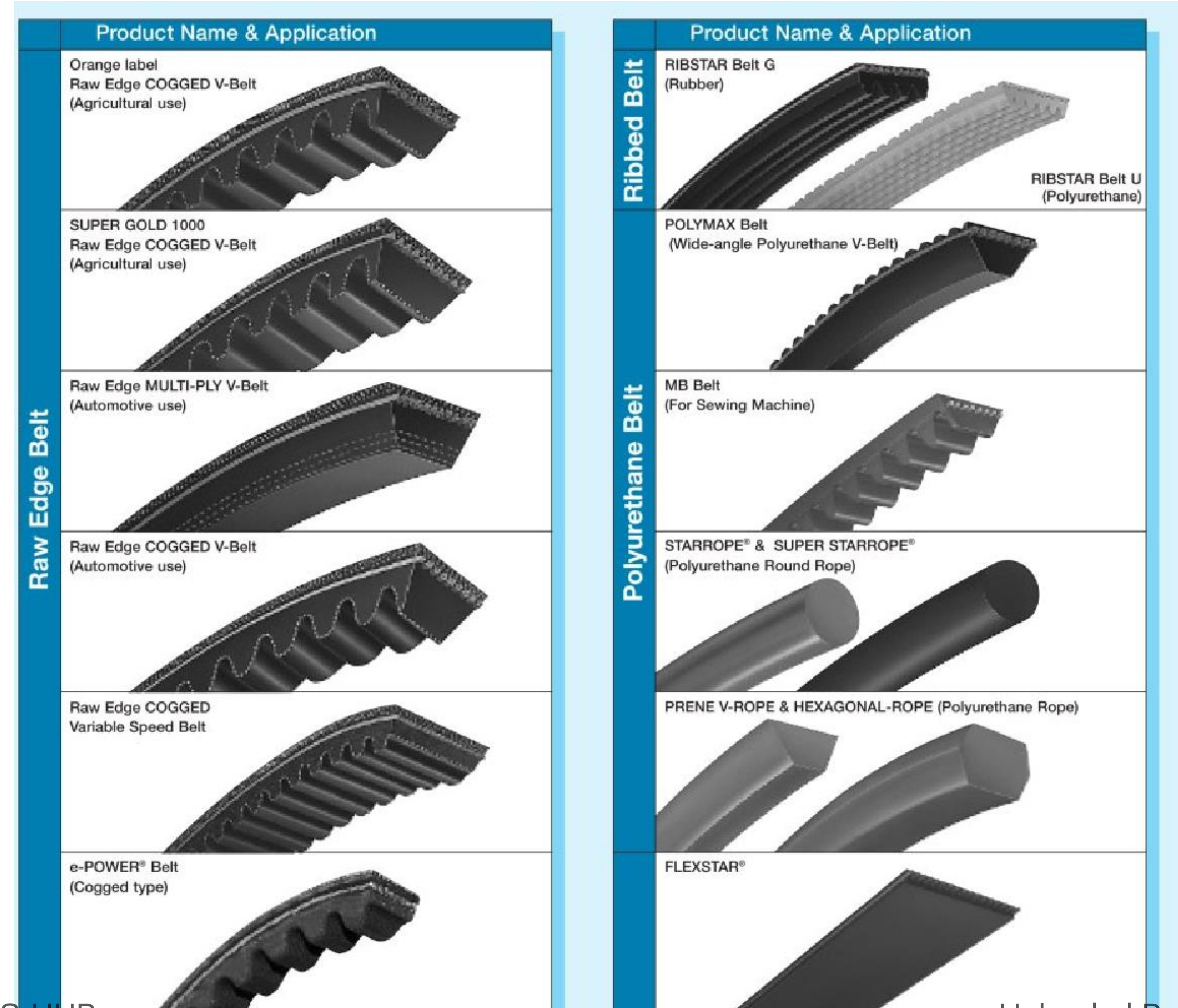
- They may be used for long center distances.
- Except for timing belts, there is some slip and creep, and so the angular-velocity ratio between the driving and driven shafts is neither constant nor exactly equal to the ratio of the pulley diameters.
- In some cases an idler or tension pulley can be used to avoid adjustments in center distance that are ordinarily necessitated by age or the installation of new belts.

**Table 17–1**

Characteristics of Some Common Belt Types (Figures are cross sections except for the timing belt, which is a side view).

| Belt Type | Figure | Joint | Size Range | Center Distance |
|---|---|---|---|---|
| Flat |   | Yes | $t = \begin{cases} 0.03 \text{ to } 0.20 \text{ in} \\ 0.75 \text{ to } 5 \text{ mm} \end{cases}$ | No upper limit |
| Round |   | Yes | $d = \frac{1}{8}$ to $\frac{3}{4}$ in | No upper limit |
| V |   | None | $b = \begin{cases} 0.31 \text{ to } 0.91 \text{ in} \\ 8 \text{ to } 19 \text{ mm} \end{cases}$ | Limited |
| Timing |   | None | $p$ = 2 mm and up | Limited |

# 17.1 Belts - Types

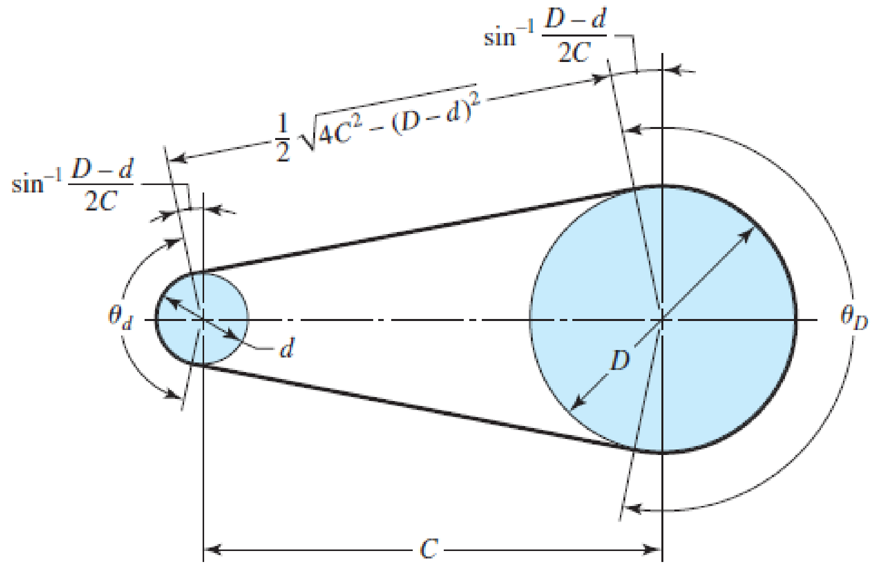


# 17.1 Belts - Types



**Figure 17–1**

Flat-belt geometry. (*a*) Open belt. (*b*) Crossed belt.

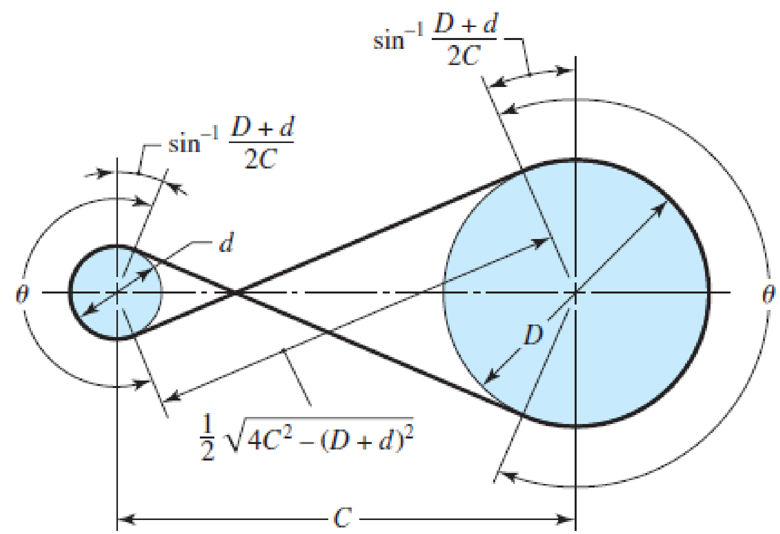



$$\theta_d = \pi - 2\sin^{-1}\frac{D-d}{2C}$$

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

$$L = \sqrt{4C^2-(D-d)^2} + \tfrac{1}{2}(D\theta_D + d\theta_d)$$

(*a*)




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

$$L = \sqrt{4C^2-(D+d)^2} + \tfrac{1}{2}(D+d)\theta$$

(*b*)

# 17.1 Belts - Types

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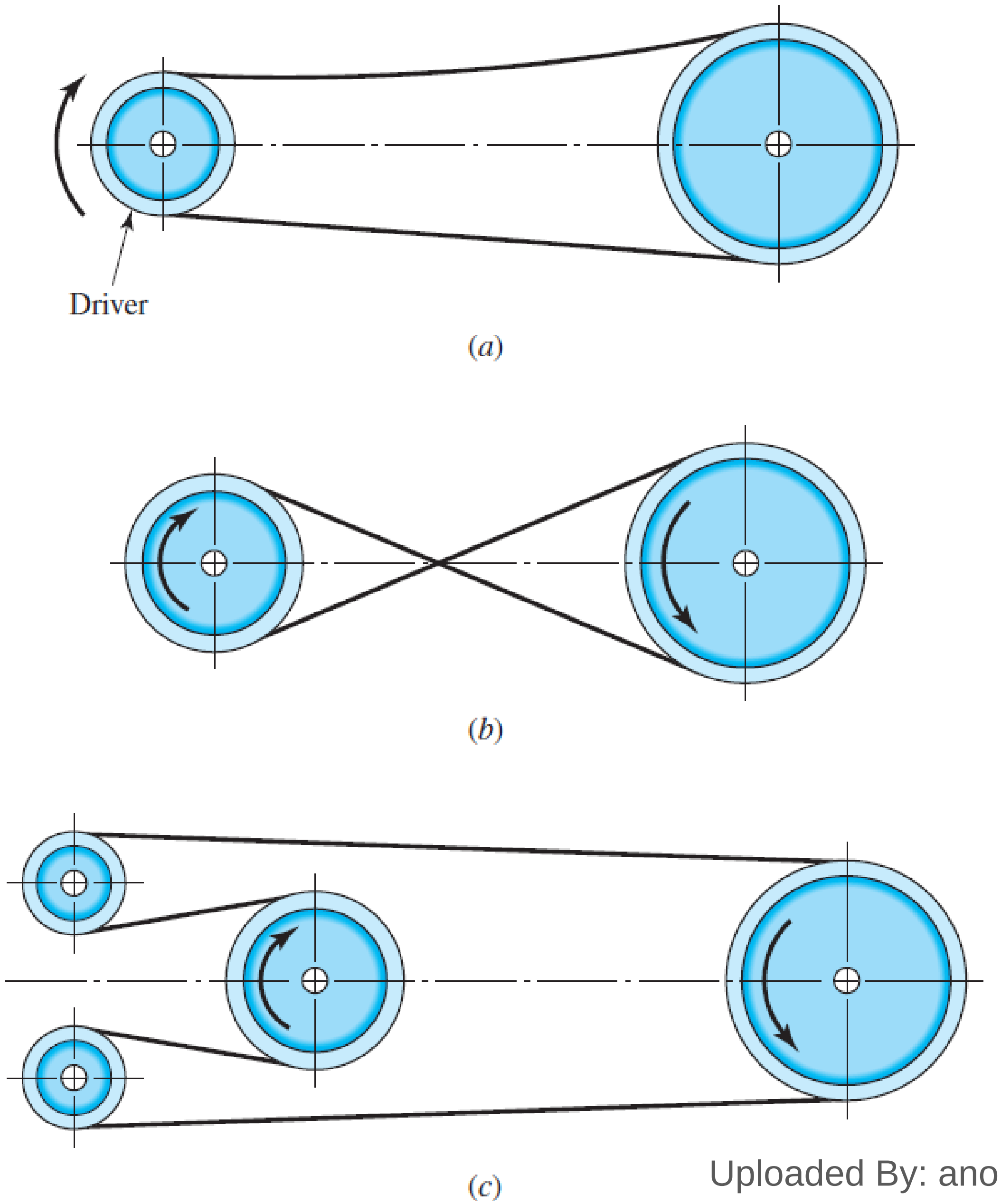
**Figure 17–2**

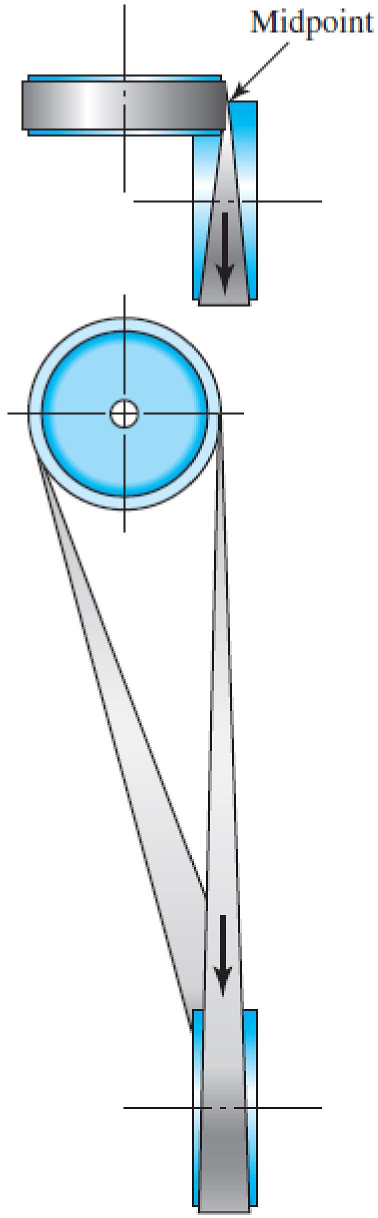
Nonreversing and reversing belt drives. (*a*) Nonreversing open belt. (*b*) Reversing crossed belt. Crossed belts must be separated to prevent rubbing if high-friction materials are used. (*c*) Reversing open-belt drive.

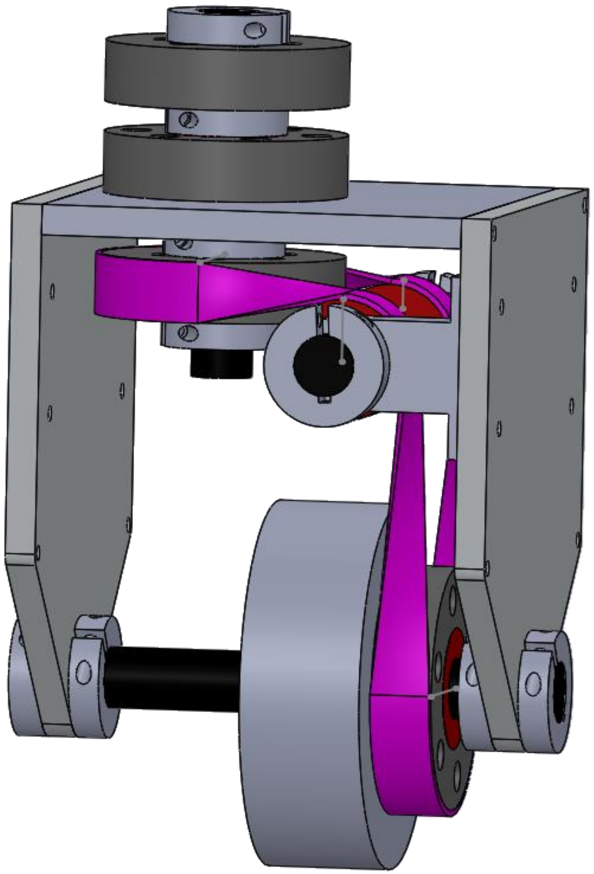


# 17.1 Belts - Types

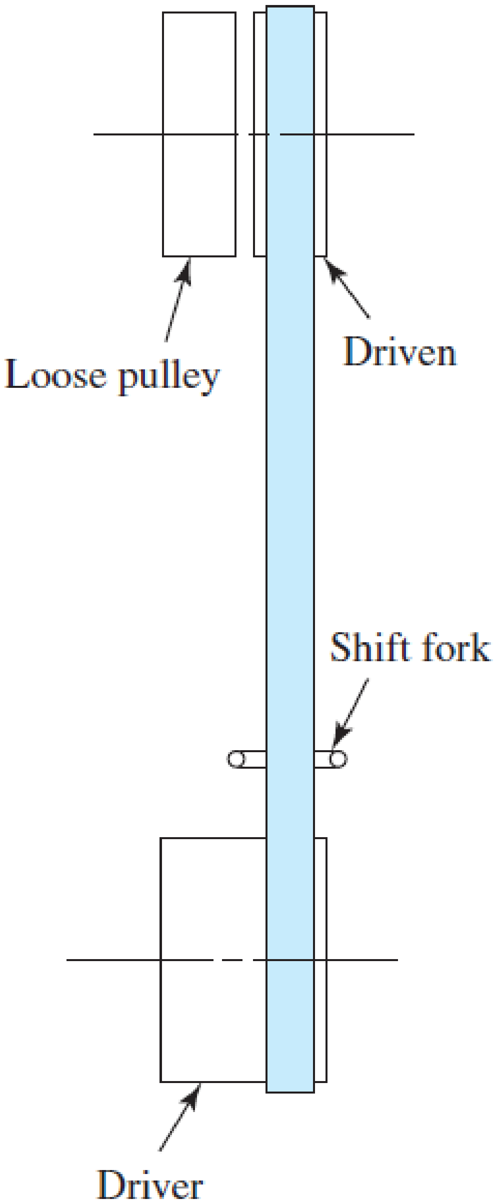
**Figure 17–3**

Quarter-twist belt drive; an idler guide pulley must be used if motion is to be in both directions.



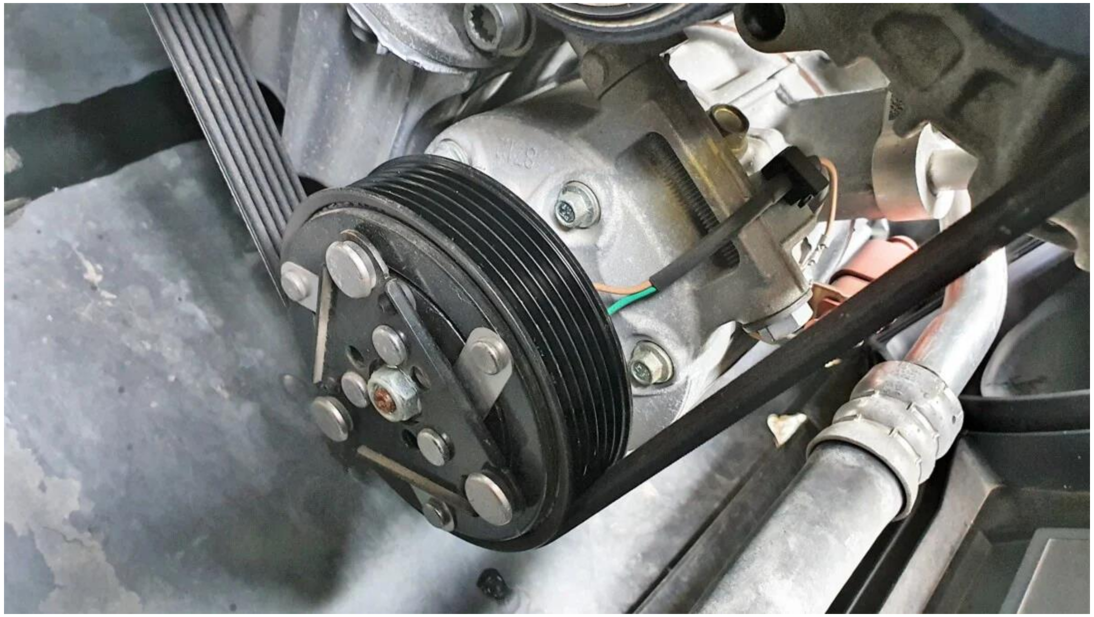



# 17.1 Belts - Types

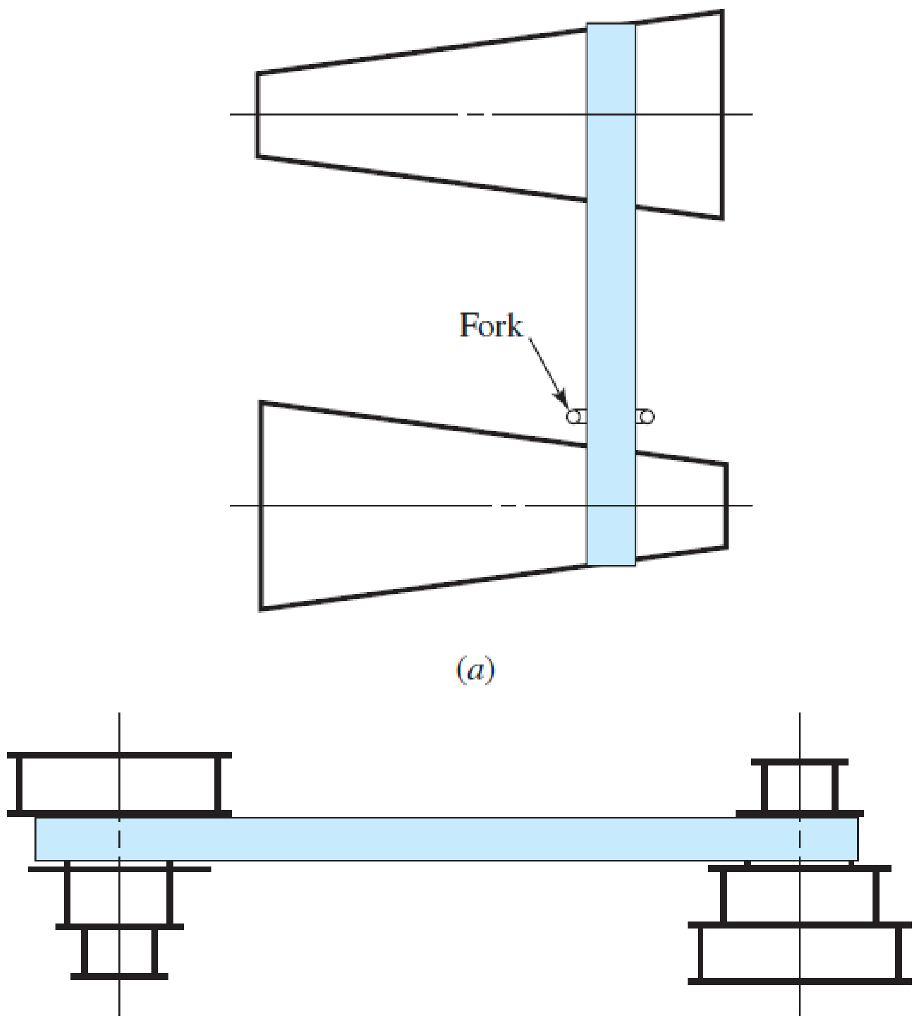



## Figure 17–4

This drive eliminates the need for a clutch. Flat belt can be shifted left or right by use of a fork.



# 17.1 Belts - Types




(a)

(b)

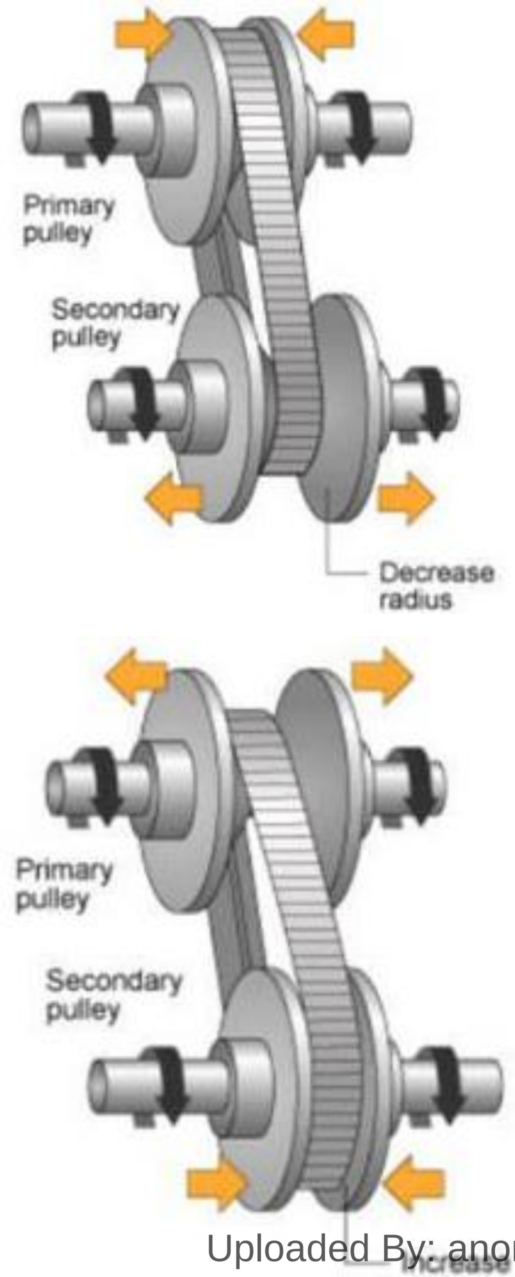
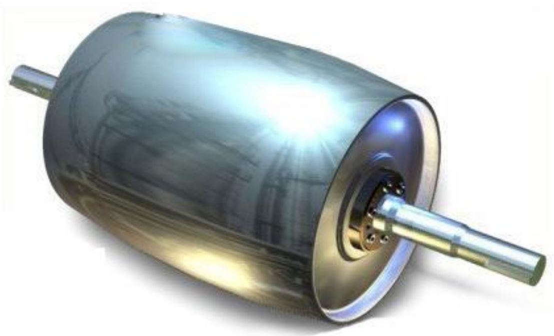
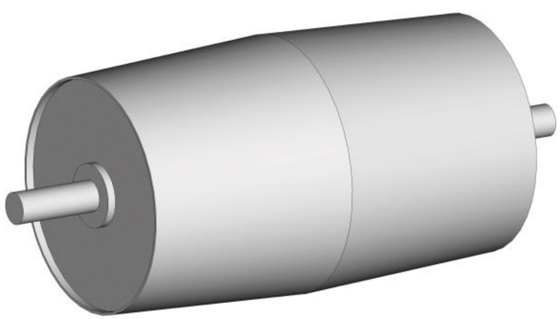



**Figure 17–5**

Variable-speed belt drives.

# 17.1 Belts - Types



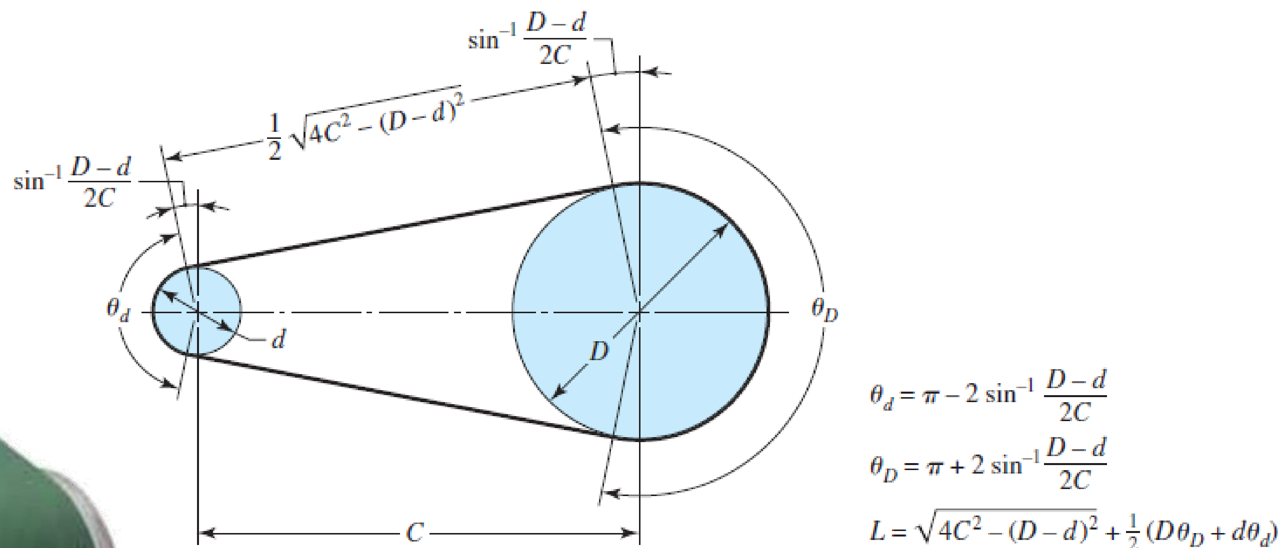


# 17.2 Flat and Rounded Drives



**Figure 17–1**

Flat-belt geometry. (*a*) Open belt. (*b*) Crossed belt.




$$\theta_d = \pi - 2\sin^{-1}\frac{D-d}{2C}$$
$$\theta_D = \pi + 2\sin^{-1}\frac{D-d}{2C} \qquad (17\text{–}1)$$

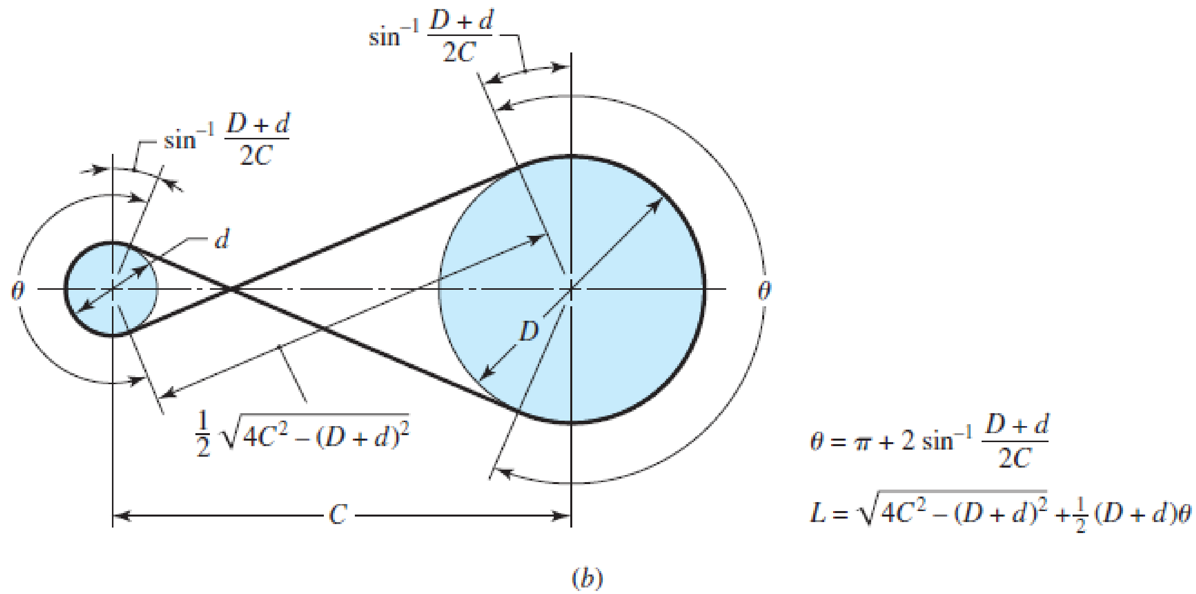
where $D$ = diameter of large pulley
$d$ = diameter of small pulley
$C$ = center distance
$\theta$ = angle of contact

The length of the belt is found by summing the two arc lengths with twice the distance between the beginning and end of contact. The result is

$$L = [4C^2 - (D-d)^2]^{1/2} + \frac{1}{2}(D\theta_D + d\theta_d) \qquad (17\text{–}2)$$

# 17.2 Flat and Rounded Drives






(*b*)

$$\theta = \pi + 2\sin^{-1}\frac{D+d}{2C} \qquad (17\text{–}3)$$

The belt length for crossed belts is found to be

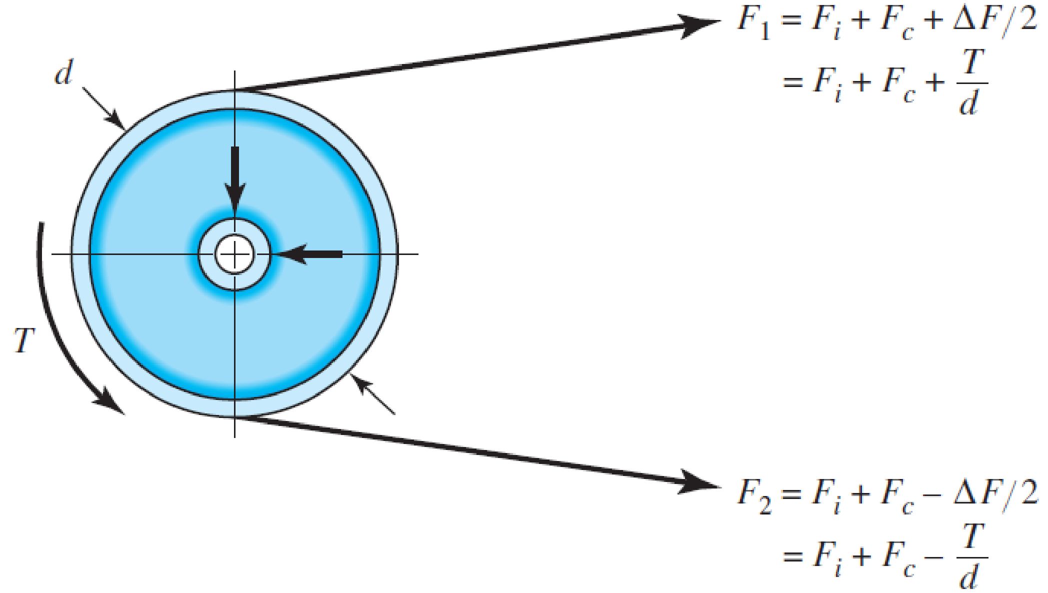
$$L = [4C^2 - (D+d)^2]^{1/2} + \frac{1}{2}(D+d)\theta \qquad (17\text{–}4)$$

# 17.2 Flat and Rounded Drives

*tight-side tension $F_1$*

**Figure 17–7**

Forces and torques on a pulley.




*loose-side tension $F_2$*

# 17.2 Flat and Rounded Drives

$$\frac{F_1 - mr^2\omega^2}{F_2 - mr^2\omega^2} = \frac{F_1 - F_c}{F_2 - F_c} = \exp(f\phi) \qquad (17\text{–}7)$$

The weight $w$ of a foot of belt is given in terms of the weight density $\gamma$ in lbf/in$^3$ as $w = 12\gamma bt$ lbf/ft where $b$ and $t$ are in inches. $F_c$ is written as

$$F_c = \frac{w}{g}\left(\frac{V}{60}\right)^2 = \frac{w}{32.17}\left(\frac{V}{60}\right)^2 \qquad (e)$$

$$V = \pi dn/12 \qquad \text{ft/min}$$

$$F_1 - F_2 = (F_1 - F_c)\frac{\exp(f\phi) - 1}{\exp(f\phi)} \qquad (17\text{–}8)$$

## 17.2 Flat and Rounded Drives

$$F_1 = F_i + F_c + \Delta F/2 = F_i + F_c + T/d \tag{f}$$

$$F_2 = F_i + F_c - \Delta F/2 = F_i + F_c - T/d \tag{g}$$

where $F_i$ = initial tension

$F_c$ = hoop tension due to centrifugal force

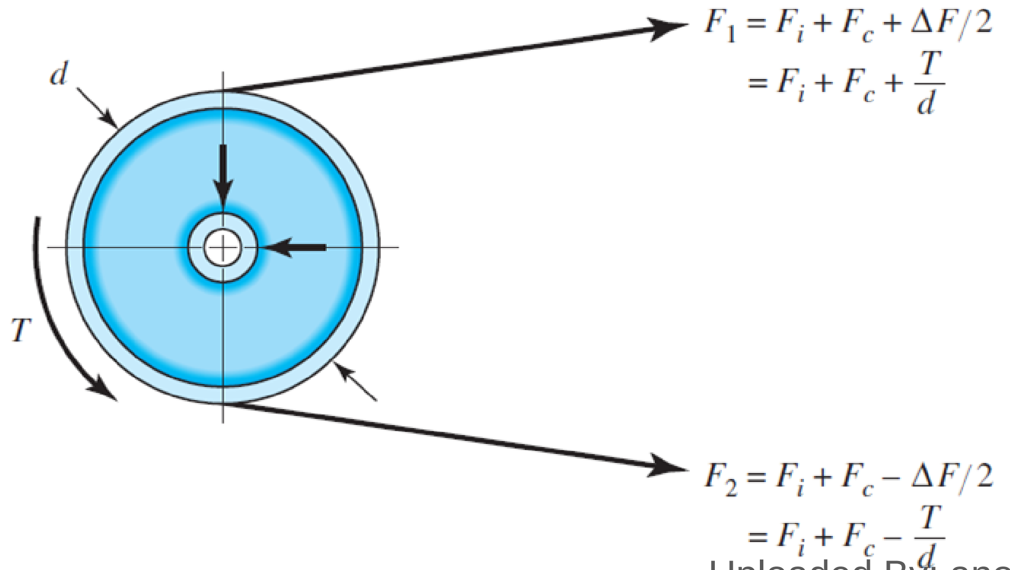
$\Delta F/2$ = tension due to the transmitted torque $T$

$d$ = diameter of the pulley

$$F_1 - F_2 = \frac{2T}{d}$$

$$F_1 + F_2 = 2F_i + 2F_c$$

$$F_i = \frac{F_1 + F_2}{2} - F_c$$



# 17.2 Flat and Rounded Drives

$$F_i = \frac{F_1 + F_2}{2} - F_c$$

OR

$$F_i = \frac{T}{d}\,\frac{\exp(f\phi) + 1}{\exp(f\phi) - 1} \qquad (17\text{–}9)$$

$$F_1 = F_c + F_i\frac{2\exp(f\phi)}{\exp(f\phi) + 1} \qquad (17\text{–}10)$$

$$F_2 = F_c + F_i\frac{2}{\exp(f\phi) + 1} \qquad (17\text{–}11)$$

$$H = \frac{(F_1 - F_2)V}{33000}$$

# 17.2 Flat and Rounded Drives

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$$H_{nom} = \frac{(F_1 - F_2)V}{33000}$$

$$n_{fs} = H_a/(H_{nom}K_s)$$

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

$$(F_1)_a = bF_aC_pC_v$$

where $(F_1)_a$ = allowable largest tension, lbf
$b$ = belt width, in
$F_a$ = manufacturer's allowed tension, lbf/in
$C_p$ = pulley correction factor (Table 17–4)
$C_v$ = velocity correction factor

Check the friction development, $f' < f$. Use Eq. (17–7) solved for $f'$:

$$f' = \frac{1}{\phi}\ln\frac{(F_1)_a - F_c}{F_2 - F_c}$$

## 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 | 5.2[e] | 0.038–0.045 | 0.7 |
| | $w = 0.75$ in | $t = 0.078$ | Table | 9.8[e] | 0.038–0.045 | 0.7 |
| | $w = 1.25$ in | $t = 0.090$ | 17–3 | 18.9[e] | 0.038–0.045 | 0.7 |
| | Round | $d = \frac{1}{4}$ | See | 8.3[e] | 0.038–0.045 | 0.7 |
| | | $d = \frac{3}{8}$ | Table | 18.6[e] | 0.038–0.045 | 0.7 |
| | | $d = \frac{1}{2}$ | 17–3 | 33.0[e] | 0.038–0.045 | 0.7 |
| | | $d = \frac{3}{4}$ | | 74.3[e] | 0.038–0.045 | 0.7 |

$$(F_1)_a = bF_aC_pC_v$$

## 17.2 Flat and Rounded Drives



$$(F_1)_a = bF_a C_p C_v$$

$C_p$ = pulley correction factor (Table 17–4)

**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 |

*Average values of $C_p$ for the given ranges were approximated from curves in the *Habasit Engineering Manual*, Habasit Belting, Inc., Chamblee (Atlanta), Ga.

## 17.2 Flat and Rounded Drives

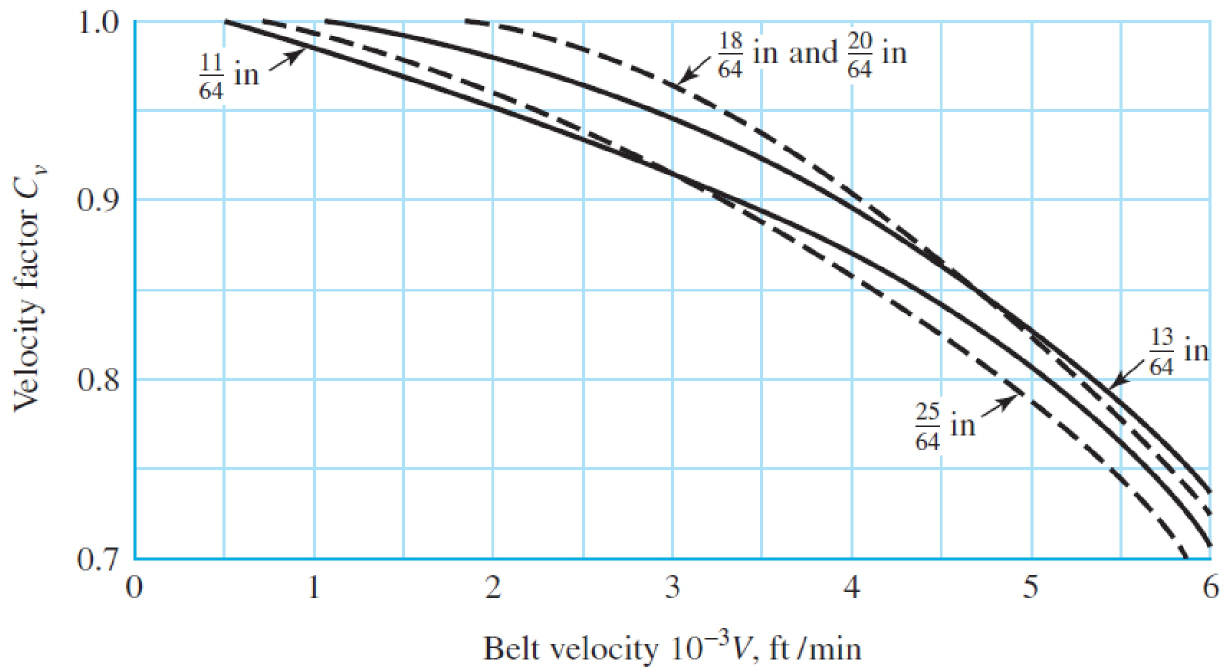


$$(F_1)_a = bF_aC_pC_v$$

$C_v$ = velocity correction factor

**Figure 17–9**

Velocity correction factor $C_v$ for leather belts for various thicknesses. *(Data source:* Machinery's Handbook, 20th ed., *Industrial Press, New York, 1976, p. 1047.)*



## 17.2 Flat and Rounded Drives



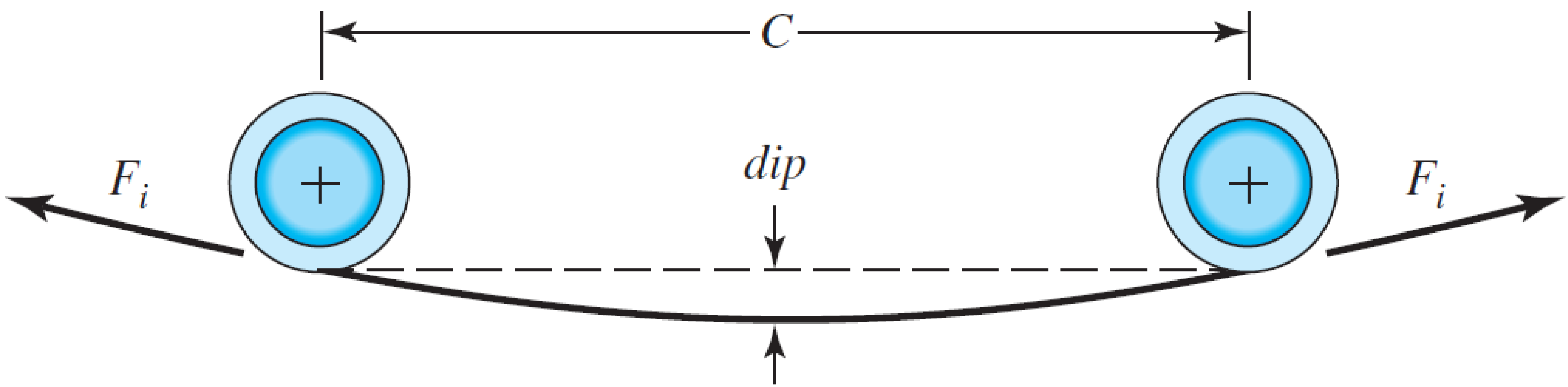
$$dip = \frac{12(C/12)^2 w}{8F_i} = \frac{C^2 w}{96F_i}$$

where $dip$ = dip, in

$C$ = center-to-center distance, in

$w$ = weight per foot of the belt, lbf/ft

$F_i$ = initial tension, lbf



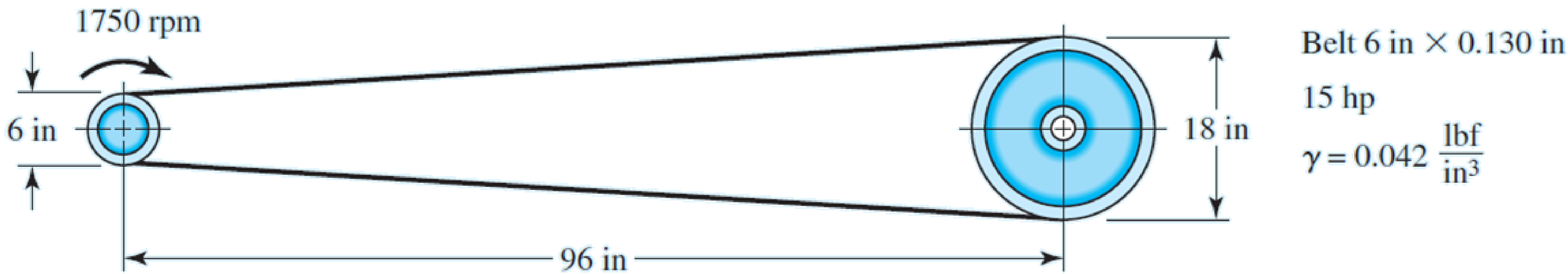

(c)

# 17.2 Flat and Rounded Drives – Example 17.1



A polyamide A-3 flat belt 6 in wide is used to transmit 15 hp under light shock conditions where $K_s = 1.25$, and a factor of safety equal to or greater than 1.1 is appropriate. The pulley rotational axes are parallel and in the horizontal plane. The shafts are 8 ft apart. The 6-in driving pulley rotates at 1750 rev/min in such a way that the loose side is on top. The driven pulley is 18 in in diameter.

($a$) Estimate the centrifugal tension $F_c$ and the torque $T$.
($b$) Estimate the allowable $F_1$, $F_2$, $F_i$ and allowable power $H_a$.
($c$) Estimate the factor of safety. Is it satisfactory?



## 17.2 Flat and Rounded Drives – Example 17.1

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The steps in analyzing a flat-belt drive can include (see Ex. 17–1)

1 Find $\exp(f\,\phi)$ from belt-drive geometry and friction

2 From belt geometry and speed find $F_c$

3 From $T = 63\,025 H_{\mathrm{nom}} K_s n_d / n$ find necessary torque

4 From torque $T$ find the necessary $(F_1)_a - F_2 = 2T/d$

5 From Tables 17–2 and 17–4, and Eq. (17–12) determine $(F_1)_a$.

6 Find $F_2$ from $(F_1)_a - [(F_1)_a - F_2]$

7 From Eq. ($i$) find the necessary initial tension $F_i$

8 Check the friction development, $f' < f$. Use Eq. (17–7) solved for $f'$:

$$f' = \frac{1}{\phi} \ln \frac{(F_1)_a - F_c}{F_2 - F_c}$$

9 Find the factor of safety from $n_{fs} = H_a/(H_{\mathrm{nom}} K_s)$

## 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/in³ | 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 | 5.2[e] | 0.038–0.045 | 0.7 |
| | $w = 0.75$ in | $t = 0.078$ | Table | 9.8[e] | 0.038–0.045 | 0.7 |
| | $w = 1.25$ in | $t = 0.090$ | 17–3 | 18.9[e] | 0.038–0.045 | 0.7 |
| | Round | $d = \frac{1}{4}$ | See | 8.3[e] | 0.038–0.045 | 0.7 |
| | | $d = \frac{3}{8}$ | Table | 18.6[e] | 0.038–0.045 | 0.7 |
| | | $d = \frac{1}{2}$ | 17–3 | 33.0[e] | 0.038–0.045 | 0.7 |
| | | $d = \frac{3}{4}$ | | 74.3[e] | 0.038–0.045 | 0.7 |

# 17.2 Flat and Rounded Drives



$$(F_1)_a = bF_a C_p C_v$$

$C_p$ = pulley correction factor (Table 17–4)

**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 |

*Average values of $C_P$ for the given ranges were approximated from curves in the *Habasit Engineering Manual*, Habasit Belting, Inc., Chamblee (Atlanta), Ga.

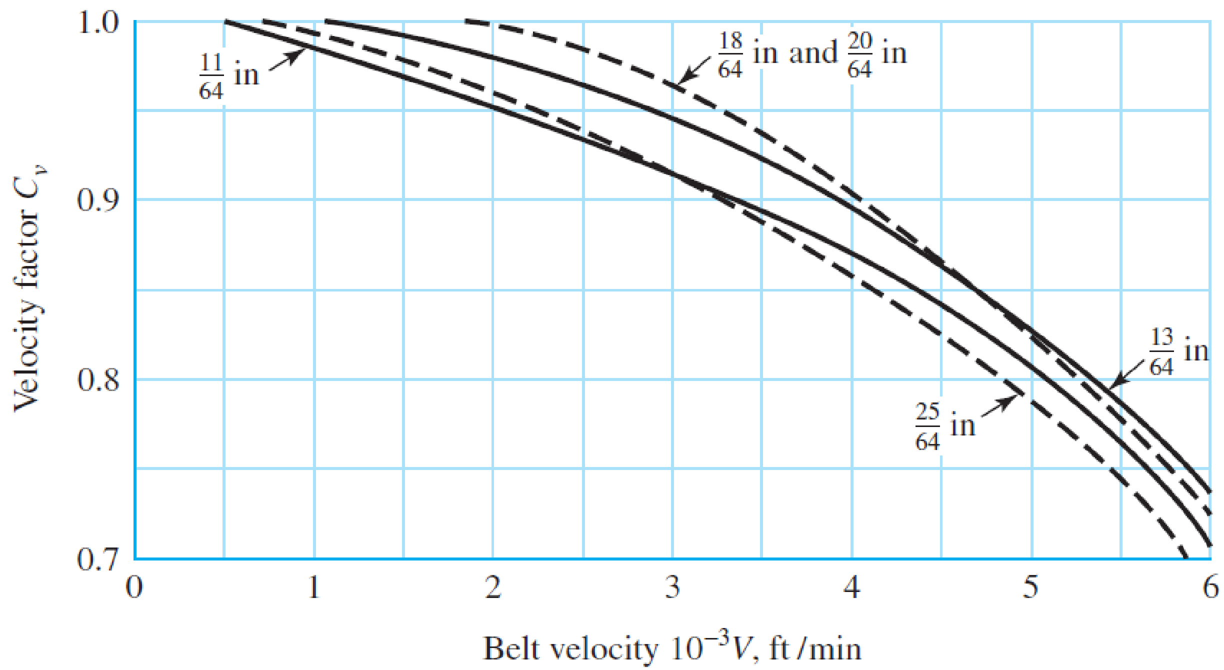
# 17.2 Flat and Rounded Drives

$$(F_1)_a = bF_aC_pC_v$$

$C_v$ = velocity correction factor

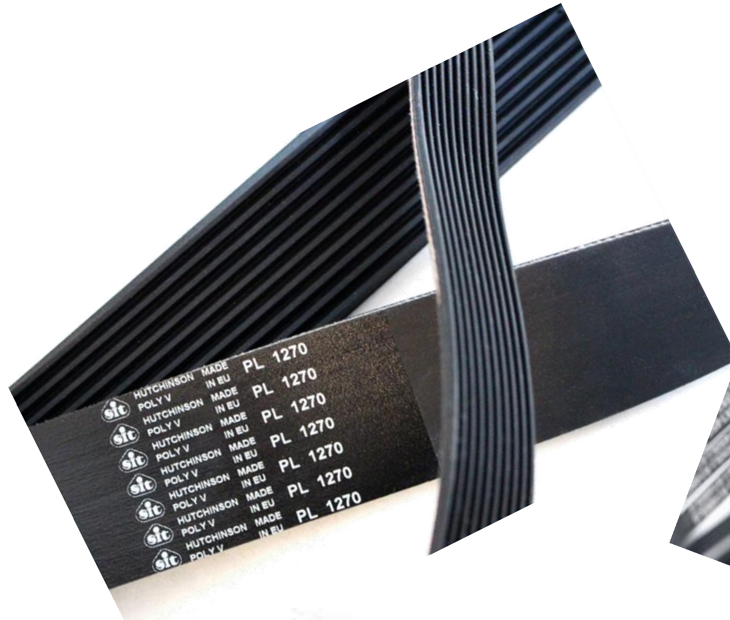
**Figure 17–9**

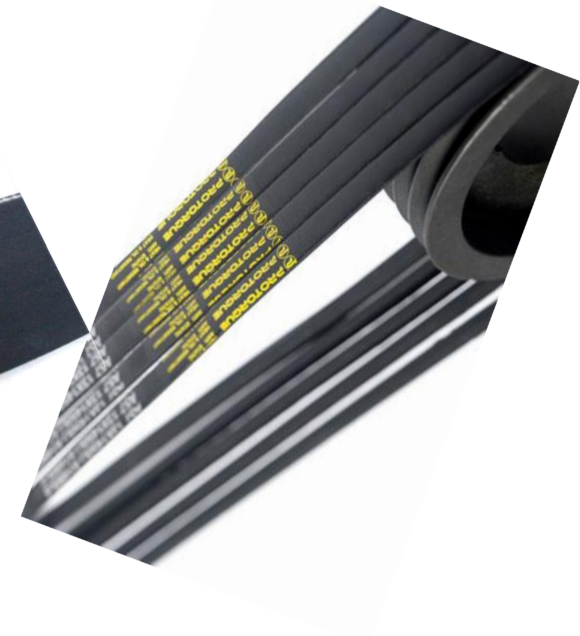
Velocity correction factor $C_v$ for leather belts for various thicknesses. *(Data source:* Machinery's Handbook, 20th ed., *Industrial Press, New York, 1976, p. 1047.)*

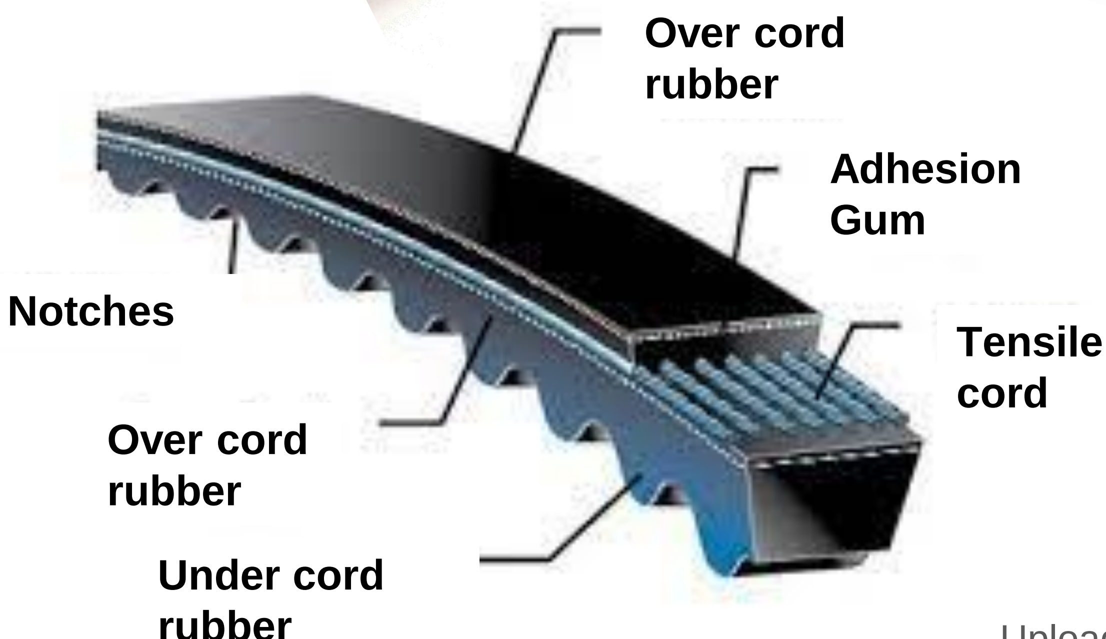


# 17.3 V Belts




HUTCHINSON MADE IN EU
POLY V
PL 1270


PROTORQUE

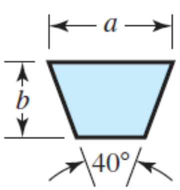

Over cord rubber
Adhesion Gum
Tensile cord
Notches
Over cord rubber
Under cord rubber

# 17.3 V Belts




**Table 17–9**

Standard V-Belt Sections




| Belt Section | Width $a$, in | Thickness $b$, in | Minimum Sheave Diameter, in | hp Range, One or More Belts |
|---|---|---|---|---|
| A | $\frac{1}{2}$ | $\frac{11}{32}$ | 3.0 | $\frac{1}{4}$–10 |
| B | $\frac{21}{32}$ | $\frac{7}{16}$ | 5.4 | 1–25 |
| C | $\frac{7}{8}$ | $\frac{17}{32}$ | 9.0 | 15–100 |
| D | $1\frac{1}{4}$ | $\frac{3}{4}$ | 13.0 | 50–250 |
| E | $1\frac{1}{2}$ | 1 | 21.6 | 100 and up |

# 17.3 V Belts



**Table 17–10**

Inside Circumferences of Standard V Belts

| Section | Circumference, in |
|---|---|
| A | 26, 31, 33, 35, 38, 42, 46, 48, 51, 53, 55, 57, 60, 62, 64, 66, 68, 71, 75, 78, 80, 85, 90, 96, 105, 112, 120, 128 |
| B | 35, 38, 42, 46, 48, 51, 53, 55, 57, 60, 62, 64, 65, 66, 68, 71, 75, 78, 79, 81, 83, 85, 90, 93, 97, 100, 103, 105, 112, 120, 128, 131, 136, 144, 158, 173, 180, 195, 210, 240, 270, 300 |
| C | 51, 60, 68, 75, 81, 85, 90, 96, 105, 112, 120, 128, 136, 144, 158, 162, 173, 180, 195, 210, 240, 270, 300, 330, 360, 390, 420 |
| D | 120, 128, 144, 158, 162, 173, 180, 195, 210, 240, 270, 300, 330, 360, 390, 420, 480, 540, 600, 660 |
| E | 180, 195, 210, 240, 270, 300, 330, 360, 390, 420, 480, 540, 600, 660 |

**Table 17–11**

Length Conversion Dimensions (Add the listed quantity to the inside circumference to obtain the pitch length in inches).

| Belt section | A | B | C | D | E |
|---|---|---|---|---|---|
| Quantity to be added | 1.3 | 1.8 | 2.9 | 3.3 | 4.5 |

$$L_p = 2C + \pi(D + d)/2 + (D - d)^2/(4C) \qquad (17\text{–}16a)$$

# 17.3 V Belts



**Table 17–10**

Inside Circumferences of Standard V Belts

| Section | Circumference, in |
|---|---|
| A | 26, 31, 33, 35, 38, 42, 46, 48, 51, 53, 55, 57, 60, 62, 64, 66, 68, 71, 75, 78, 80, 85, 90, 96, 105, 112, 120, 128 |
| B | 35, 38, 42, 46, 48, 51, 53, 55, 57, 60, 62, 64, 65, 66, 68, 71, 75, 78, 79, 81, 83, 85, 90, 93, 97, 100, 103, 105, 112, 120, 128, 131, 136, 144, 158, 173, 180, 195, 210, 240, 270, 300 |
| C | 51, 60, 68, 75, 81, 85, 90, 96, 105, 112, 120, 128, 136, 144, 158, 162, 173, 180, 195, 210, 240, 270, 300, 330, 360, 390, 420 |
| D | 120, 128, 144, 158, 162, 173, 180, 195, 210, 240, 270, 300, 330, 360, 390, 420, 480, 540, 600, 660 |
| E | 180, 195, 210, 240, 270, 300, 330, 360, 390, 420, 480, 540, 600, 660 |

**Table 17–11**

Length Conversion Dimensions (Add the listed quantity to the inside circumference to obtain the pitch length in inches).

| Belt section | A | B | C | D | E |
|---|---|---|---|---|---|
| Quantity to be added | 1.3 | 1.8 | 2.9 | 3.3 | 4.5 |

$$C = 0.25\left\{\left[L_p - \frac{\pi}{2}(D+d)\right] + \sqrt{\left[L_p - \frac{\pi}{2}(D+d)\right]^2 - 2(D-d)^2}\right\} \quad (17\text{–}16b)$$

## 17.3 V Belts

**Table 17–12**

Horsepower Ratings of Standard V Belts

| Belt Section | Sheave Pitch Diameter, in | Belt Speed, ft/min 1000 | 2000 | 3000 | 4000 | 5000 |
|---|---|---|---|---|---|---|
| A | 2.6 | 0.47 | 0.62 | 0.53 | 0.15 | |
| | 3.0 | 0.66 | 1.01 | 1.12 | 0.93 | 0.38 |
| | 3.4 | 0.81 | 1.31 | 1.57 | 1.53 | 1.12 |
| | 3.8 | 0.93 | 1.55 | 1.92 | 2.00 | 1.71 |
| | 4.2 | 1.03 | 1.74 | 2.20 | 2.38 | 2.19 |
| | 4.6 | 1.11 | 1.89 | 2.44 | 2.69 | 2.58 |
| | 5.0 and up | 1.17 | 2.03 | 2.64 | 2.96 | 2.89 |
| B | 4.2 | 1.07 | 1.58 | 1.68 | 1.26 | 0.22 |
| | 4.6 | 1.27 | 1.99 | 2.29 | 2.08 | 1.24 |
| | 5.0 | 1.44 | 2.33 | 2.80 | 2.76 | 2.10 |
| | 5.4 | 1.59 | 2.62 | 3.24 | 3.34 | 2.82 |
| | 5.8 | 1.72 | 2.87 | 3.61 | 3.85 | 3.45 |
| | 6.2 | 1.82 | 3.09 | 3.94 | 4.28 | 4.00 |
| | 6.6 | 1.92 | 3.29 | 4.23 | 4.67 | 4.48 |
| | 7.0 and up | 2.01 | 3.46 | 4.49 | 5.01 | 4.90 |
| C | 6.0 | 1.84 | 2.66 | 2.72 | 1.87 | |
| | 7.0 | 2.48 | 3.94 | 4.64 | 4.44 | 3.12 |
| | 8.0 | 2.96 | 4.90 | 6.09 | 6.36 | 5.52 |
| | 9.0 | 3.34 | 5.65 | 7.21 | 7.86 | 7.39 |
| | 10.0 | 3.64 | 6.25 | 8.11 | 9.06 | 8.89 |
| | 11.0 | 3.88 | 6.74 | 8.84 | 10.0 | 10.1 |
| | 12.0 and up | 4.09 | 7.15 | 9.46 | 10.9 | 11.1 |
| D | 10.0 | 4.14 | 6.13 | 6.55 | 5.09 | 1.35 |
| | 11.0 | 5.00 | 7.83 | 9.11 | 8.50 | 5.62 |
| | 12.0 | 5.71 | 9.26 | 11.2 | 11.4 | 9.18 |
| | 13.0 | 6.31 | 10.5 | 13.0 | 13.8 | 12.2 |
| | 14.0 | 6.82 | 11.5 | 14.6 | 15.8 | 14.8 |
| | 15.0 | 7.27 | 12.4 | 15.9 | 17.6 | 17.0 |
| | 16.0 | 7.66 | 13.2 | 17.1 | 19.2 | 19.0 |
| | 17.0 and up | 8.01 | 13.9 | 18.1 | 20.6 | 20.7 |
| E | 16.0 | 8.68 | 14.0 | 17.5 | 18.1 | 15.3 |
| | 18.0 | 9.92 | 16.7 | 21.2 | 23.0 | 21.5 |
| | 20.0 | 10.9 | 18.7 | 24.2 | 26.9 | 26.4 |
| | 22.0 | 11.7 | 20.3 | 26.6 | 30.2 | 30.5 |
| | 24.0 | 12.4 | 21.6 | 28.6 | 32.9 | 33.8 |
| | 26.0 | 13.0 | 22.8 | 30.3 | 35.1 | 36.7 |
| | 28.0 and up | 13.4 | 23.7 | 31.8 | 37.1 | 39.1 |

# 17.3 V Belts

The rating, whether in terms of hours or belt passes, is for a belt running on equal-diameter sheaves (180° of wrap), of moderate length, and transmitting a steady load. Deviations from these laboratory test conditions are acknowledged by multiplicative adjustments. If the tabulated power of a belt for a C-section belt is 9.46 hp for a 12-in-diameter sheave at a peripheral speed of 3000 ft/min (Table 17–12), then, when the belt is used under other conditions, the tabulated value $H_{\text{tab}}$ is adjusted as follows:

$$H_a = K_1 K_2 H_{\text{tab}} \tag{17–17}$$

where $H_a$ = allowable power, per belt

$K_1$ = angle-of-wrap ($\phi$) correction factor, Table 17–13

$K_2$ = belt length correction factor, Table 17–14

# 17.3 V Belts

**Table 17–13**

Angle of Contact Correction Factor $K_1$ for VV* and V-Flat Drives

| $\frac{D-d}{C}$ | $\theta$, deg | $K_1$ VV | $K_1$ V Flat |
|---|---|---|---|
| 0.00 | 180 | 1.00 | 0.75 |
| 0.10 | 174.3 | 0.99 | 0.76 |
| 0.20 | 166.5 | 0.97 | 0.78 |
| 0.30 | 162.7 | 0.96 | 0.79 |
| 0.40 | 156.9 | 0.94 | 0.80 |
| 0.50 | 151.0 | 0.93 | 0.81 |
| 0.60 | 145.1 | 0.91 | 0.83 |
| 0.70 | 139.0 | 0.89 | 0.84 |
| 0.80 | 132.8 | 0.87 | 0.85 |
| 0.90 | 126.5 | 0.85 | 0.85 |
| 1.00 | 120.0 | 0.82 | 0.82 |
| 1.10 | 113.3 | 0.80 | 0.80 |
| 1.20 | 106.3 | 0.77 | 0.77 |
| 1.30 | 98.9 | 0.73 | 0.73 |
| 1.40 | 91.1 | 0.70 | 0.70 |
| 1.50 | 82.8 | 0.65 | 0.65 |

# 17.3 V Belts



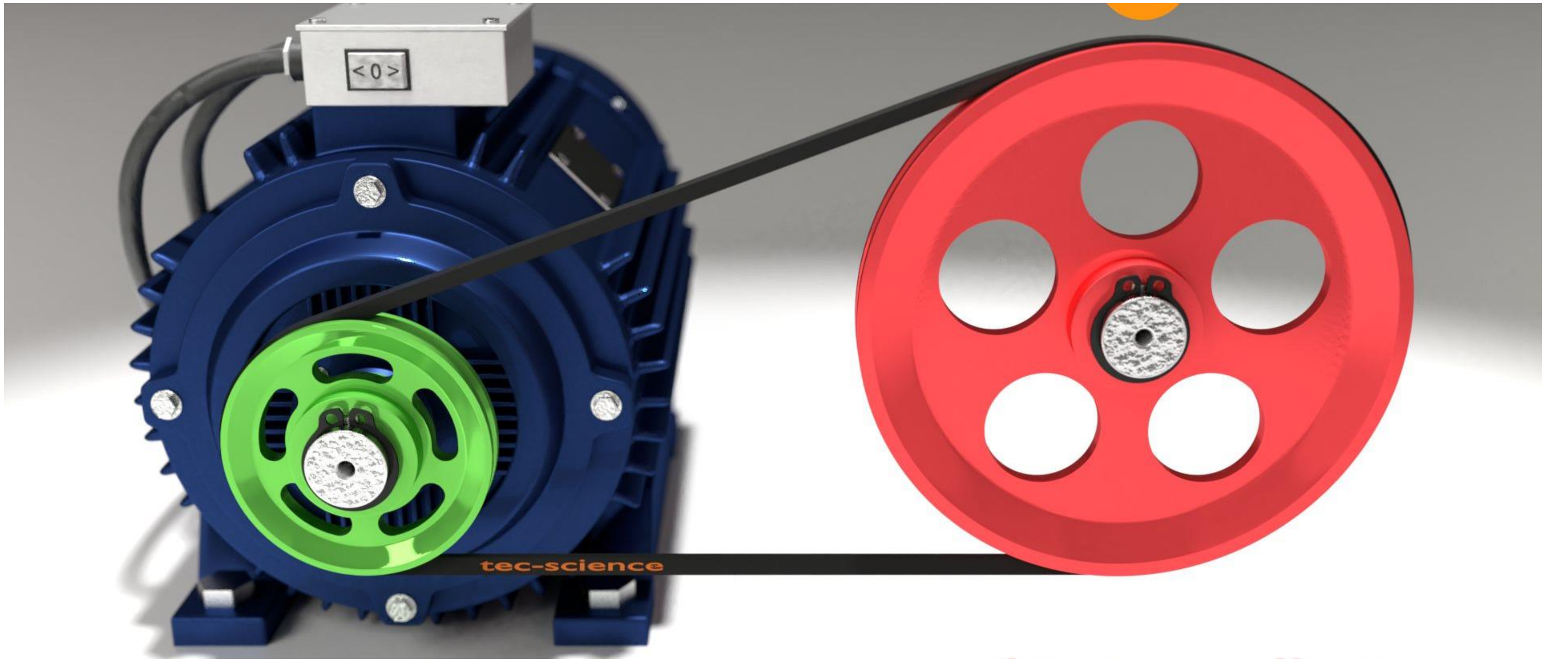
**Table 17–14**

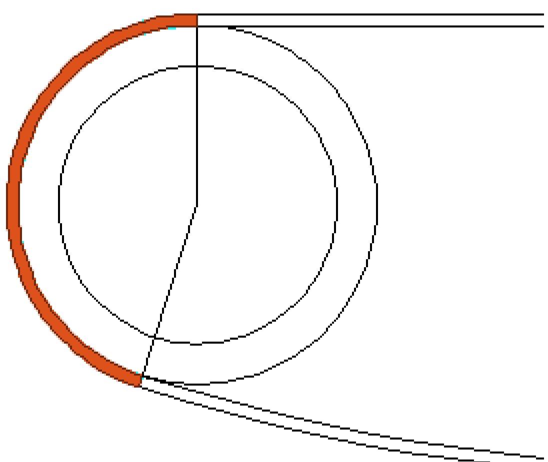
Belt-Length Correction Factor $K_2^*$

| | Nominal Belt Length, in | | | | |
|---|---|---|---|---|---|
| Length Factor | A Belts | B Belts | C Belts | D Belts | E Belts |
| 0.85 | Up to 35 | Up to 46 | Up to 75 | Up to 128 | |
| 0.90 | 38–46 | 48–60 | 81–96 | 144–162 | Up to 195 |
| 0.95 | 48–55 | 62–75 | 105–120 | 173–210 | 210–240 |
| 1.00 | 60–75 | 78–97 | 128–158 | 240 | 270–300 |
| 1.05 | 78–90 | 105–120 | 162–195 | 270–330 | 330–390 |
| 1.10 | 96–112 | 128–144 | 210–240 | 360–420 | 420–480 |
| 1.15 | 120 and up | 158–180 | 270–300 | 480 | 540–600 |
| 1.20 | | 195 and up | 330 and up | 540 and up | 660 |

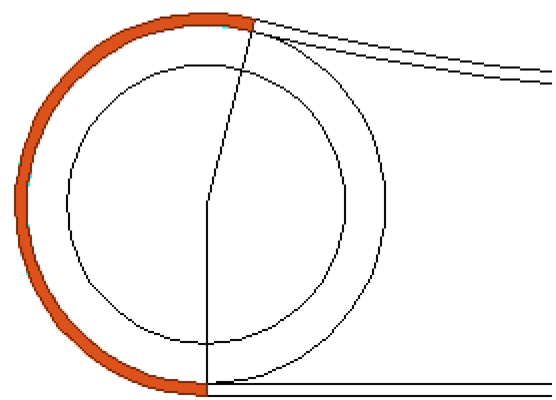
*Multiply the rated horsepower per belt by this factor to obtain the corrected horsepower.

## 17.3 V Belts



Lower (slack) - low angle of contact



Upeer (Slack) - high angle of contact

# 17.3 V Belts

Tension forces relation

$$\frac{F_1 - F_c}{F_2 - F_c} = \exp(0.5123\phi)$$

Design Power

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

where $H_{\text{nom}}$ is the nominal power, $K_s$ is the service factor

**Table 17–15**

Suggested Service Factors $K_S$ for V-Belt Drives

| | Source of Power | |
|---|---|---|
| **Driven Machinery** | **Normal Torque Characteristic** | **High or Nonuniform Torque** |
| Uniform | 1.0 to 1.2 | 1.1 to 1.3 |
| Light shock | 1.1 to 1.3 | 1.2 to 1.4 |
| Medium shock | 1.2 to 1.4 | 1.4 to 1.6 |
| Heavy shock | 1.3 to 1.5 | 1.5 to 1.8 |

# 17.3 V Belts

Tension forces relation

$$\frac{F_1 - F_c}{F_2 - F_c} = \exp(0.5123\phi)$$

Design Power

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

Number of Belts

$$N_b \geq \frac{H_d}{H_a} \qquad N_b = 1, 2, 3, \ldots$$

Factor of safety

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

# 17.3 V Belts

The centrifugal tension $F_c$ is given by

$$F_c = K_c\left(\frac{V}{1000}\right)^2 \tag{17–21}$$

**Table 17–16**

Some V-Belt Parameters*

| Belt Section | $K_b$ | $K_c$ |
|---|---|---|
| A | 220 | 0.561 |
| B | 576 | 0.965 |
| C | 1 600 | 1.716 |
| D | 5 680 | 3.498 |
| E | 10 850 | 5.041 |
| 3V | 230 | 0.425 |
| 5V | 1098 | 1.217 |
| 8V | 4830 | 3.288 |

*Data courtesy of Gates Rubber Co., Denver, Colo.

## 17.3 V Belts

The power that is transmitted per belt is based on $\Delta F = F_1 - F_2$, where

$$\Delta F = \frac{63\,025 H_d/N_b}{n(d/2)} \tag{17–22}$$

then from Eq. (17–8) the largest tension $F_1$ is given by

$$F_1 = F_c + \frac{\Delta F \exp(f\phi)}{\exp(f\phi) - 1} \tag{17–23}$$

From the definition of $\Delta F$, the least tension $F_2$ is

$$F_2 = F_1 - \Delta F \tag{17–24}$$

From Eq. ($j$) in Sec. 17–2

$$F_i = \frac{F_1 + F_2}{2} - F_c \tag{17–25}$$

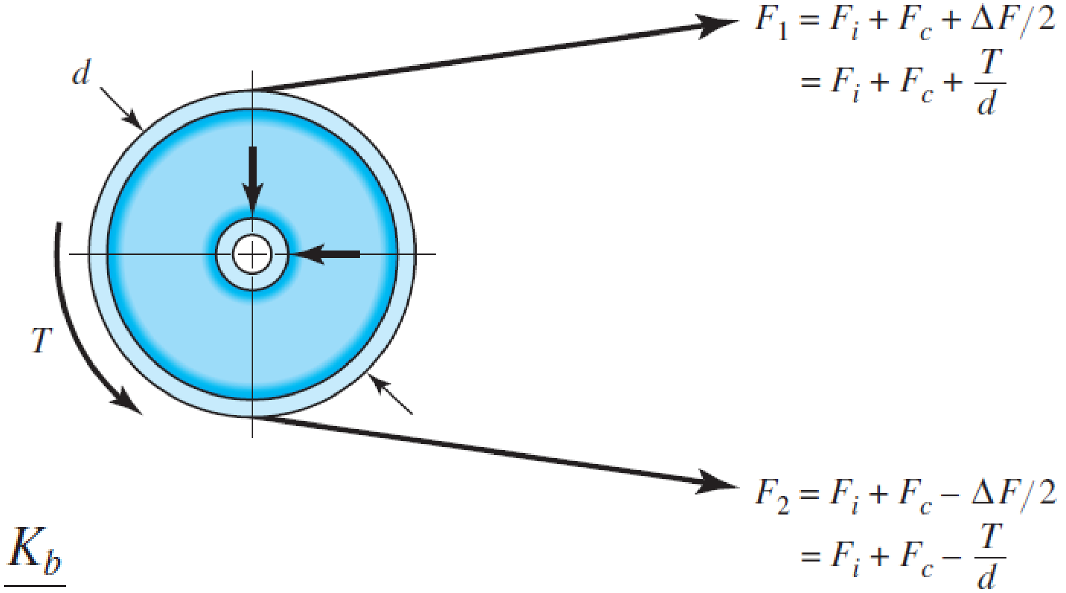
# 17.3 V Belts



*tight-side tension $F_1$*

**Figure 17–7**

Forces and torques on a pulley.




$$T_1 = F_1 + (F_b)_1 = F_1 + \frac{K_b}{d}$$

*loose-side tension $F_2$*

$$T_2 = F_1 + (F_b)_2 = F_1 + \frac{K_b}{D}$$

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# 17.3 V Belts

$$T_1 = F_1 + (F_b)_1 = F_1 + \frac{K_b}{d}$$

$$T_2 = F_1 + (F_b)_2 = F_1 + \frac{K_b}{D}$$

**Table 17–16**

Some V-Belt Parameters*

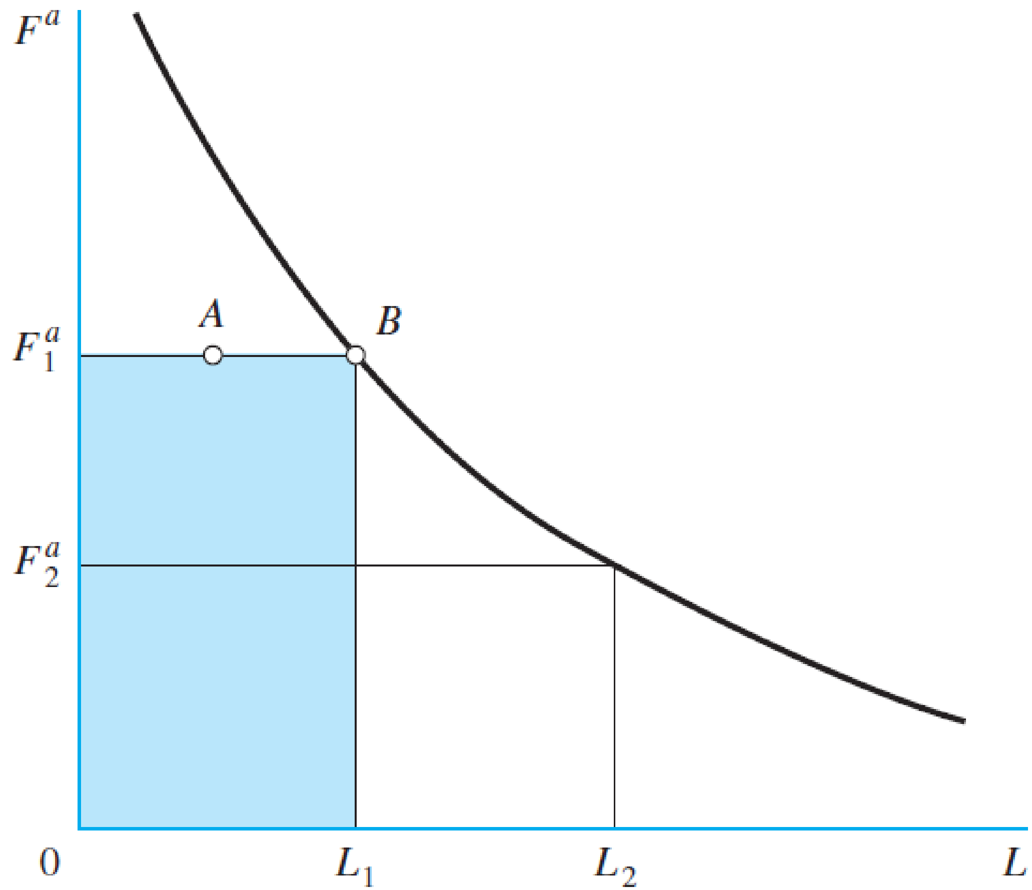
| Belt Section | $K_b$ | $K_c$ |
|---|---|---|
| A | 220 | 0.561 |
| B | 576 | 0.965 |
| C | 1 600 | 1.716 |
| D | 5 680 | 3.498 |
| E | 10 850 | 5.041 |
| 3V | 230 | 0.425 |
| 5V | 1098 | 1.217 |
| 8V | 4830 | 3.288 |

*Data courtesy of Gates Rubber Co., Denver, Colo.

# 11.7 Variable Loading

**Figure 11–9**

Plot of $F^a$ as ordinate and $L$ as abscissa for $F^aL$ = constant. The linear damage hypothesis says that in the case of load $F_1$, the area under the curve from $L = 0$ to $L = L_A$ is a measure of the damage $D = F_1^a L_A$. The complete damage to failure is measured by $C_{10}^a L_B$.




**Bearing**

$$F^aL = \text{constant} = K$$

**V-Belt**

$$T^b N_P = K^b$$

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# 17.3 V Belts

$N_P$ : Number of passes

$$\frac{1}{N_P} = \left(\frac{K}{T_1}\right)^{-b} + \left(\frac{K}{T_2}\right)^{-b}$$

or

$$N_P = \left[\left(\frac{K}{T_1}\right)^{-b} + \left(\frac{K}{T_2}\right)^{-b}\right]^{-1} \tag{17–27}$$

**Table 17–17**

Durability Parameters for Some V-Belt Sections

*Source:* M. E. Spotts, *Design of Machine Elements*, 6th ed. Prentice Hall, Englewood Cliffs, N.J., 1985.

| Belt Section | $10^8$ to $10^9$ Force Peaks | | $10^9$ to $10^{10}$ Force Peaks | | Minimum Sheave Diameter, in |
|---|---|---|---|---|---|
| | $K$ | $b$ | $K$ | $b$ | |
| A | 674 | 11.089 | | | 3.0 |
| B | 1193 | 10.926 | | | 5.0 |
| C | 2038 | 11.173 | | | 8.5 |
| D | 4208 | 11.105 | | | 13.0 |
| E | 6061 | 11.100 | | | 21.6 |
| 3V | 728 | 12.464 | 1062 | 10.153 | 2.65 |
| 5V | 1654 | 12.593 | 2394 | 10.283 | 7.1 |
| 8V | 3638 | 12.629 | 5253 | 10.319 | 12.5 |

## 17.3 V Belts

$N_P$ : Number of passes

$$\frac{1}{N_P} = \left(\frac{K}{T_1}\right)^{-b} + \left(\frac{K}{T_2}\right)^{-b}$$

or

$$N_P = \left[\left(\frac{K}{T_1}\right)^{-b} + \left(\frac{K}{T_2}\right)^{-b}\right]^{-1} \qquad (17\text{–}27)$$

The lifetime $t$ in hours is given by

$$t = \frac{N_P L_p}{720V} \qquad (17\text{–}28)$$

## 17.3 V Belts

The analysis of a V-belt drive can consist of the following steps:

- Find $V$, $L_p$, $C$, $\phi$, and $\exp(0.5123\phi)$
- Find $H_d$, $H_a$, and $N_b$ from $H_d/H_a$ and round up
- Find $F_c$, $\Delta F$, $F_1$, $F_2$, and $F_i$, and $n_{fs}$
- Find belt life in number of passes, or hours, if possible

## Example 17.4

A 10-hp split-phase motor running at 1750 rev/min is used to drive a rotary pump, which operates 24 hours per day. An engineer has specified a 7.4-in small sheave, an 11-in large sheave, and three B112 belts. The service factor of 1.2 was augmented by 0.1 because of the continuous-duty requirement. Analyze the drive and estimate the belt life in passes and hours.

## 17.3 V Belts

**Table 17–12**

Horsepower Ratings of Standard V Belts

| Belt Section | Sheave Pitch Diameter, in | Belt Speed, ft/min 1000 | 2000 | 3000 | 4000 | 5000 |
|---|---|---|---|---|---|---|
| A | 2.6 | 0.47 | 0.62 | 0.53 | 0.15 | |
| | 3.0 | 0.66 | 1.01 | 1.12 | 0.93 | 0.38 |
| | 3.4 | 0.81 | 1.31 | 1.57 | 1.53 | 1.12 |
| | 3.8 | 0.93 | 1.55 | 1.92 | 2.00 | 1.71 |
| | 4.2 | 1.03 | 1.74 | 2.20 | 2.38 | 2.19 |
| | 4.6 | 1.11 | 1.89 | 2.44 | 2.69 | 2.58 |
| | 5.0 and up | 1.17 | 2.03 | 2.64 | 2.96 | 2.89 |
| B | 4.2 | 1.07 | 1.58 | 1.68 | 1.26 | 0.22 |
| | 4.6 | 1.27 | 1.99 | 2.29 | 2.08 | 1.24 |
| | 5.0 | 1.44 | 2.33 | 2.80 | 2.76 | 2.10 |
| | 5.4 | 1.59 | 2.62 | 3.24 | 3.34 | 2.82 |
| | 5.8 | 1.72 | 2.87 | 3.61 | 3.85 | 3.45 |
| | 6.2 | 1.82 | 3.09 | 3.94 | 4.28 | 4.00 |
| | 6.6 | 1.92 | 3.29 | 4.23 | 4.67 | 4.48 |
| | 7.0 and up | 2.01 | 3.46 | 4.49 | 5.01 | 4.90 |
| C | 6.0 | 1.84 | 2.66 | 2.72 | 1.87 | |
| | 7.0 | 2.48 | 3.94 | 4.64 | 4.44 | 3.12 |
| | 8.0 | 2.96 | 4.90 | 6.09 | 6.36 | 5.52 |
| | 9.0 | 3.34 | 5.65 | 7.21 | 7.86 | 7.39 |
| | 10.0 | 3.64 | 6.25 | 8.11 | 9.06 | 8.89 |
| | 11.0 | 3.88 | 6.74 | 8.84 | 10.0 | 10.1 |
| | 12.0 and up | 4.09 | 7.15 | 9.46 | 10.9 | 11.1 |
| D | 10.0 | 4.14 | 6.13 | 6.55 | 5.09 | 1.35 |
| | 11.0 | 5.00 | 7.83 | 9.11 | 8.50 | 5.62 |
| | 12.0 | 5.71 | 9.26 | 11.2 | 11.4 | 9.18 |
| | 13.0 | 6.31 | 10.5 | 13.0 | 13.8 | 12.2 |
| | 14.0 | 6.82 | 11.5 | 14.6 | 15.8 | 14.8 |
| | 15.0 | 7.27 | 12.4 | 15.9 | 17.6 | 17.0 |
| | 16.0 | 7.66 | 13.2 | 17.1 | 19.2 | 19.0 |
| | 17.0 and up | 8.01 | 13.9 | 18.1 | 20.6 | 20.7 |
| E | 16.0 | 8.68 | 14.0 | 17.5 | 18.1 | 15.3 |
| | 18.0 | 9.92 | 16.7 | 21.2 | 23.0 | 21.5 |
| | 20.0 | 10.9 | 18.7 | 24.2 | 26.9 | 26.4 |
| | 22.0 | 11.7 | 20.3 | 26.6 | 30.2 | 30.5 |
| | 24.0 | 12.4 | 21.6 | 28.6 | 32.9 | 33.8 |
| | 26.0 | 13.0 | 22.8 | 30.3 | 35.1 | 36.7 |
| | 28.0 and up | 13.4 | 23.7 | 31.8 | 37.1 | 39.1 |

# 17.3 V Belts



**Table 17–10**

Inside Circumferences of Standard V Belts

| Section | Circumference, in |
|---|---|
| A | 26, 31, 33, 35, 38, 42, 46, 48, 51, 53, 55, 57, 60, 62, 64, 66, 68, 71, 75, 78, 80, 85, 90, 96, 105, 112, 120, 128 |
| B | 35, 38, 42, 46, 48, 51, 53, 55, 57, 60, 62, 64, 65, 66, 68, 71, 75, 78, 79, 81, 83, 85, 90, 93, 97, 100, 103, 105, $\boxed{112}$, 120, 128, 131, 136, 144, 158, 173, 180, 195, 210, 240, 270, 300 |
| C | 51, 60, 68, 75, 81, 85, 90, 96, 105, 112, 120, 128, 136, 144, 158, 162, 173, 180, 195, 210, 240, 270, 300, 330, 360, 390, 420 |
| D | 120, 128, 144, 158, 162, 173, 180, 195, 210, 240, 270, 300, 330, 360, 390, 420, 480, 540, 600, 660 |
| E | 180, 195, 210, 240, 270, 300, 330, 360, 390, 420, 480, 540, 600, 660 |

**Table 17–11**

Length Conversion Dimensions (Add the listed quantity to the inside circumference to obtain the pitch length in inches).

| Belt section | A | B | C | D | E |
|---|---|---|---|---|---|
| Quantity to be added | 1.3 | $\boxed{1.8}$ | 2.9 | 3.3 | 4.5 |

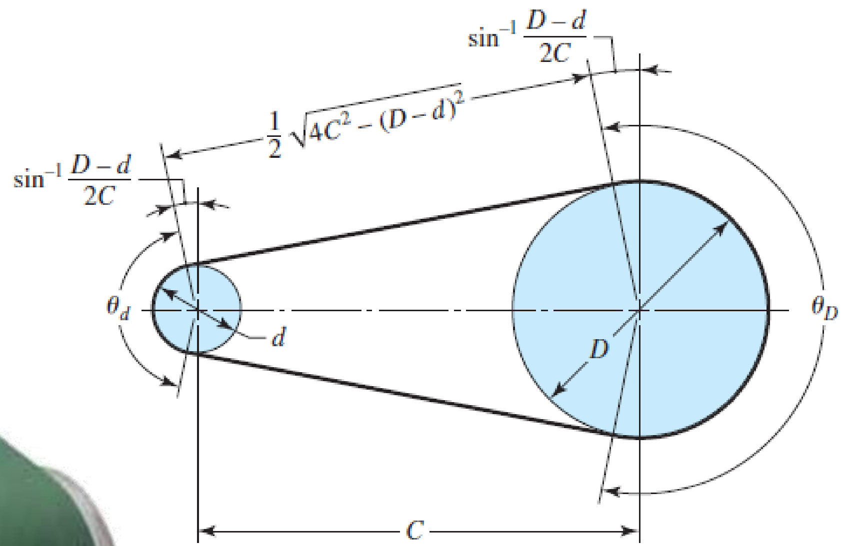
$$L_p = 2C + \pi(D + d)/2 + (D - d)^2/(4C) \qquad (17\text{–}16a)$$

# 17.2 Flat and Rounded Drives



**Figure 17–1**

Flat-belt geometry. (*a*) Open belt. (*b*) Crossed belt.




$$\theta_d = \pi - 2\sin^{-1}\frac{D-d}{2C}$$

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

$$L = \sqrt{4C^2-(D-d)^2} + \tfrac{1}{2}(D\theta_D + d\theta_d)$$

$$\theta_d = \pi - 2\sin^{-1}\frac{D-d}{2C}$$

$$\theta_D = \pi + 2\sin^{-1}\frac{D-d}{2C} \qquad (17\text{–}1)$$

where $D$ = diameter of large pulley

$d$ = diameter of small pulley

$C$ = center distance

$\theta$ = angle of contact

The length of the belt is found by summing the two arc lengths with twice the distance between the beginning and end of contact. The result is

$$L = [4C^2 - (D-d)^2]^{1/2} + \frac{1}{2}(D\theta_D + d\theta_d) \qquad (17\text{–}2)$$

# 17.3 V Belts

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**Table 17–13**

Angle of Contact Correction Factor $K_1$ for VV* and V-Flat Drives

| $\frac{D-d}{C}$ | $\theta$, deg | $K_1$ VV | $K_1$ V Flat |
|---|---|---|---|
| 0.00 | 180 | 1.00 | 0.75 |
| 0.10 | 174.3 | 0.99 | 0.76 |
| 0.20 | 166.5 | 0.97 | 0.78 |
| 0.30 | 162.7 | 0.96 | 0.79 |
| 0.40 | 156.9 | 0.94 | 0.80 |
| 0.50 | 151.0 | 0.93 | 0.81 |
| 0.60 | 145.1 | 0.91 | 0.83 |
| 0.70 | 139.0 | 0.89 | 0.84 |
| 0.80 | 132.8 | 0.87 | 0.85 |
| 0.90 | 126.5 | 0.85 | 0.85 |
| 1.00 | 120.0 | 0.82 | 0.82 |
| 1.10 | 113.3 | 0.80 | 0.80 |
| 1.20 | 106.3 | 0.77 | 0.77 |
| 1.30 | 98.9 | 0.73 | 0.73 |
| 1.40 | 91.1 | 0.70 | 0.70 |
| 1.50 | 82.8 | 0.65 | 0.65 |

# 17.3 V Belts



**Table 17–14**

Belt-Length Correction Factor $K_2^*$

| | Nominal Belt Length, in | | | | |
|---|---|---|---|---|---|
| **Length Factor** | **A Belts** | **B Belts** | **C Belts** | **D Belts** | **E Belts** |
| 0.85 | Up to 35 | Up to 46 | Up to 75 | Up to 128 | |
| 0.90 | 38–46 | 48–60 | 81–96 | 144–162 | Up to 195 |
| 0.95 | 48–55 | 62–75 | 105–120 | 173–210 | 210–240 |
| 1.00 | 60–75 | 78–97 | 128–158 | 240 | 270–300 |
| 1.05 | 78–90 | $\boxed{105–120}$ | 162–195 | 270–330 | 330–390 |
| 1.10 | 96–112 | 128–144 | 210–240 | 360–420 | 420–480 |
| 1.15 | 120 and up | 158–180 | 270–300 | 480 | 540–600 |
| 1.20 | | 195 and up | 330 and up | 540 and up | 660 |

*Multiply the rated horsepower per belt by this factor to obtain the corrected horsepower.

## 17.3 V Belts



$$T_1 = F_1 + (F_b)_1 = F_1 + \frac{K_b}{d}$$

$$T_2 = F_1 + (F_b)_2 = F_1 + \frac{K_b}{D}$$

**Table 17–16**

Some V-Belt Parameters*

| Belt Section | $K_b$ | $K_c$ |
|---|---|---|
| A | 220 | 0.561 |
| B | 576 | 0.965 |
| C | 1 600 | 1.716 |
| D | 5 680 | 3.498 |
| E | 10 850 | 5.041 |
| 3V | 230 | 0.425 |
| 5V | 1098 | 1.217 |
| 8V | 4830 | 3.288 |

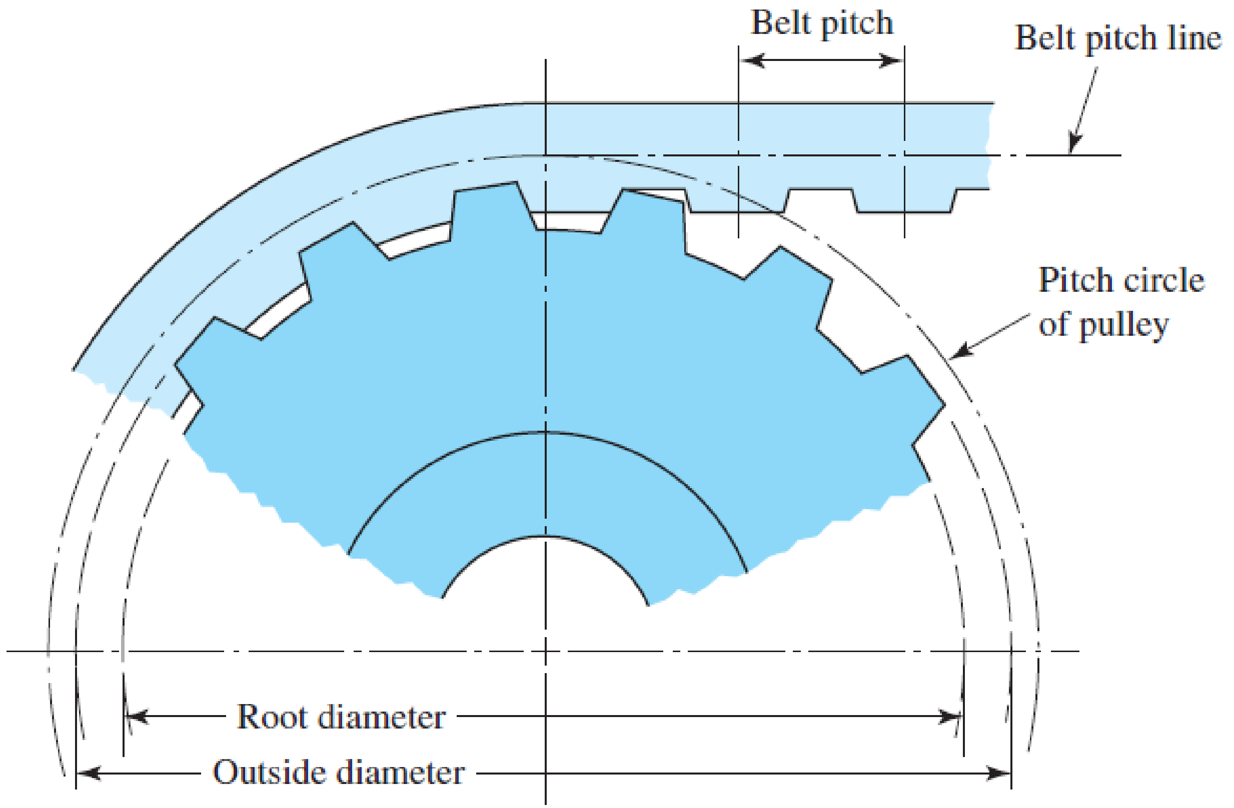
*Data courtesy of Gates Rubber Co., Denver, Colo.

# 17.4 Timing Belts



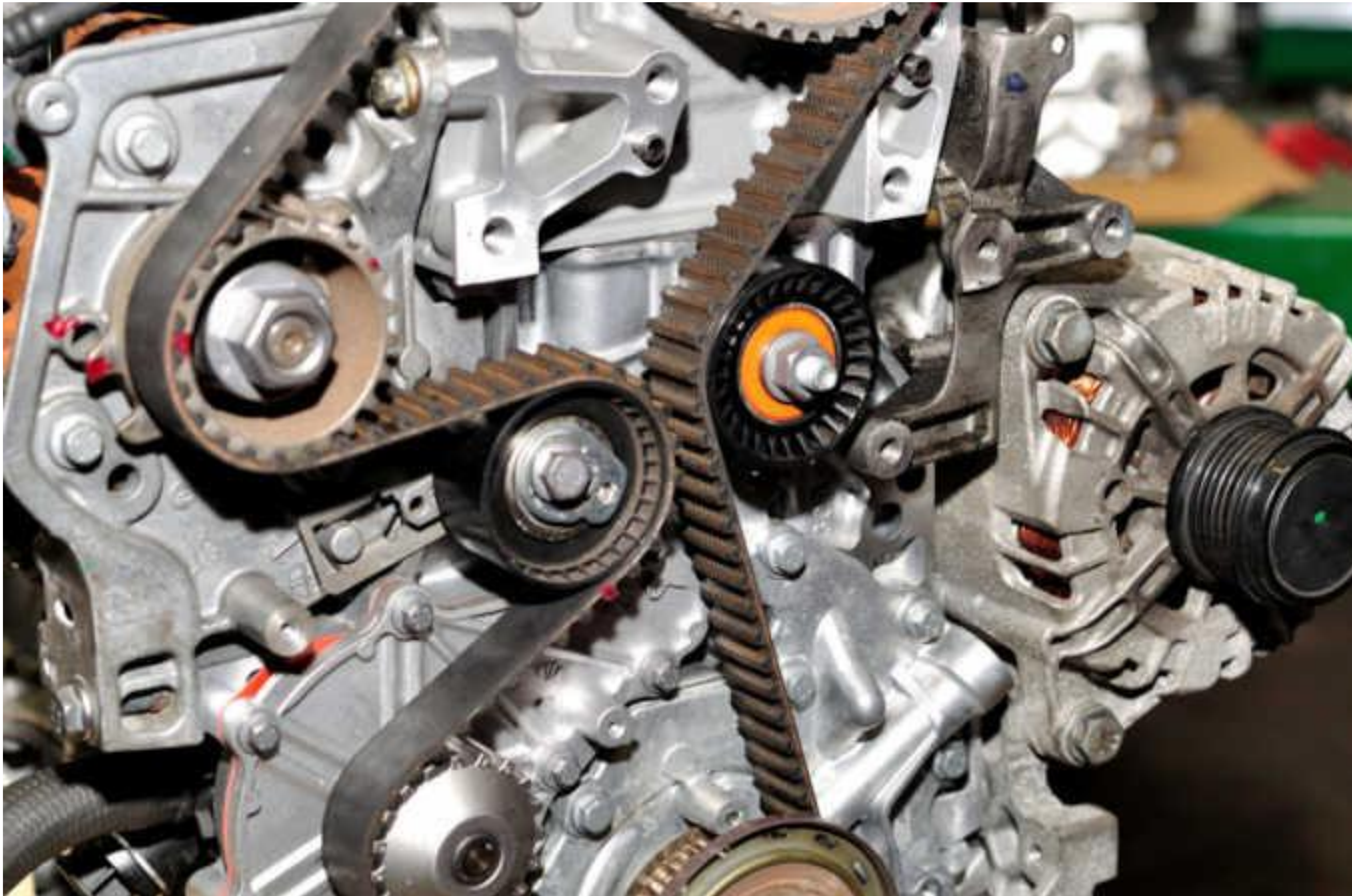
**Figure 17–15**

Timing-belt drive showing portions of the pulley and belt. Note that the pitch diameter of the pulley is greater than the diametral distance across the top lands of the teeth.



# 17.4 Timing Belts





## 17.4 Timing Belts

- A timing belt is made of a rubberized fabric coated with a nylon fabric, and has steel wire within to take the tension load.
- It has teeth that fit into grooves cut on the periphery of the pulleys. A timing belt does not stretch appreciably or slip and consequently transmits power at a constant angular-velocity ratio.
- No initial tension is needed. Such belts can operate over a very wide range of speeds, have efficiencies in the range of 97 to 99 %, require no lubrication, and are quieter than chain drives.
- The design and selection process for timing belts is so similar to that for V belts that the process will not be presented here.

# 17.5 Roller Chain

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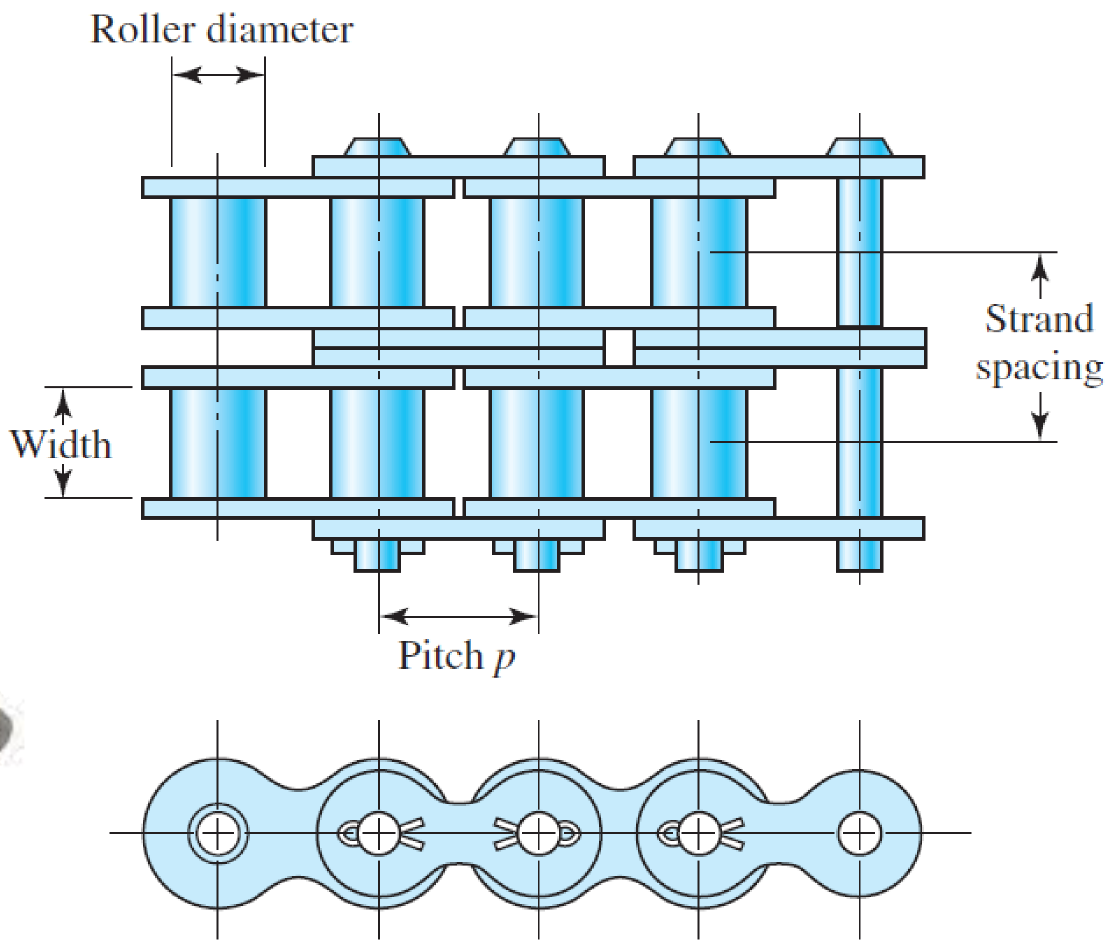
**Figure 17–16**

Portion of a double-strand roller chain.




These chains are manufactured in single, double, triple, and quadruple strands.

**Table 17–19**

Dimensions of American Standard Roller Chains—Single Strand

*Source:* Compiled from ANSI B29.1-1975.

| ANSI Chain Number | Pitch, in (mm) | Width, in (mm) | Minimum Tensile Strength, lbf (N) | Average Weight, lbf/ft (N/m) | Roller Diameter, in (mm) | Multiple-Strand Spacing, in (mm) |
|---|---|---|---|---|---|---|
| 25 | 0.250 (6.35) | 0.125 (3.18) | 780 (3 470) | 0.09 (1.31) | 0.130 (3.30) | 0.252 (6.40) |
| 35 | 0.375 (9.52) | 0.188 (4.76) | 1 760 (7 830) | 0.21 (3.06) | 0.200 (5.08) | 0.399 (10.13) |
| 41 | 0.500 (12.70) | 0.25 (6.35) | 1 500 (6 670) | 0.25 (3.65) | 0.306 (7.77) | — — |
| 40 | 0.500 (12.70) | 0.312 (7.94) | 3 130 (13 920) | 0.42 (6.13) | 0.312 (7.92) | 0.566 (14.38) |
| 50 | 0.625 (15.88) | 0.375 (9.52) | 4 880 (21 700) | 0.69 (10.1) | 0.400 (10.16) | 0.713 (18.11) |
| 60 | 0.750 (19.05) | 0.500 (12.7) | 7 030 (31 300) | 1.00 (14.6) | 0.469 (11.91) | 0.897 (22.78) |
| 80 | 1.000 (25.40) | 0.625 (15.88) | 12 500 (55 600) | 1.71 (25.0) | 0.625 (15.87) | 1.153 (29.29) |
| 100 | 1.250 (31.75) | 0.750 (19.05) | 19 500 (86 700) | 2.58 (37.7) | 0.750 (19.05) | 1.409 (35.76) |
| 120 | 1.500 (38.10) | 1.000 (25.40) | 28 000 (124 500) | 3.87 (56.5) | 0.875 (22.22) | 1.789 (45.44) |
| 140 | 1.750 (44.45) | 1.000 (25.40) | 38 000 (169 000) | 4.95 (72.2) | 1.000 (25.40) | 1.924 (48.87) |
| 160 | 2.000 (50.80) | 1.250 (31.75) | 50 000 (222 000) | 6.61 (96.5) | 1.125 (28.57) | 2.305 (58.55) |
| 180 | 2.250 (57.15) | 1.406 (35.71) | 63 000 (280 000) | 9.06 (132.2) | 1.406 (35.71) | 2.592 (65.84) |
| 200 | 2.500 (63.50) | 1.500 (38.10) | 78 000 (347 000) | 10.96 (159.9) | 1.562 (39.67) | 2.817 (71.55) |
| 240 | 3.00 (76.70) | 1.875 (47.63) | 112 000 (498 000) | 16.4 (239) | 1.875 (47.62) | 3.458 (87.83) |

# 17.5 Roller Chain

# 17.5 Roller Chain



$$\sin\frac{\gamma}{2} = \frac{p/2}{D/2} \qquad \text{or} \qquad D = \frac{p}{\sin(\gamma/2)}$$

Since $\gamma = 360°/N$,

where $N$ is the number of sprocket teeth,

$$D = \frac{p}{\sin(180°/N)}$$

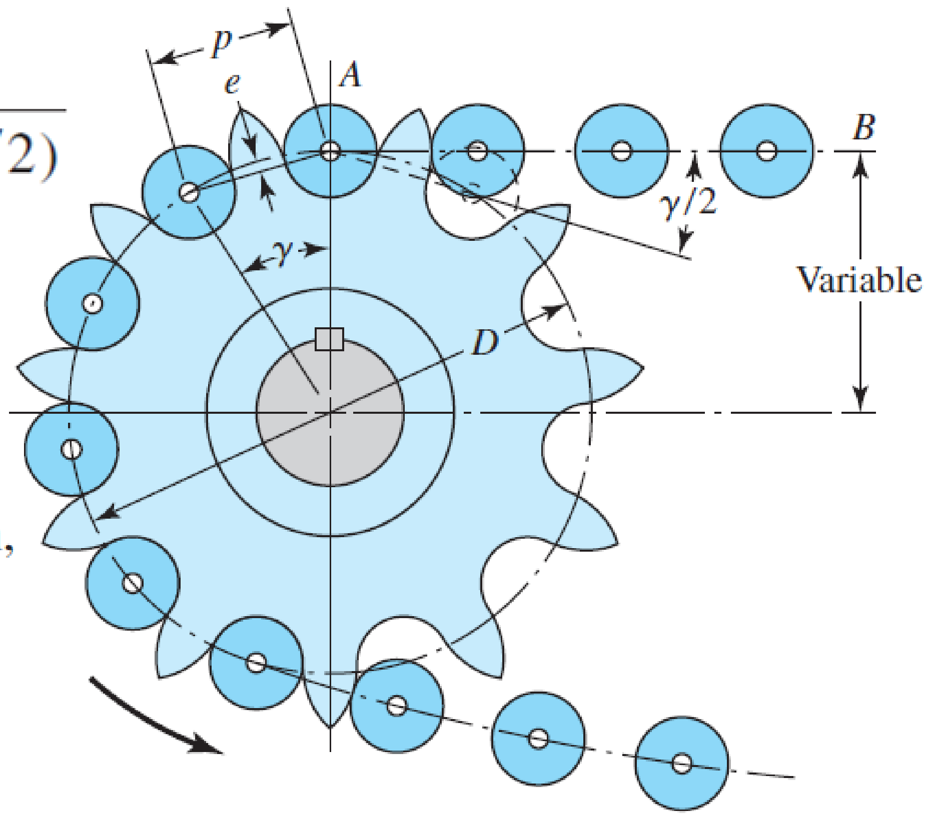



**Figure 17–17**

Engagement of a chain and sprocket.

# 17.5 Roller Chain



The chain velocity $V$ is defined as the number of feet coming off the sprocket per unit time. Thus the chain velocity in feet per minute is

$$V = \frac{Npn}{12} \tag{17–30}$$

where $N$ = number of sprocket teeth
$p$ = chain pitch, in
$n$ = sprocket speed, rev/min

The maximum exit velocity of the chain is

$$v_{max} = \frac{\pi Dn}{12} = \frac{\pi np}{12 \sin(\gamma/2)} \tag{b}$$

Thus the minimum exit velocity is

$$v_{min} = \frac{\pi dn}{12} = \frac{\pi np}{12} \frac{\cos(\gamma/2)}{\sin(\gamma/2)}$$

$$d = D \cos \frac{\gamma}{2}$$

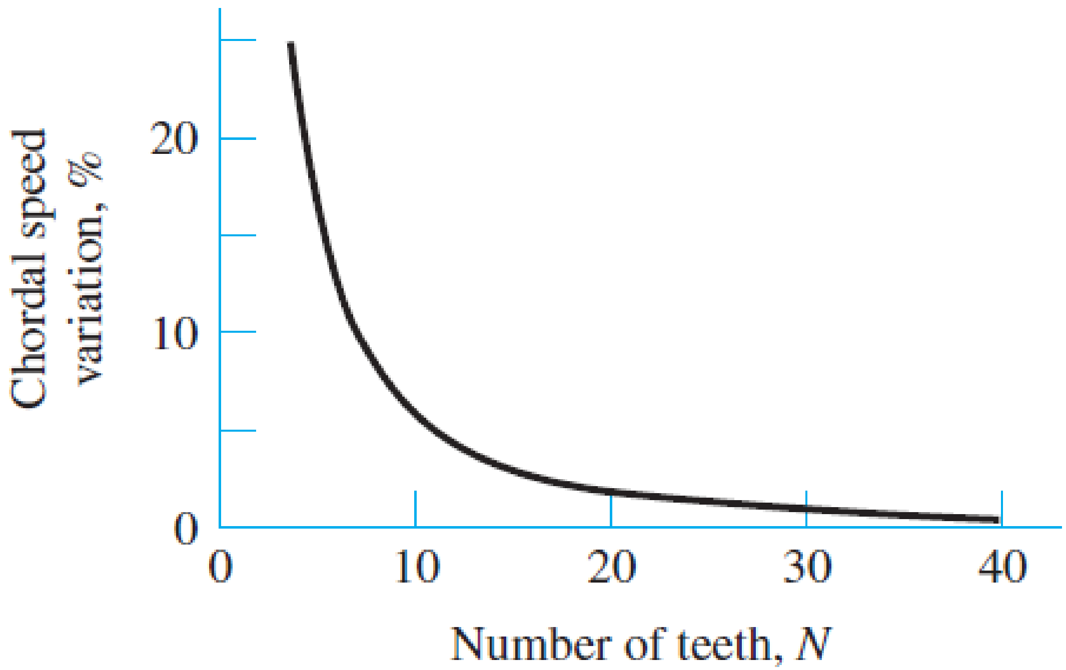
# 17.5 Roller Chain



## Chordal speed variation

Now substituting $\gamma/2 = 180°/N$ and employing Eqs. (17–30), (*b*), and (*d*), we find the speed variation to be

$$\frac{\Delta V}{V} = \frac{v_{\max} - v_{\min}}{V} = \frac{\pi}{N}\left[\frac{1}{\sin(180°/N)} - \frac{1}{\tan(180°/N)}\right] \tag{17–31}$$



## 17.5 Roller Chain



- For smooth operation at moderate and high speeds it is considered good practice to use a driving sprocket with at least 17 teeth; 19 or 21 will, of course, give a better life expectancy with less chain noise.

- The most successful drives have velocity ratios up to 6:1, but higher ratios may be used at the sacrifice of chain life.

- Roller chains seldom fail because they high tensile strength; they more often fail because they have been subjected to a great many hours of service. Actual failure may be due either to wear of the rollers on the pins or to fatigue of the surfaces of the rollers.

**Table 17–20**

Rated Horsepower Capacity of Single-Strand Single-Pitch Roller Chain for a 17-Tooth Sprocket

*Source:* Compiled from ANSI B29.1-1975 information only section, and from B29.9-1958.

| Sprocket Speed, rev/min | ANSI Chain Number 25 | 35 | 40 | 41 | 50 | 60 |
|---|---|---|---|---|---|---|
| 50 | 0.05 | 0.16 | 0.37 | 0.20 | 0.72 | 1.24 |
| 100 | 0.09 | 0.29 | 0.69 | 0.38 | 1.34 | 2.31 |
| 150 | 0.13* | 0.41* | 0.99* | 0.55* | 1.92* | 3.32 |
| 200 | 0.16* | 0.54* | 1.29 | 0.71 | 2.50 | 4.30 |
| 300 | 0.23 | 0.78 | 1.85 | 1.02 | 3.61 | 6.20 |
| 400 | 0.30* | 1.01* | 2.40 | 1.32 | 4.67 | 8.03 |
| 500 | 0.37 | 1.24 | 2.93 | 1.61 | 5.71 | 9.81 |
| 600 | 0.44* | 1.46* | 3.45* | 1.90* | 6.72* | 11.6 |
| 700 | 0.50 | 1.68 | 3.97 | 2.18 | 7.73 | 13.3 |
| 800 | 0.56* | 1.89* | 4.48* | 2.46* | 8.71* | 15.0 |
| 900 | 0.62 | 2.10 | 4.98 | 2.74 | 9.69 | 16.7 |
| 1000 | 0.68* | 2.31* | 5.48 | 3.01 | 10.7 | 18.3 |
| 1200 | 0.81 | 2.73 | 6.45 | 3.29 | 12.6 | 21.6 |
| 1400 | 0.93* | 3.13* | 7.41 | 2.61 | 14.4 | 18.1 |
| 1600 | 1.05* | 3.53* | 8.36 | 2.14 | 12.8 | 14.8 |
| 1800 | 1.16 | 3.93 | 8.96 | 1.79 | 10.7 | 12.4 |
| 2000 | 1.27* | 4.32* | 7.72* | 1.52* | 9.23* | 10.6 |
| 2500 | 1.56 | 5.28 | 5.51* | 1.10* | 6.58* | 7.57 |
| 3000 | 1.84 | 5.64 | 4.17 | 0.83 | 4.98 | 5.76 |

Type A — Type B — Type C

*Estimated from ANSI tables by linear interpolation.

*Note:* Type A—manual or drip lubrication; type B—bath or disk lubrication; type C—oil-stream lubrication.

## Table 17–20

Rated Horsepower Capacity of Single-Strand Single-Pitch Roller Chain for a 17-Tooth Sprocket

*(Continued)*

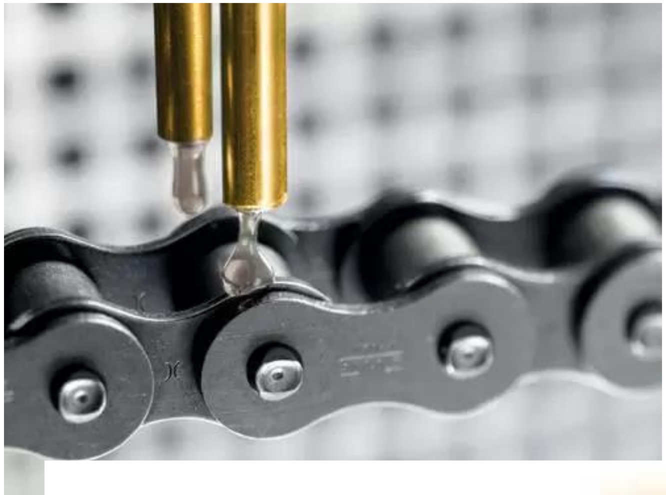
| Sprocket Speed, rev/min | | ANSI Chain Number 80 | 100 | 120 | 140 | 160 | 180 | 200 | 240 |
|---|---|---|---|---|---|---|---|---|---|
| 50 | Type A | 2.88 | 5.52 | 9.33 | 14.4 | 20.9 | 28.9 | 38.4 | 61.8 |
| 100 | | 5.38 | 10.3 | 17.4 | 26.9 | 39.1 | 54.0 | 71.6 | 115 |
| 150 | | 7.75 | 14.8 | 25.1 | 38.8 | 56.3 | 77.7 | 103 | 166 |
| 200 | | 10.0 | 19.2 | 32.5 | 50.3 | 72.9 | 101 | 134 | 215 |
| 300 | | 14.5 | 27.7 | 46.8 | 72.4 | 105 | 145 | 193 | 310 |
| 400 | | 18.7 | 35.9 | 60.6 | 93.8 | 136 | 188 | 249 | 359 |
| 500 | Type B | 22.9 | 43.9 | 74.1 | 115 | 166 | 204 | 222 | 0 |
| 600 | | 27.0 | 51.7 | 87.3 | 127 | 141 | 155 | 169 | |
| 700 | | 31.0 | 59.4 | 89.0 | 101 | 112 | 123 | 0 | |
| 800 | | 35.0 | 63.0 | 72.8 | 82.4 | 91.7 | 101 | | |
| 900 | | 39.9 | 52.8 | 61.0 | 69.1 | 76.8 | 84.4 | | |
| 1000 | | 37.7 | 45.0 | 52.1 | 59.0 | 65.6 | 72.1 | | |
| 1200 | | 28.7 | 34.3 | 39.6 | 44.9 | 49.9 | 0 | | |
| 1400 | | 22.7 | 27.2 | 31.5 | 35.6 | 0 | | | |
| 1600 | | 18.6 | 22.3 | 25.8 | 0 | | | | |
| 1800 | | 15.6 | 18.7 | 21.6 | | | | | |
| 2000 | | 13.3 | 15.9 | 0 | | | | | |
| 2500 | | 9.56 | 0.40 | | | | | | |
| 3000 | | 7.25 | 0 | | | | | | |
| Type C | | | | | Type C′ | | | | |

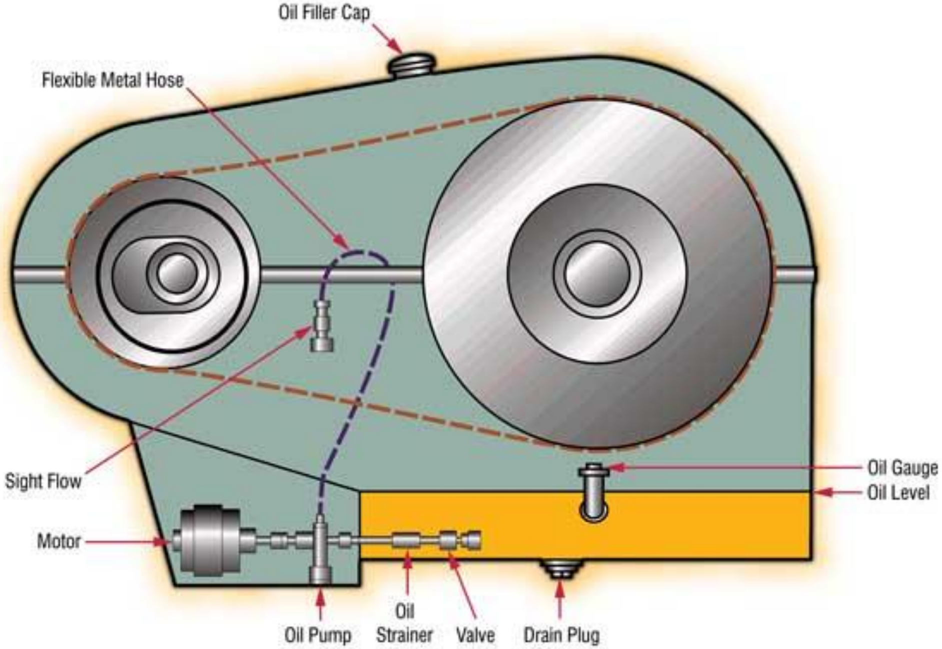
*Note:* Type A—manual or drip lubrication; type B—bath or disk lubrication; type C—oil-stream lubrication;

mit design to manufacturer for evaluation.

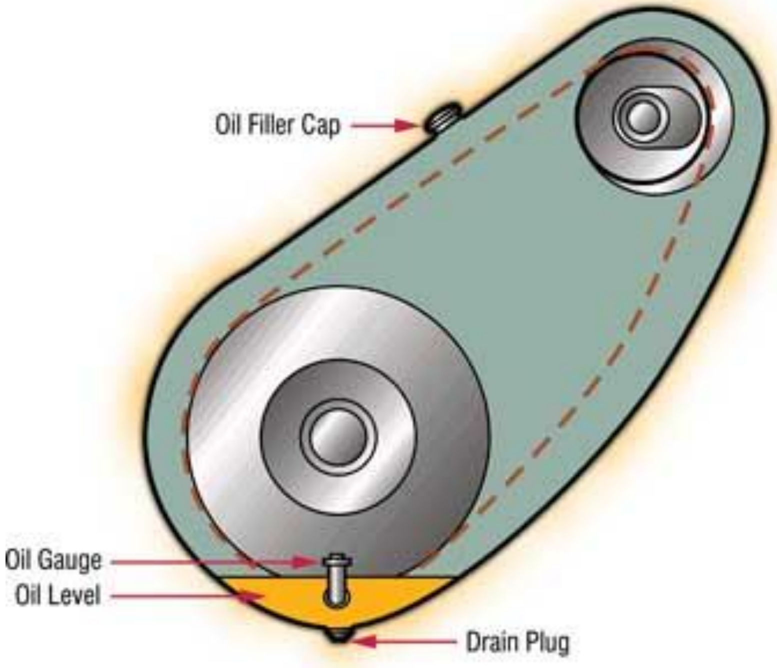
The capacities of chains are based on the following:

# 17.5 Roller Chain






Oil Stream Lubrication




Oil Bath Lubrication

## 17.5 Roller Chain

The allowable power $H_a$ is given by:

$$H_a = K_1 K_2 H_{\text{tab}} \qquad (17\text{–}37)$$

where $K_1$ = correction factor for tooth number other than 17 (Table 17–22)

$K_2$ = strand correction (Table 17–23)

The horsepower that must be transmitted $H_d$ is given by:

$$H_d = H_{\text{nom}} K_s n_d \qquad (17\text{–}38)$$

# 17.5 Roller Chain



**Table 17–22**

Tooth Correction Factors, $K_1$

| Number of Teeth on Driving Sprocket | $K_1$ Pre-extreme Horsepower | $K_1$ Post-extreme Horsepower |
|---|---|---|
| 11 | 0.62 | 0.52 |
| 12 | 0.69 | 0.59 |
| 13 | 0.75 | 0.67 |
| 14 | 0.81 | 0.75 |
| 15 | 0.87 | 0.83 |
| 16 | 0.94 | 0.91 |
| 17 | 1.00 | 1.00 |
| 18 | 1.06 | 1.09 |
| 19 | 1.13 | 1.18 |
| 20 | 1.19 | 1.28 |
| $N$ | $(N_1/17)^{1.08}$ | $(N_1/17)^{1.5}$ |

# 17.5 Roller Chain

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**Table 17–23**

Multiple-Strand Factors, $K_2$

| Number of Strands | $K_2$ |
|---|---|
| 1 | 1.0 |
| 2 | 1.7 |
| 3 | 2.5 |
| 4 | 3.3 |
| 5 | 3.9 |
| 6 | 4.6 |
| 8 | 6.0 |

## 17.5 Roller Chain

It is preferable to have an odd number of teeth on the driving sprocket (17, 19, . . .) and an even number of pitches in the chain to avoid a special link.

The approximate length of the chain $L$ in pitches is

$$\frac{L}{p} \approx \frac{2C}{p} + \frac{N_1 + N_2}{2} + \frac{(N_2 - N_1)^2}{4\pi^2 C/p} \qquad (17\text{–}34)$$

The Center to Center distance is given by:

$$C = \frac{p}{4}\left[-A + \sqrt{A^2 - 8\left(\frac{N_2 - N_1}{2\pi}\right)^2}\right] \qquad (17\text{–}35)$$

$$A = \frac{N_1 + N_2}{2} - \frac{L}{p} \qquad (17\text{–}36)$$

# 17.5 Roller Chain



## Table 17–21

Single-Strand Sprocket Tooth Counts Available from One Supplier*

| No. | Available Sprocket Tooth Counts |
|---|---|
| 25 | 8-30, 32, 34, 35, 36, 40, 42, 45, 48, 54, 60, 64, 65, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120 |
| 35 | 4-45, 48, 52, 54, 60, 64, 65, 68, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120 |
| 41 | 6-60, 64, 65, 68, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120 |
| 40 | 8-60, 64, 65, 68, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120 |
| 50 | 8-60, 64, 65, 68, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120 |
| 60 | 8-60, 62, 63, 64, 65, 66, 67, 68, 70, 72, 76, 80, 84, 90, 95, 96, 102, 112, 120 |
| 80 | 8-60, 64, 65, 68, 70, 72, 76, 78, 80, 84, 90, 95, 96, 102, 112, 120 |
| 100 | 8-60, 64, 65, 67, 68, 70, 72, 74, 76, 80, 84, 90, 95, 96, 102, 112, 120 |
| 120 | 9-45, 46, 48, 50, 52, 54, 55, 57, 60, 64, 65, 67, 68, 70, 72, 76, 80, 84, 90, 96, 102, 112, 120 |
| 140 | 9-28, 30, 31, 32, 33, 34, 35, 36, 37, 39, 40, 42, 43, 45, 48, 54, 60, 64, 65, 68, 70, 72, 76, 80, 84, 96 |
| 160 | 8-30, 32–36, 38, 40, 45, 46, 50, 52, 53, 54, 56, 57, 60, 62, 63, 64, 65, 66, 68, 70, 72, 73, 80, 84, 96 |
| 180 | 13-25, 28, 35, 39, 40, 45, 54, 60 |
| 200 | 9-30, 32, 33, 35, 36, 39, 40, 42, 44, 45, 48, 50, 51, 54, 56, 58, 59, 60, 63, 64, 65, 68, 70, 72 |
| 240 | 9-30, 32, 35, 36, 40, 44, 45, 48, 52, 54, 60 |

*Morse Chain Company, Ithaca, NY, Type B hub sprockets.

 

# 17.5 Roller Chain



## Example: 17.5

Select drive components for a 2:1 reduction, 90-hp input at 300 rev/min, moderate shock, an abnormally long 18-hour day, poor lubrication, cold temperatures, dirty surroundings, short drive $C/p = 25$.