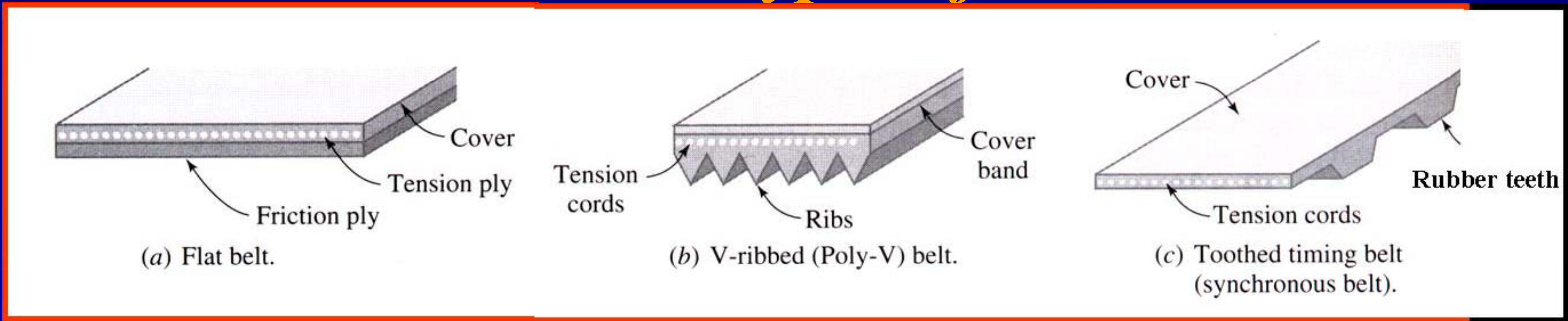
Flexible Mechanical Elements for Motion & Power Transmission

- Belt drives
- Chain and sprocket drives
- Wire ropes
- Flexible shafts

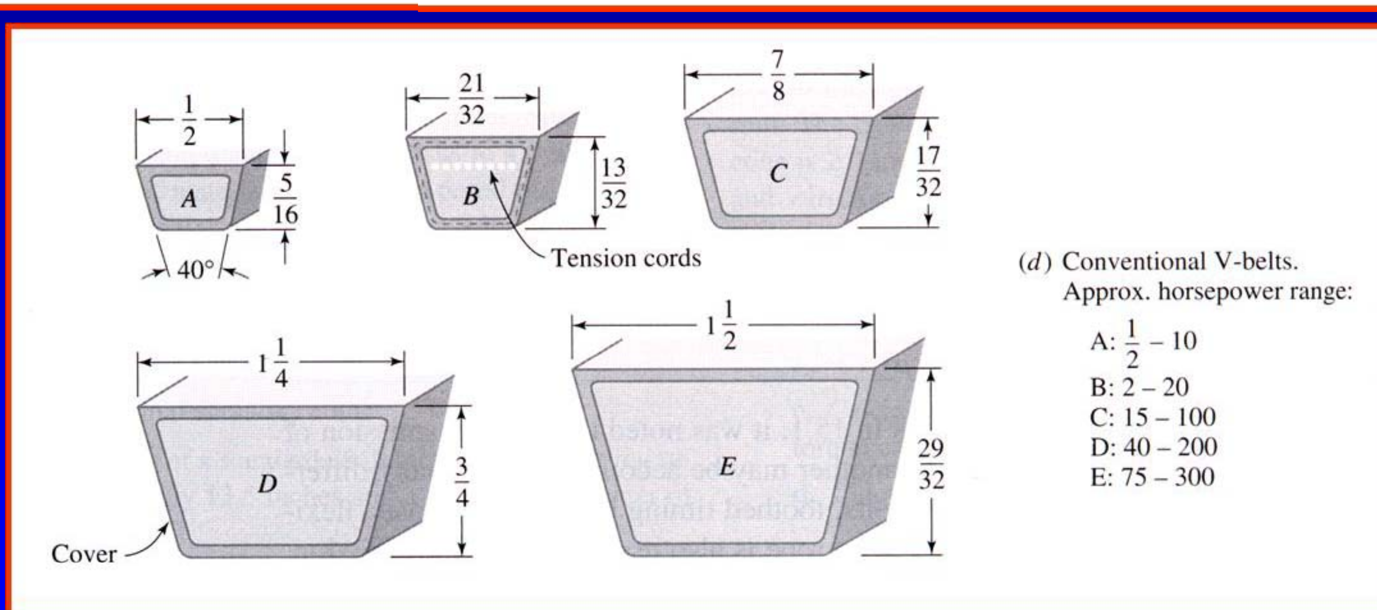
Various Types of Belts



(*a*) Flat belt.

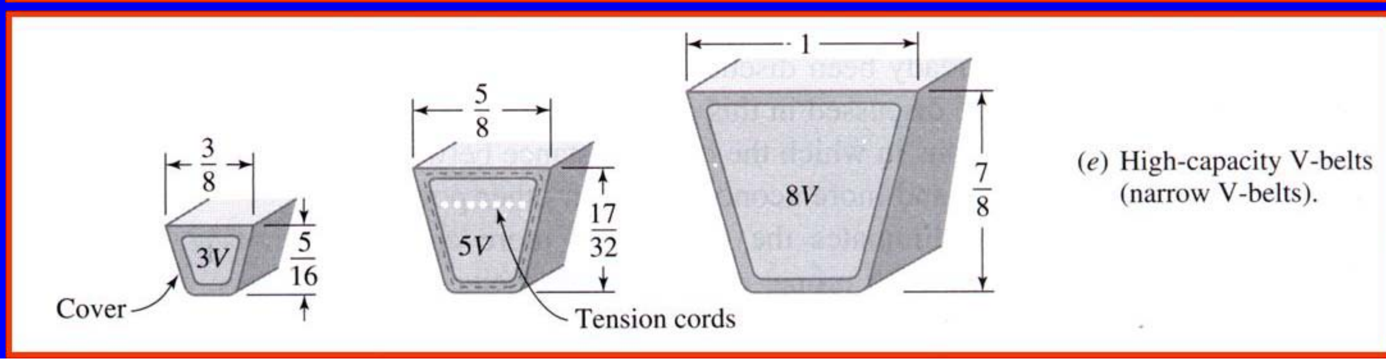
(*b*) V-ribbed (Poly-V) belt.

(*c*) Toothed timing belt (synchronous belt).



(*d*) Conventional V-belts.
Approx. horsepower range:

A: $\frac{1}{2}$ – 10
B: 2 – 20
C: 15 – 100
D: 40 – 200
E: 75 – 300

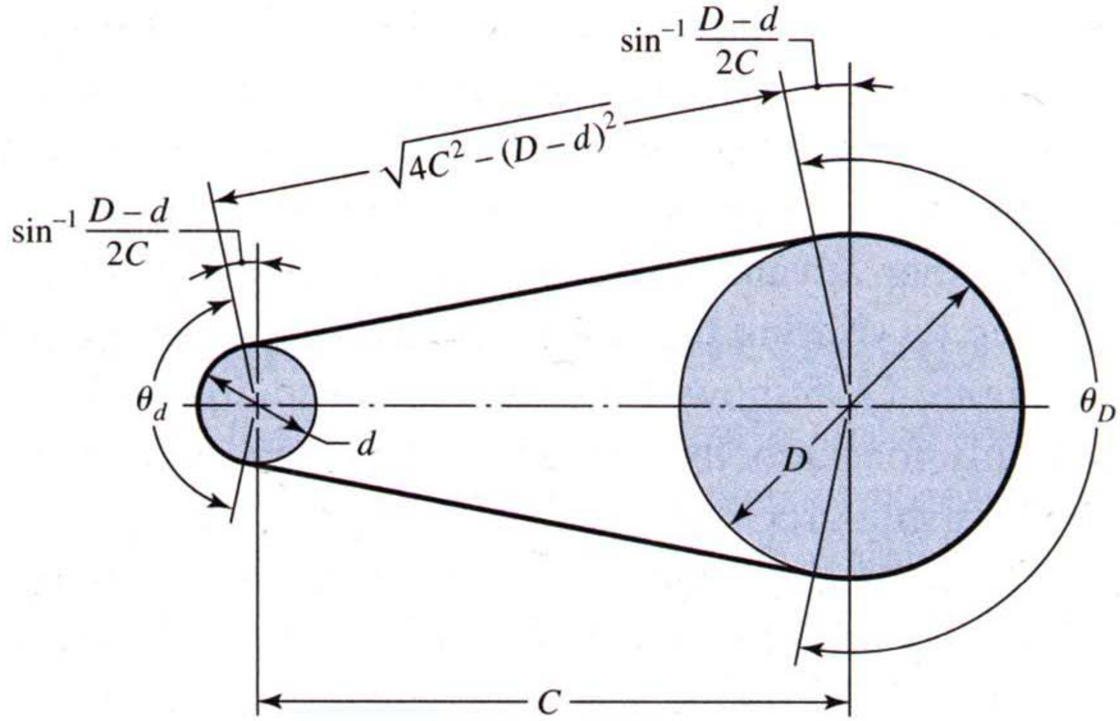


(*e*) High-capacity V-belts (narrow V-belts).

Flat Belts

Flat Belt arrangement

Open loop



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

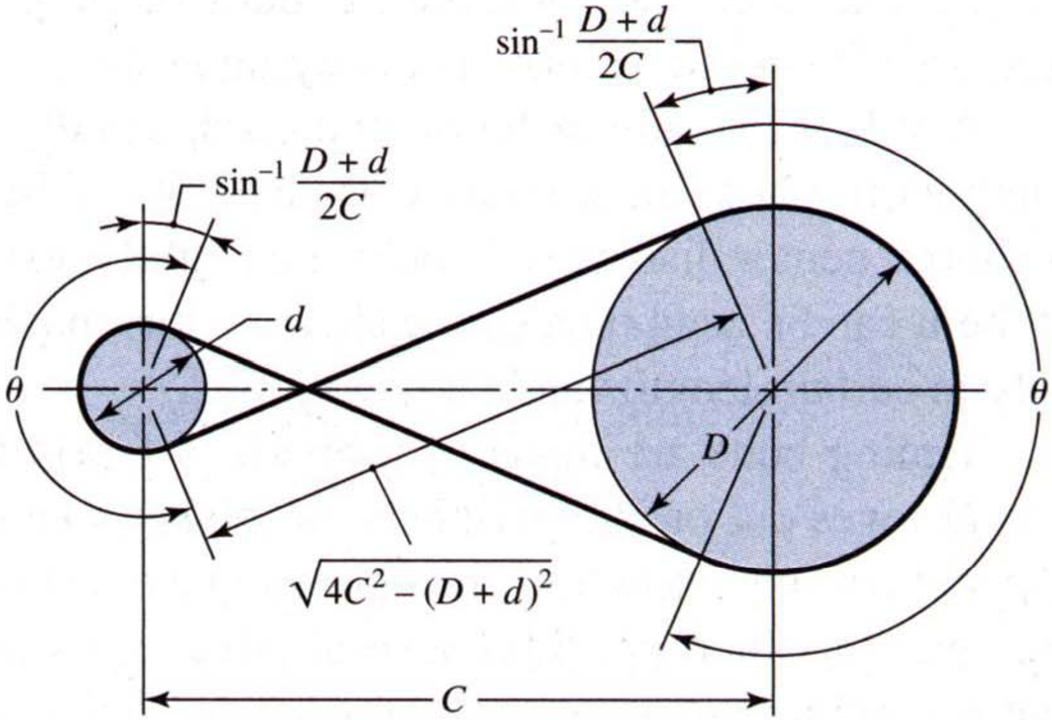
$$\theta_D = \pi + 2\sin^{-1}\frac{D-d}{2C}$$

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

(*a*)

Flat Belts

Closed loop (reversing)



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

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

Flat Belts

$\Sigma F_y = 0$, and for small angle $\sin d\theta/2 = d\theta/2$

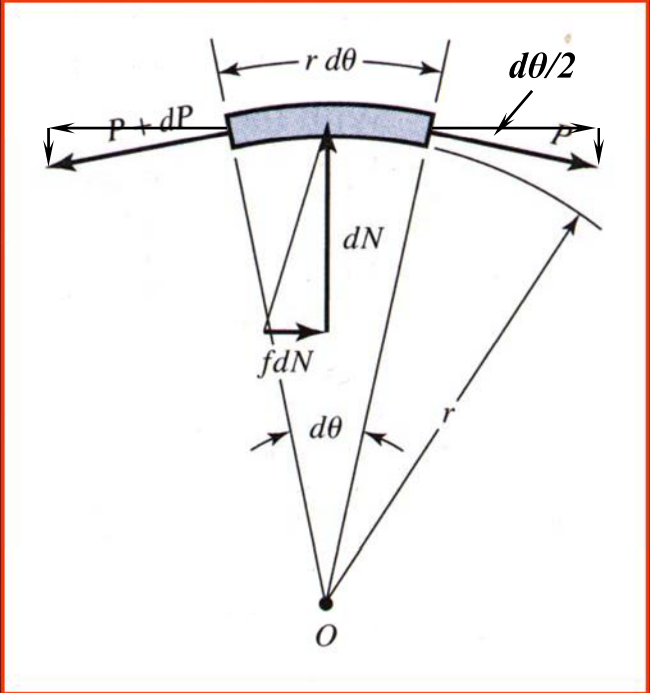
$$(P + dP)\sin\frac{d\theta}{2} + P\sin\frac{d\theta}{2} - dN = 0$$

$$dN = P\,d\theta$$

$\Sigma F_x = 0$, and for small angle $\cos(d\theta/2) \doteq 1$

$$(P + dP)\cos\frac{d\theta}{2} - P\cos\frac{d\theta}{2} - f\,dN = 0$$

$$dP - f\,dN = 0$$



$$\int_{P_2}^{P_1}\frac{dP}{P} = f\int_0^{\phi} d\theta \quad \text{or} \quad \ln\frac{P_1}{P_2} = f\phi \longrightarrow \frac{P_1}{P_2} = e^{f\phi}$$

Low speed application

For relatively high speed application, the centrifugal force acting on the belt creates the tension P_c

$$\frac{P_1 - P_c}{P_2 - P_c} = e^{f\phi}$$

$$P_c = m'V^2 = m'\omega^2 r^2$$

Where *m'* is mass per unit length of belt *V* is the belt linear velocity, ω the angular speed, and *r* the pulley radius.

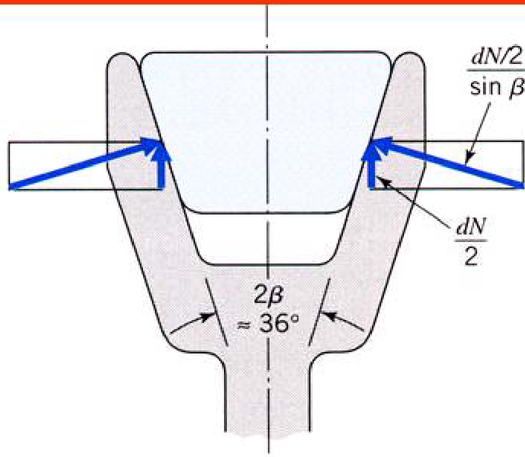
Torque that can be transmitted by a flat belt

$$T = (P_1 - P_2)r$$

Initial belt tension

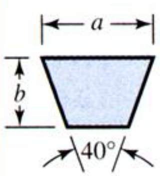
$$P_i = (P_1 + P_2)/2$$

V-Belts



$$\frac{P_1 - P_c}{P_2 - P_c} = e^{f\phi/\sin\beta}$$

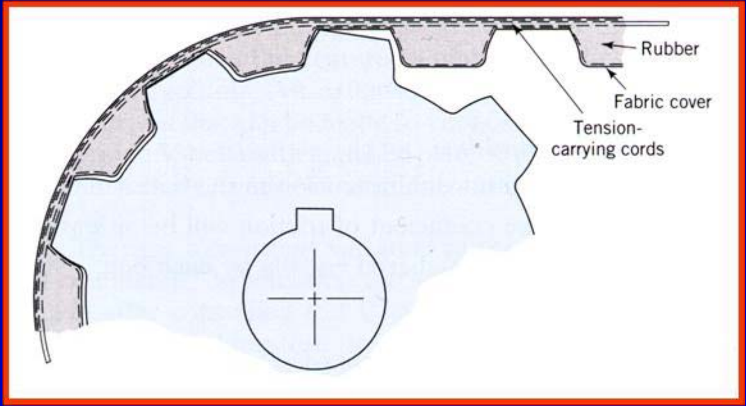
Standard V-Belt Sections



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

Timing (toothed) Belts

- Transmits torque by virtue of positive engagement, provides a constant angular velocity ratio (no slip or creep).



- Can transmit high torque and power.
- Can be operated at high speed, up to 16,000 ft/min.
- Requires minimal initial tension, just enough to prevent tooth skipping when starting or braking.

Refer to manufacturers catalog for belt selection procedures.

Belts

Belt drive is specially suited for applications where the center distance between rotating shafts are large.

Advantages

- Eliminates the need for a more complicated arrangement of gears, bearings, and shafts.
- Runs relatively quiet.
- Reduce the transmission of shock and vibration between shafts.
- Simple to install.
- It has high reliability and warning to failure.
- Requires minimum maintenance.
- Belt drives are adaptable to variety of applications

Belts

Disadvantages

- The torque capacity is limited by the coefficient of friction and interfacial pressure between belt and pulley.
- Because of slip and/or creep, the angular velocity ratio will vary between the rotating shafts and may be inexact.
- Low speed reduction ratio, up to 3:1.
- Belt tension needs to be adjusted periodically.

Belt Material

Table 3 Comparison of Different Belt Body Materials*

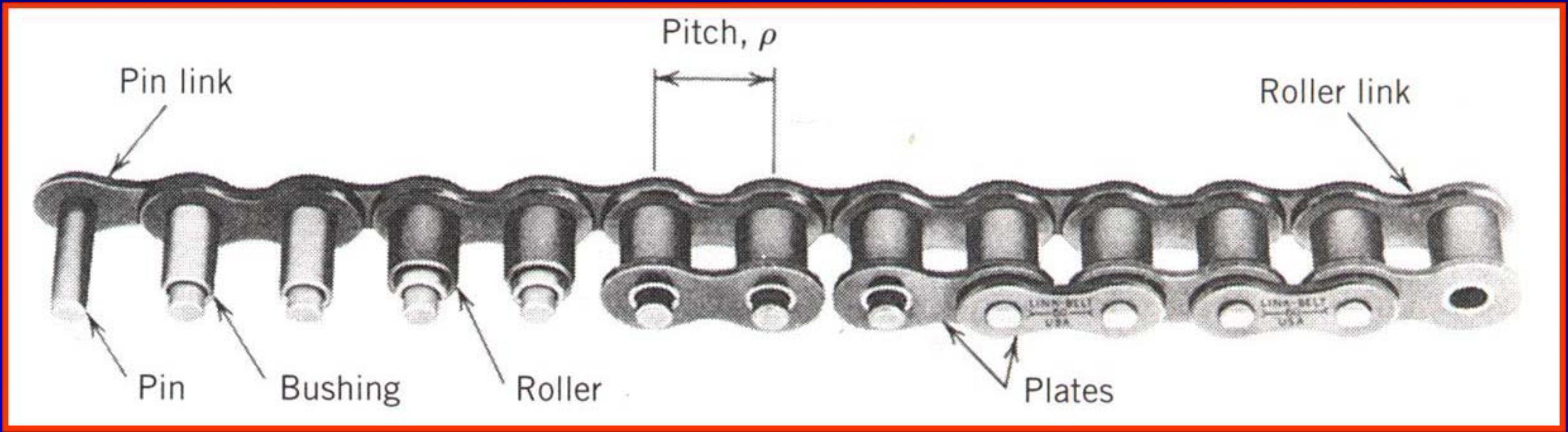
Common Name	Natural Rubber	Neoprene	Urethane, Polyurethane
Chemical Definition	Polyisoprene	Polychloroprene	Polyester/Polyether Urethane
Durometer Range (Shore A)	20 – 100	20 – 95	35 – 100
Tensile Range (p.s.i.)	500 – 3500	500 – 3000	500 – 6000
Elongation (Max. %)	700	600	750
Compression Set	Excellent	Good	Poor
Resilience – Rebound	Excellent	Excellent	Good
Abrasion Resistance	Excellent	Excellent	Excellent
Tear Resistance	Excellent	Good	Excellent
Solvent Resistance	Poor	Fair	Poor
Oil Resistance	Poor	Fair	Good
Low Temperature Usage (°F)	–20° to –60°	+10° to –50°	–10° to –30°
High Temperature Usage (°F)	to 175°	to 185°	to 175°
Aging Weather – Sunlight	Poor	Good	Excellent
Adhesion to Metals	Excellent	Good to Excellent	Fair to Good

Gates 5V-Belt

Rated Horsepower per Belt -- For 5V Predator® Belts

RPM of Faster Shaft	Basic Horsepower per Belt for Small Sheave Outside Diameter															
	7.10	7.50	8.00	8.50	9.00	9.25	9.75	10.30	10.90	11.30	11.80	12.50	13.20	14.00	15.00	16.00
435	6.50	7.46	8.66	9.86	11.1	11.7	12.8	14.2	15.6	16.5	17.7	19.3	21.0	22.9	25.2	27.5
485	7.16	8.23	9.56	10.9	12.2	12.9	14.2	15.7	17.2	18.3	19.6	21.4	23.2	25.3	27.8	30.4
575	8.32	9.58	11.2	12.7	14.3	15.1	16.6	18.3	20.1	21.4	22.9	25.0	27.2	29.6	32.6	35.6
690	9.78	11.3	13.1	15.0	16.8	17.8	19.6	21.6	23.8	25.2	27.1	29.6	32.1	34.9	38.5	42.0
725	10.2	11.8	13.7	15.7	17.6	18.6	20.5	22.6	24.9	26.4	28.3	30.9	33.6	36.5	40.2	43.9
870	12.0	13.8	16.1	18.4	20.7	21.9	24.1	26.6	29.3	31.1	33.3	36.4	39.5	43.0	47.3	51.5
950	12.9	14.9	17.4	19.9	22.4	23.6	26.1	28.8	31.7	33.6	36.0	39.4	42.7	46.4	51.1	55.6
1160	15.3	17.7	20.7	23.7	26.7	28.1	31.1	34.3	37.7	40.0	42.9	46.8	50.7	55.0	60.4	65.7
1425	18.1	21.0	24.6	28.2	31.7	33.5	36.9	40.7	44.8	47.5	50.8	55.4	59.9	64.9	71.1	77.0
1750	21.3	24.7	29.0	33.2	37.4	39.4	43.5	47.9	52.6	55.7	59.5	64.7	69.8	75.3	82.0	
2850	29.1	34.0	40.0	45.7	51.2	53.9										
3450	31.2	36.5														

Roller Chains

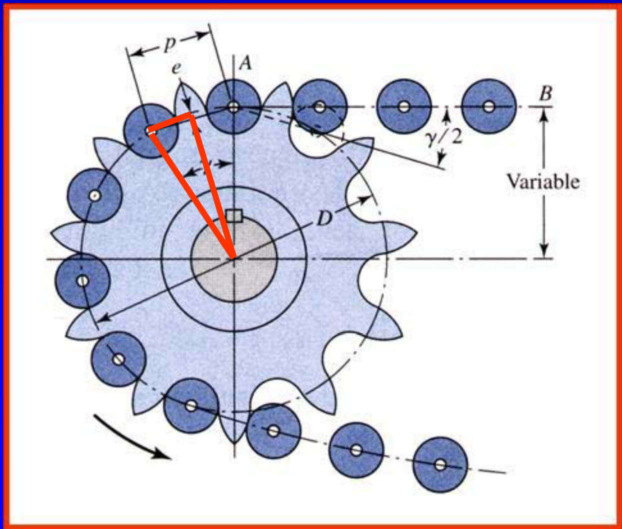


D = pitch diameter of the sprocket

γ = pitch angle

N = number of teeth on the sprocket

p = chain pitch

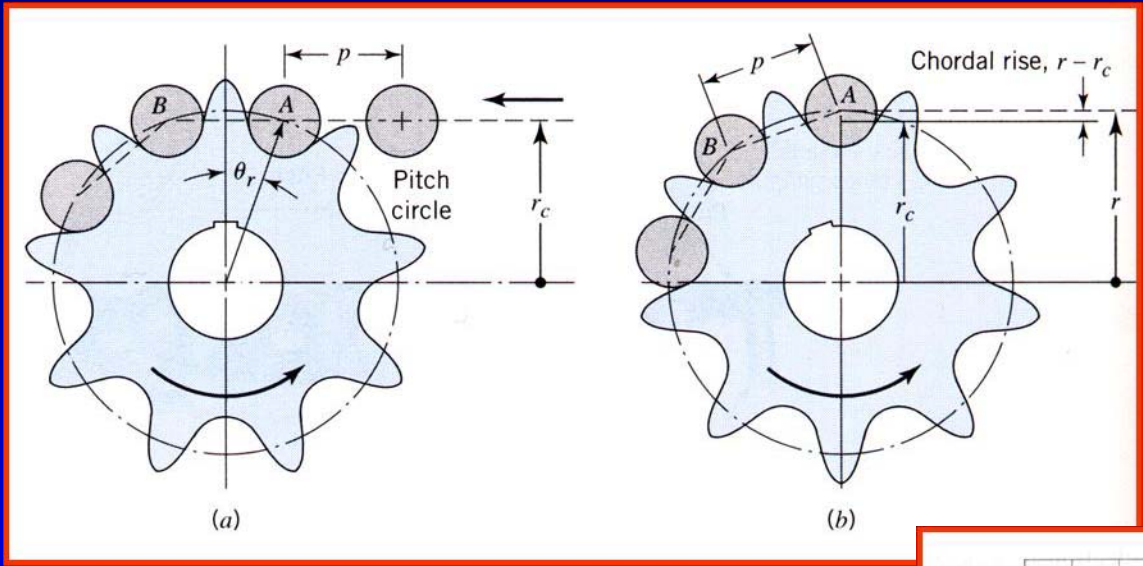


$$\sin\frac{\gamma}{2} = \frac{p/2}{D/2} \qquad \text{or} \qquad D = \frac{p}{\sin(\gamma/2)}$$

$$D = \frac{p}{\sin(180^\circ/N)} \qquad \frac{\gamma}{2} = \text{articulation angle}$$

Roller Chains

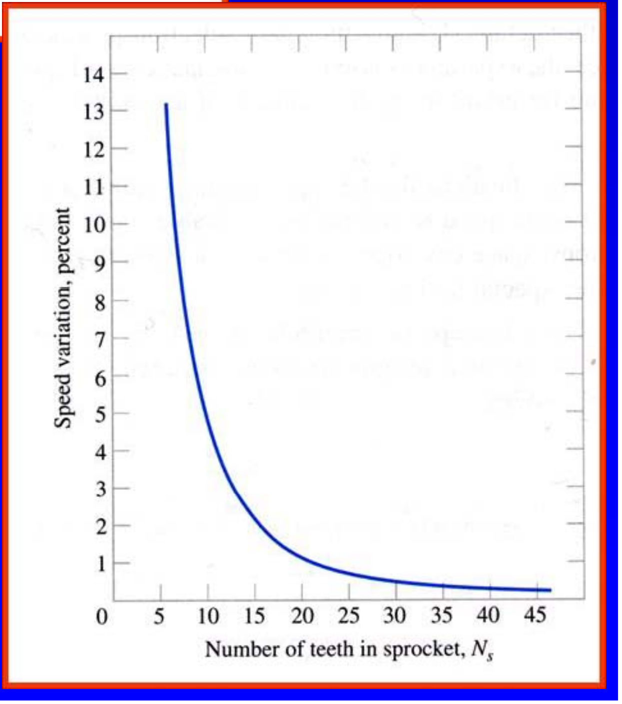
Chordal Action



$$\Delta r = r_c - r = r(1 - \cos\theta) = r[1 - \cos(180°/N_t)]$$

$$(\Delta V/V)100 = (\Delta r/r)100 = \%\text{ speed variation}$$

For *N*=20, speed variation is 1.23%



ANSI Standards for Roller Chains

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)

Rated Horsepower Capacity of Single-Strand Single-Pitch Rolle 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.

[redacted]

Rated Horsepower Capacity of Single-Strand Single-Pitch Roller Chain for a 17-Tooth Sprocket *(Continued)*

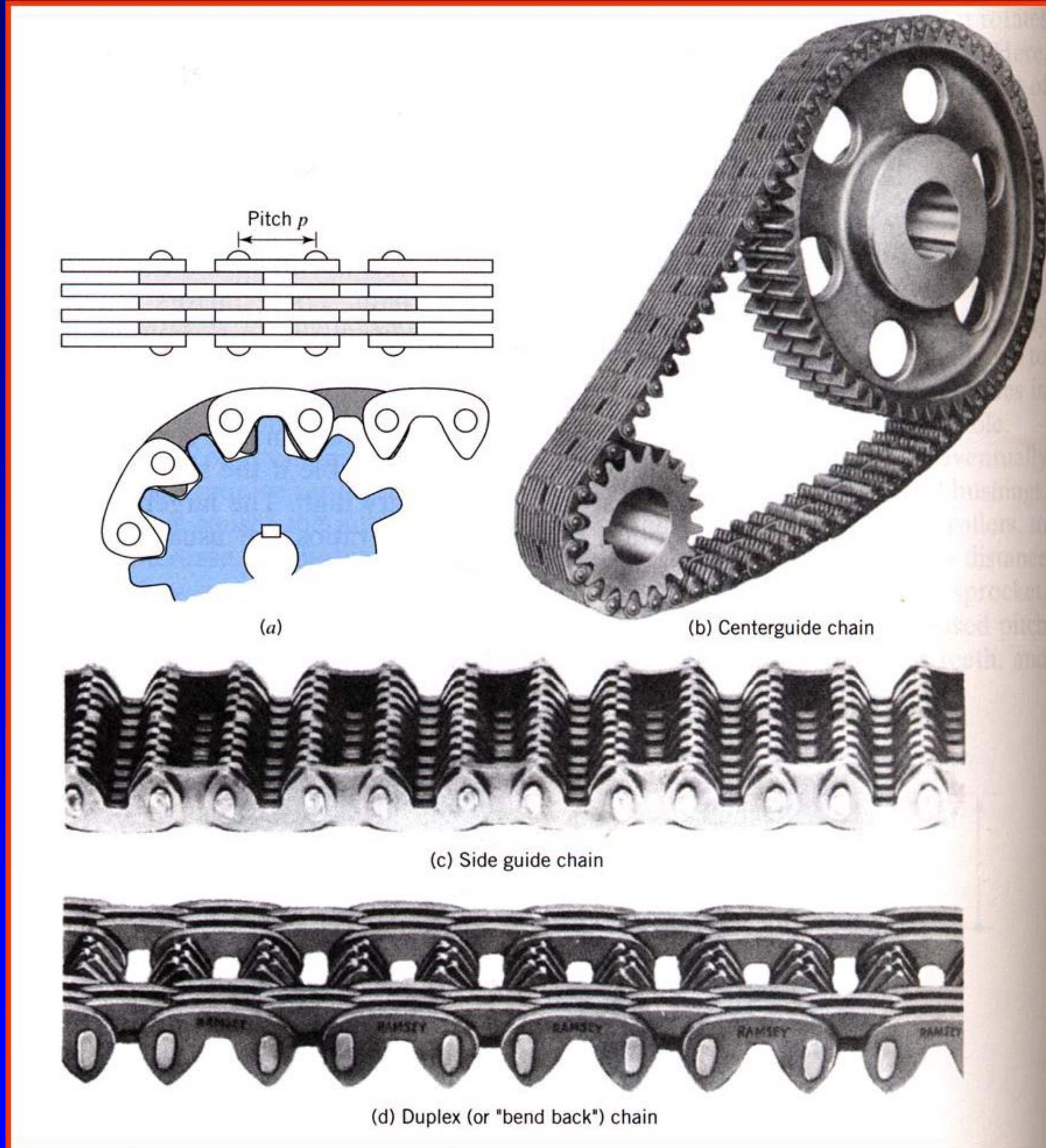
[redacted]

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		22.9	43.9	74.1	115	166	204	222	0
600	Type B	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; type C′—type C, but this is a galling region; submit design to manufacturer for evaluation.

Inverted-Tooth Chains (Silent Chains)



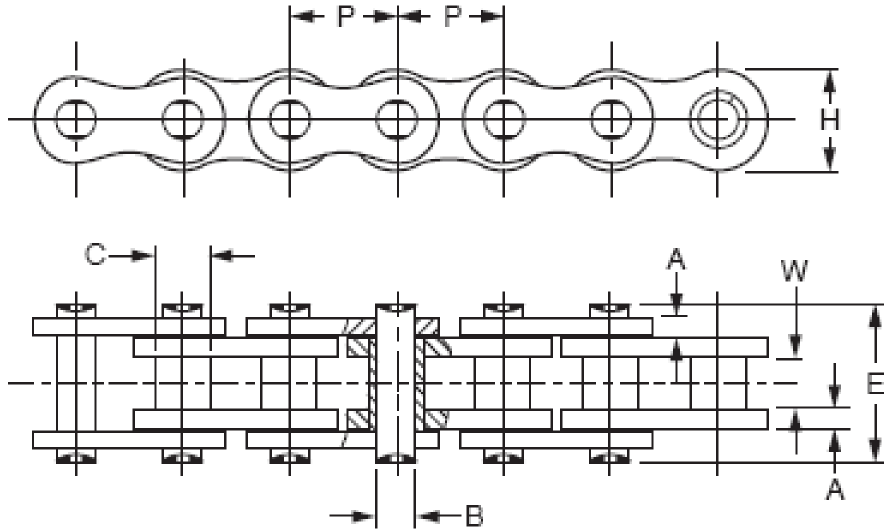
Inch Inch Inch Inch Inch Inch

SDP/SI

Roller Chain & Links - .250 Pitch

Stock Drive Products/Sterling Instrument ■ Phone: 516-328-3300 ■

■ STAINLESS STEEL ■ STEEL ■ SINGLE STRAND ■ RIVETED



Product Details

Part Number	A 6Q 7-25
Unit	Inch
Pitch	0.2500"
Material	Hardened Steel
Available Length	Priced / Foot"
Assembly Method	Connecting Link
Approx. Links / Foot	48
No. Of Strand	1
Avg. Tensile Load	925 lbs
Weight / Foot	0.090 lbs

• **ROLLER CHAIN** Priced Per Foot

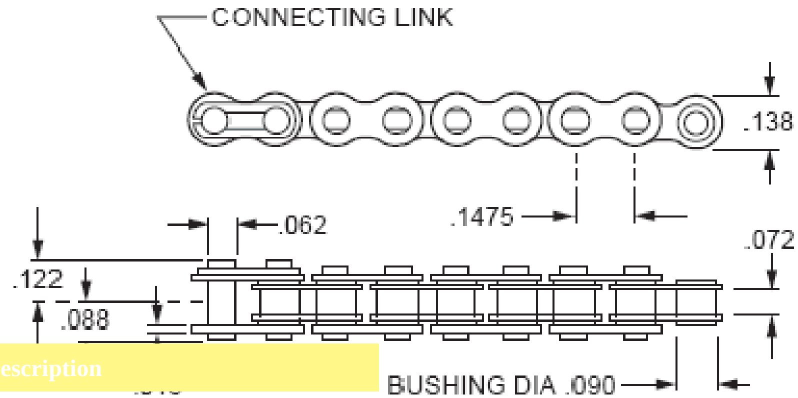
STANDARD-DUTY TYPE

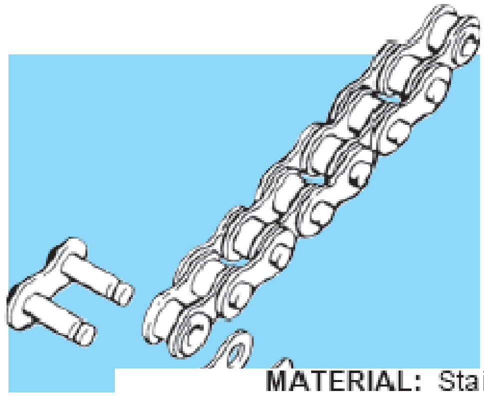
Catalog Number	Material	P Pitch	W	H Width	A Thick-ness	B Pin Dia.	L Pin Length	C Roller Dia.	D +.002 -.000	E	F	Tensile Load lb.	Weight Per Foot lb./ft.
A 6Q 7-25	Hardened Steel	.25	.125	.232	.03	.09	.34	.13	.19	.31	.33	787	.1
A 6Y 7-25	Stainless Steel											562	

HEAVY-DUTY TYPE

Catalog Number	Material	P Pitch	W	H Width	A Thick-ness	B Pin Dia.	L Pin Length	C Roller Dia.	D +.002 -.000	E	F	Tensile Load lb.	Weight Per Foot lb./ft.
A 6Q 7-H25	Hardened Steel	.25	.125	.232	.039	.09	.43	.13	.21	.35	.38	1169	.107
A 6Y 7-H25	Stainless Steel											562	

■ STEEL ■ SINGLE STRAND ■ RIVETED





Description

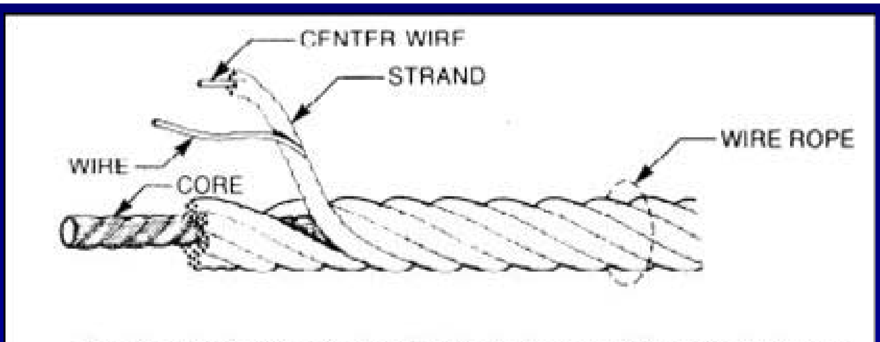
0.250" Pitch hardened steel roller chain

MATERIAL: Stainless Steel Type 18-8
FINISH: Clear Passivated
AVERAGE TENSILE LOAD: 180 lbs.
WEIGHT: .035 lbs. per foot

Catalog Number	No. of Links	Length
A 6Y 7-M040	40	5.900
A 6Y 7-M050	50	7.375
A 6Y 7-M060	60	8.850
A 6Y 7-M070	70	10.325
A 6Y 7-M080	80	11.800
A 6Y 7-M090	90	13.275
A 6Y 7-M100	100	14.750
A 6Y 7-M110	110	16.225
A 6Y 7-M120	120	17.700
A 6Y 7-M130	130	19.175
A 6Y 7-M140	140	20.650
A 6Y 7-M150	150	22.125
A 6Y 7-M160	160	23.600
A 6Y 7-M170	170	25.075
A 6Y 7-M180	180	26.550
A 6Y 7-M190	190	28.025
A 6Y 7-M200	200	29.500
A 6Y 7-M210	210	30.975
A 6Y 7-M220	220	32.450
A 6Y 7-M230	230	33.925
A 6Y 7-M240	240	35.400

SDP/SI Inch Inch Inc
Stock Drive Products/Sterling Instrument

Wire Ropes

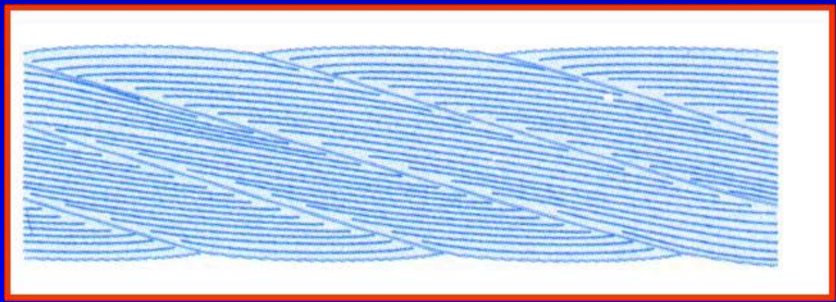


The three basic components of a typical wire rope. (Fiber core is shown.)

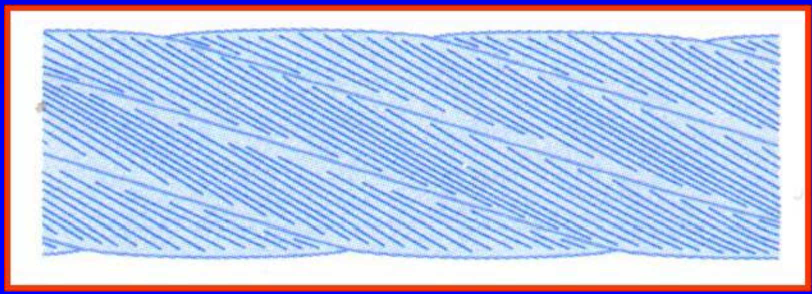
Wire ropes are used for hoisting, haulage, and conveyor applications.

Several small wires (6, 19, 37, 42) are twisted to form a strand, then several strands (3, 6, 8) are twisted about a core to form a wire rope

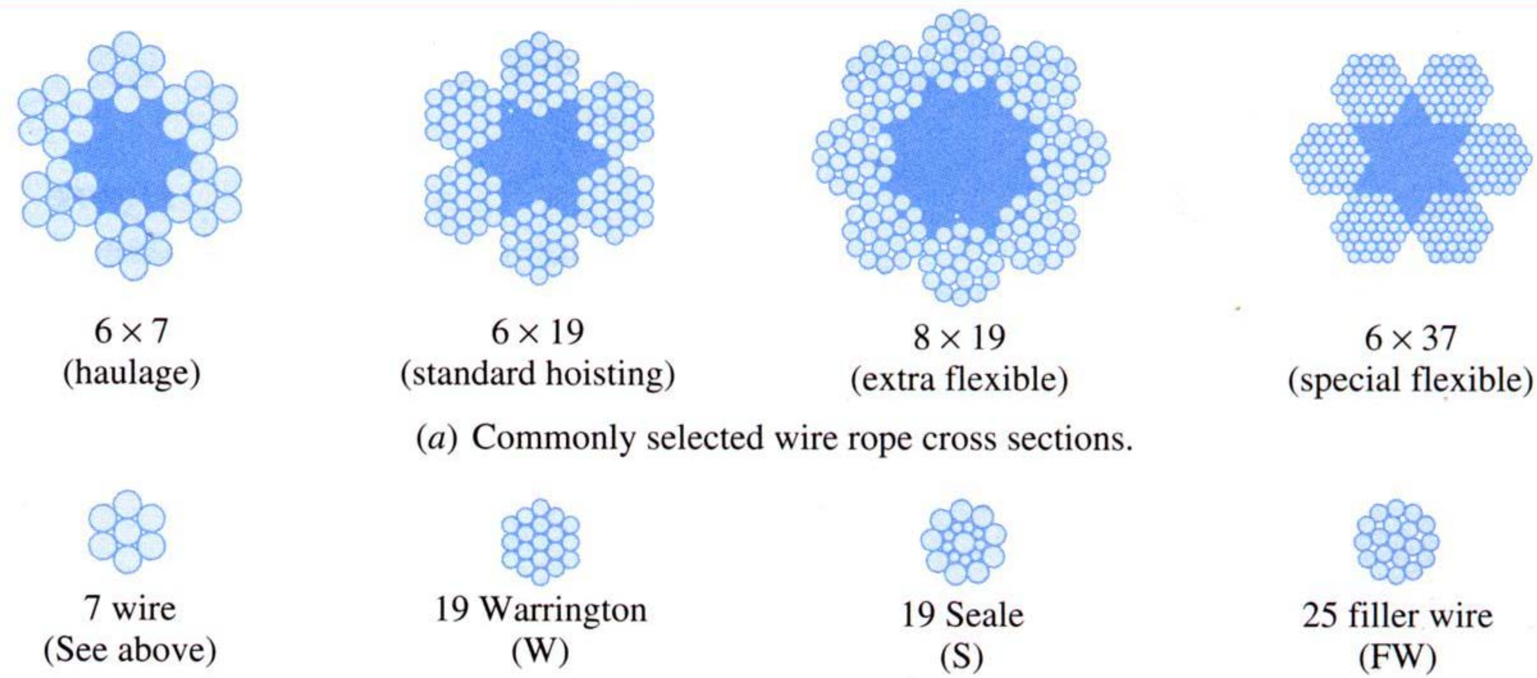
Regular Lay – wires in strands twisted in opposite direction to strands twisted to form the rope. Used for stationary applications.



Lang lay – wires in strands twisted in **same** direction as strands twisted to form rope. More likely to untwist but better wear and fatigue properties. Used for moving applications



Wire Ropes



(*a*) Commonly selected wire rope cross sections.

(*b*) Some of the available multiwire strand patterns. Combinations of these are also available.

Wire Rope Core

Fiber core

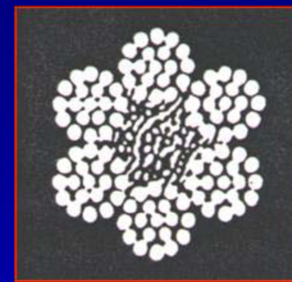
Fiber cores are generally made of cotton twine for cables less than ¼ inch and hard fiber ropes (manila or sisal) for the larger sizes.

Fiber cores extend the life by cushioning the strands and reducing internal abrasion, good for light crushing loads. Hard cores are impregnated with lubricant to deter rust and lubricate.

Wire core

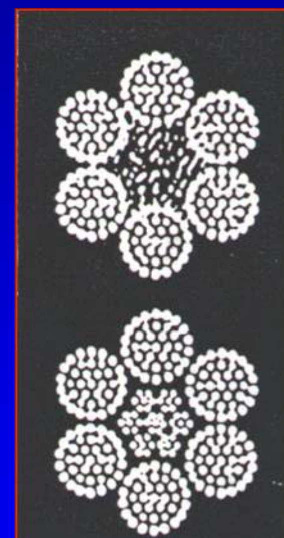
Wire cores offer less stretch, have better resistance to heavy crushing loads and are not effected by heat.

Standard Wire Ropes



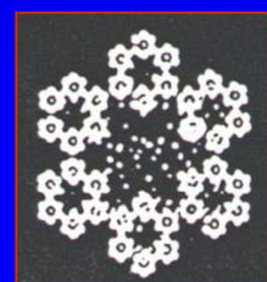
<u>6 x 19 fiber core</u>

The standard hoisting cable. Excellent strength, flexibility, and resistance to abrasion and fatigue.



<u>6 x 37 fiber or wire core</u>

More flexible than 6 x 19, good for applications where pulleys are limited in size.



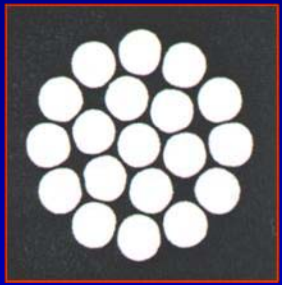
<u>6 x 42 fiber centers and core</u>

The most flexible of all standard cables, used for moderate loads.

Standard Wire Ropes

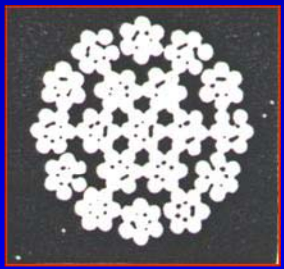
1 x 19 wire core

Primarily used for stationary (non-flexible) applications.



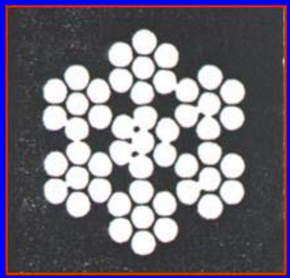
19 x 7 wire core

Designed to resist the natural tendency of a cable to rotate when freely suspended under load.



7 x 7 wire core

The standard flexible aircraft cable. High strength and rugged construction, used for towing and power transmission.



Wire Rope Stresses

- Direct tensile stress in the wires of the rope.
- Bending stress in the wires caused by the rope passing around sheaves or drums.
- Compressive stress (bearing pressure) between the rope and the sheave or drum.

Direct tensile stress

$$\sigma_t = \frac{T}{A_r}$$

T = resultant tensile force, includes load to be lifted, weight of the rope and inertial effects due to accelerating the load.

A_r = approximate cross-sectional area of the rope, a function of rope diameter, d_r.

Wire Rope Stresses – bending stress

Bending stress

Stress in one of the wires passing around a sheave

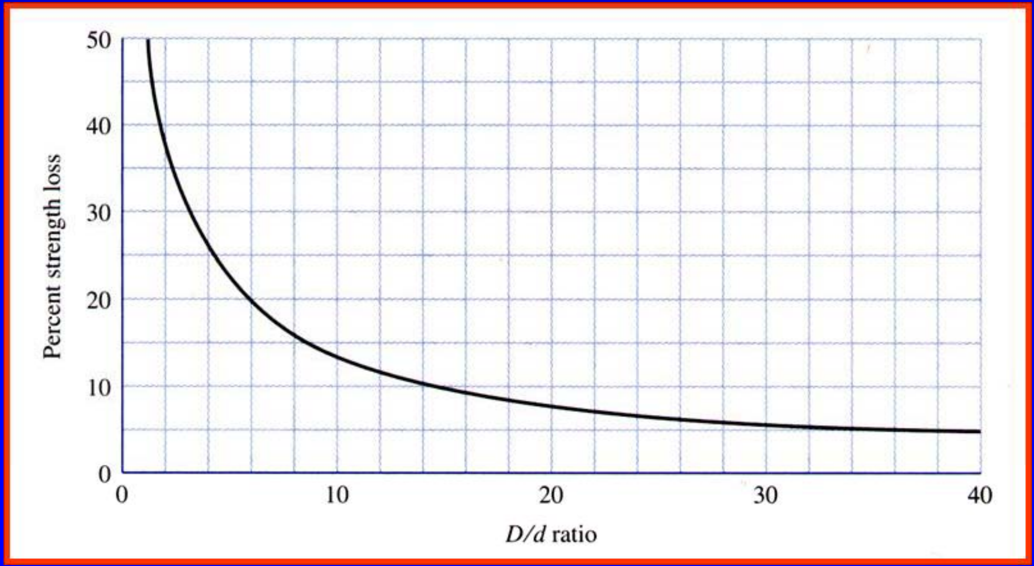
$$M = \frac{EI}{\rho} \quad \text{and} \quad M = \frac{\sigma I}{c} \Rightarrow \sigma = \frac{Ec}{\rho} \Rightarrow \sigma = E_r \frac{d_w}{D}$$

Wire diameter

Sheave diameter

Modulus of the rope

Percent strength loss due to different *D/d* ratios; derived from standard test data for 6 × 19 and 6 × 17 class ropes. *(Materials provided by the Wire Rope Technical Board (WRTB), Wire Rope Users Manual Third Edition, Second printing. Reprinted by permission.)*

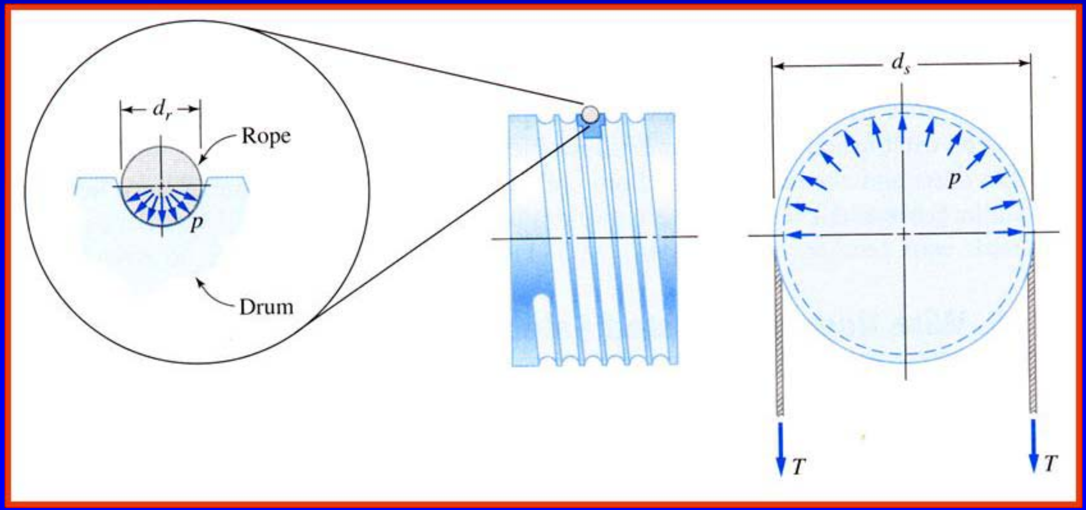


Wire Rope Stresses – bearing pressure

Compressive stress (bearing pressure)

$$pA_{proj} = p(d_r d_s) = 2T$$

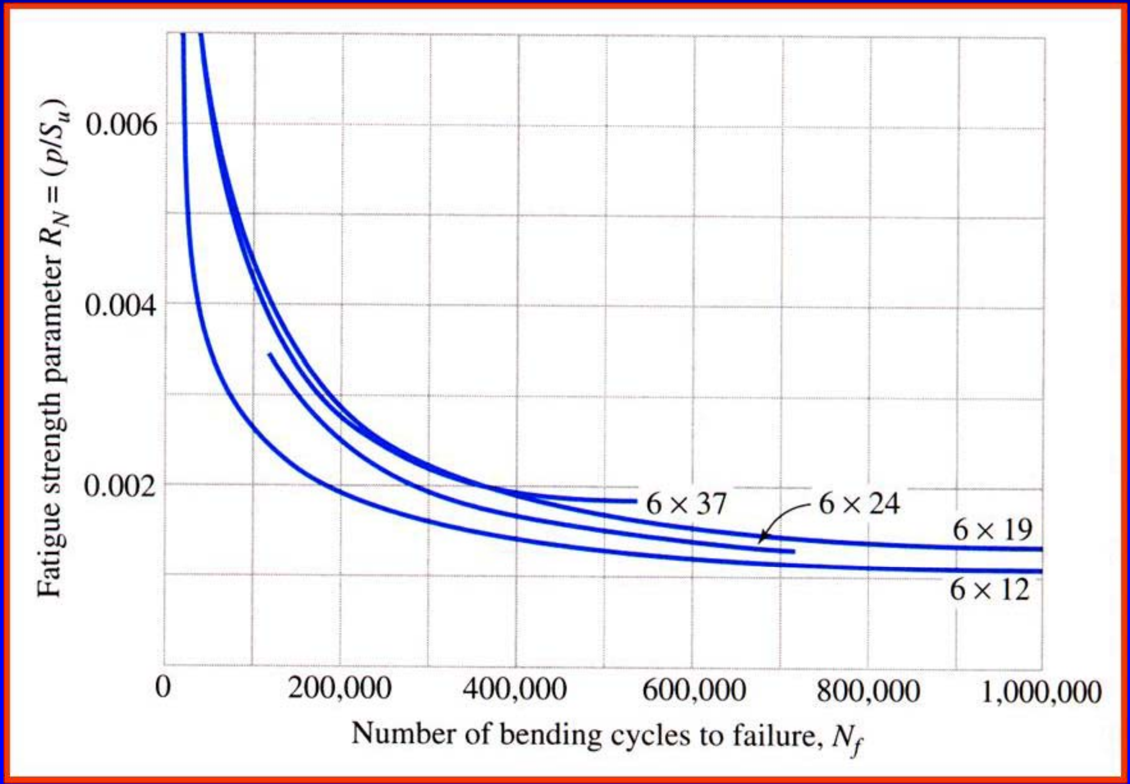
$$p = \frac{2T}{d_r d_s}$$



Wire Rope Stresses

Fatigue strength parameter

$$R_N = \frac{p}{\sigma_u}$$



Allowable Bearing Pressure

Experience-based Wear-Related Allowable Maximum Bearing Pressure Between Rope and Drums or Sheaves of Various Materials[1] (psi)

Drum or Sheave Material	Regular Lay Rope				Lang Lay Rope				Comments
	6 × 7	6 × 19	6 × 37	8 × 19	6 × 7	6 × 19	6 × 37	8 × 19	
Wood	150	250	300	350	165	275	330	400	Against end grain of beech, hickory, or gum.
Cast iron	300	480	585	680	350	550	660	800	Minimum hardness of BHN 125.
Cast carbon steel	550	900	1075	1260	600	1000	1180	1450	30–40 points of carbon; minimum hardness of BHN 160.
Manganese steel, induction or flame hardened	1470	2400	3000	3500	1650	2750	3300	4000	

[1]Abridged from ref. 4, with permission from Wire Rope Technical Board.

TABLE 17.9 Material and Construction Data for Selected Wire Rope Classes

Nominal classification		6 × 7	6 × 19	6 × 37	8 × 19
Number of outer strands		6	6	6	8
Number of wires per strand[1]		3–14	15–26	27–49	15–26
Maximum number of outer wires[1]		9	12	18	12
Approx. diameter of outer wires[1], d_w, in		$d_r/9$	$d_r/13$–$d_r/16$	$d_r/22$	$d_r/15$–$d_r/19$
Materials typically available[2,3] (approx. ultimate strength, ksi)	Core: (FC)	IPS (200)	I (80) T (130) IPS (200)	IPS (200)	I (80) T (130) IPS (200)
	Core: (IWRC)	IPS (190)	IPS (190) EIPS (220) EEIPS (255)	EIPS (220) EEIPS (255)	IPS (190) EIPS (220)
Approx. metallic cross section of rope, A_r, in^2	Core: (FC)	$0.384\ d_r^2$	$0.404\ d_r^2$ (S)[4]	$0.427\ d_r^2$ (FW)[4]	$0.366\ d_r^2$ (W)[4]
	Core: (IWRC)	$0.451\ d_r^2$	$0.470\ d_r^2$ (S)[4]	$0.493\ d_r^2$ (FW)[4]	$0.497\ d_r^2$ (W)[4]
Standard nominal rope diameters available, d_r, in		$^1/_4$–$^5/_8$ by $^1/_{16}$ th's; $^3/_4$–$1^1/_2$ by $^1/_8$ th's	$^1/_4$–$^5/_8$ by $^1/_{16}$ th's; $^3/_4$–$2^3/_4$ by $^1/_8$ th's	$^1/_4$–$^5/_8$ by $^1/_{16}$ th's; $^3/_4$–$3^1/_4$ by $^1/_8$ th's	$^1/_4$–$^5/_8$ by $^1/_{16}$ th' $^3/_4$–$1^1/_2$ by $^1/_8$ th
Unit weight of rope, lb/ft		$1.50\ d_r^2$	$1.60\ d_r^2$	$1.55\ d_r^2$	$1.45\ d_r^2$
Approx. modulus of elasticity for the rope[3,5], E_r, psi	0–20% of S_u	11.7×10^6 (FC)	10.8×10^6 (FC); 13.5×10^6 (IWRC)	9.9×10^6 (FC); 12.6×10^6 (IWRC)	8.1×10^6 (FC)
	21–65% of S_u	13.0×10^6 (FC)	12.0×10^6 (FC) 15.0×10^6 (IWRC)	11.6×10^6 (FC) 14.0×10^6 (IWRC)	9.0×10^6
Recommended min. sheave or drum diameter, $(d_s)_{min}$, in		$42\ d_r$	$34\ d_r$	$18\ d_r$	$26\ d_r$

[1]While the interior wires of a strand are of *some* significance, a strand's important characteristics relate to the number and size of the *outer* wires.

[2]Typical materials are designated as I (iron), T (traction steel), IPS (improved plow steel), EIPS (extra, improved plow steel), and EEIPS (extra, extra improved plow steel). In wire ropes, the *rope* ultimate strength is a function of rope size, wire size, and construction details, as well as material properties.

[3]Typical core constructions are *fiber core* (FC) and *independent wire rope core* (IWRC).

[4]See Figure 17.5(b) for construction details of *Seale* (S), *Filler Wire* (FW), and *Warrington* (W) strand configurations.

[5]Carefully note that the *rope* modulus E_r is not the same as Young's modulus of elasticity for the material.

Wire Rope Safety Factor

Minimum Factors of Safety for Wire Rope*

Source: Compiled from a variety of sources, including ANSI A17.1-1978.

Track cables	3.2
Guys	3.5
Mine shafts, ft:	
Up to 500	8.0
1000–2000	7.0
2000–3000	6.0
Over 3000	5.0
Hoisting	5.0
Haulage	6.0
Cranes and derricks	6.0
Electric hoists	7.0
Hand elevators	5.0
Private elevators	7.5
Hand dumbwaiter	4.5
Grain elevators	7.5
Passenger elevators, ft/min:	
50	7.60
300	9.20
800	11.25
1200	11.80
1500	11.90
Freight elevators, ft/min:	
50	6.65
300	8.20
800	10.00
1200	10.50
1500	10.55
Powered dumbwaiters, ft/min:	
50	4.8
300	6.6
500	8.0

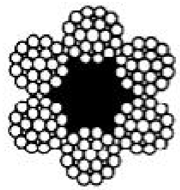
*Use of these factors does not preclude a fatigue failure.

BRIGHT WIRE ROPE

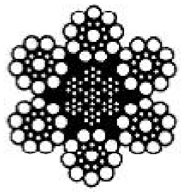
Read important warnings and information included in the beginning of this catalog section

Ratings are stated in short tons (2,000 lbs.) or pounds. All dimensions are in inches and pounds unless otherwise indicated

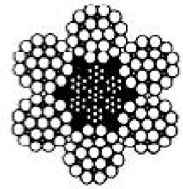
6 X 19 CLASS



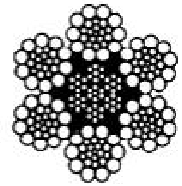
6 X 25 FILLER WIRE WITH FIBER CORE



6 X 19 SEALE WITH IWRC



6 X 25 FILLER WIRE WITH IWRC



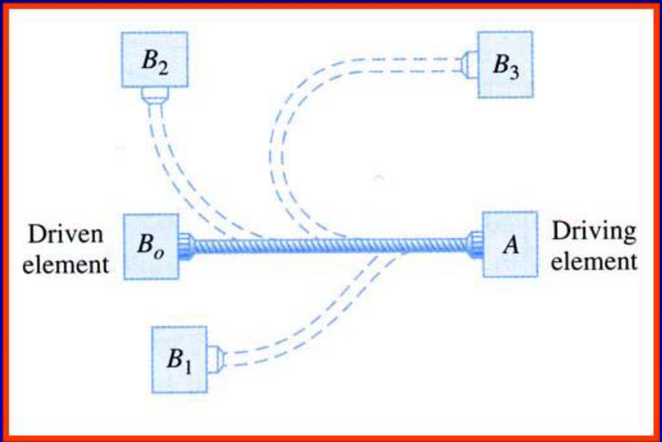
6 X 26 WARRINGTON SEALE WITH IWRC

Diameter in Inches	Fiber Core (EIPS)	
	Approx. Weight per foot in Pounds	Breaking Strength in Tons *
1/4	.105	3.01
5/16	.164	4.69
3/8	.236	6.71
7/16	.320	9.10
1/2	.420	11.80
9/16	.530	14.90
5/8	.660	18.40
3/4	.950	26.20
7/8	1.290	35.40
1	1.680	46.00
1-1/8	2.130	57.90
1-1/4	2.630	71.10
1-3/8	3.180	85.50
1-1/2	3.780	101.20

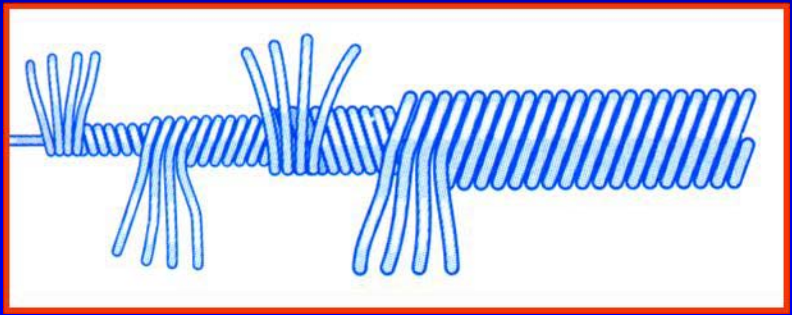
Diameter in Inches	IWRC (EIPS) **	
	Approx. Weight per foot in Pounds	Breaking Strength in Tons *
1/4	.116	3.40
5/16	.180	5.27
3/8	.260	7.55
7/16	.350	10.20
1/2	.460	13.30
9/16	.590	16.80
5/8	.720	20.60
3/4	1.040	29.40
7/8	1.420	39.80
1	1.850	51.70
1-1/8	2.340	65.00
1-1/4	2.890	79.90
1-3/8	3.500	96.00
1-1/2	4.160	114.00
1-5/8	4.880	132.00
1-3/4	5.670	153.00
2	7.390	198.00
2-1/4	9.360	247.00
2-1/2	11.600	302.00
2-3/4	14.000	361.00
3	16.600	425.00
3-1/4	19.500	492.00
3-1/2	22.700	564.00
3-3/4	26.000	641.00

Flexible Shafts

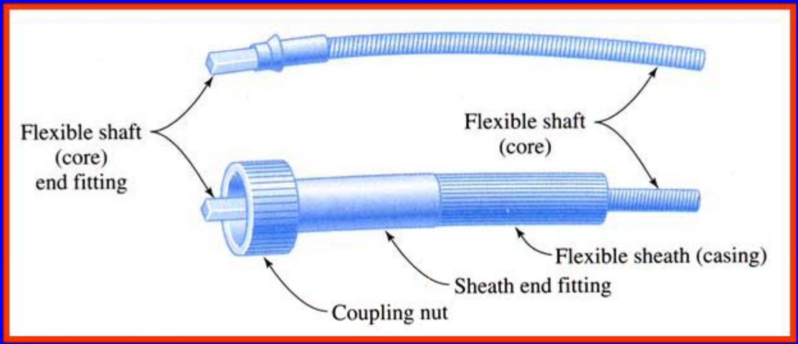
Flexible shafts are used to transmit motion or power along a curved path between two shafts that are not collinear.



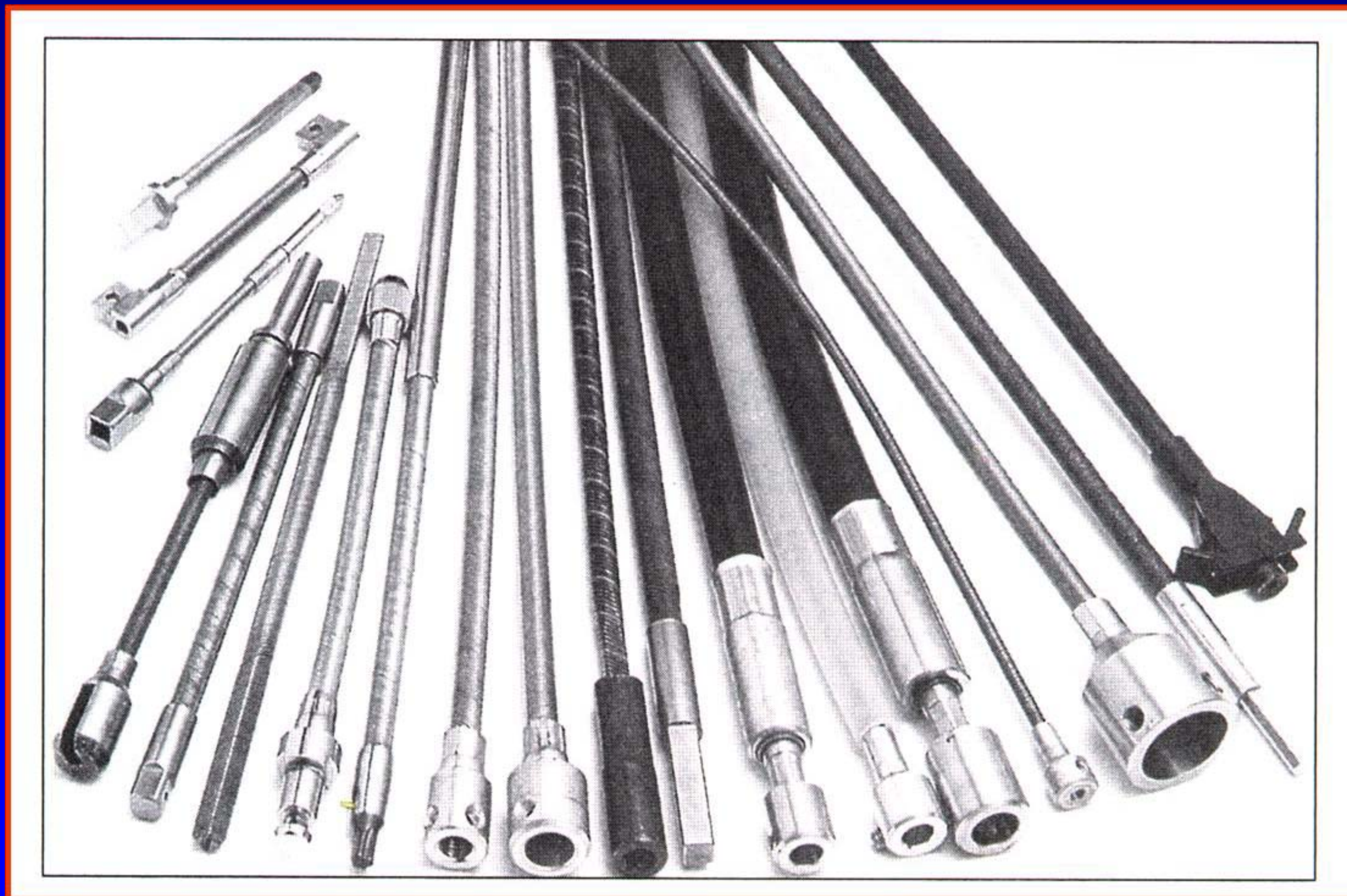
Flexible shafts are built up solid by tightly winding one layer of wire over another about a single "mandrel wire" in the center.



The shafts are encased in a metal or rubber covered flexible sheath, it protects the shaft from damage and retains the lubricant.



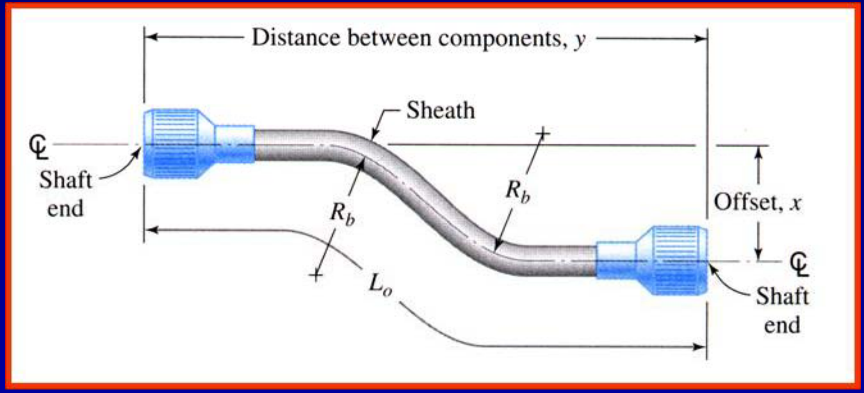
Flexible Shafts



Allowable Torque

Bend radius

$$R_b = \frac{x^2 + y^2}{4x}$$



Recommended Maximum Operating Torque[1] for Selected[2] Standard Flexible Shafts of High-Carbon Steel as a Function of Bend Radius R_b, for *Unidirectional* Operation

Shaft (Core) Diam., in	Max.-Allow. Speed, rpm	Min.-Allow. Bend Radius, in	Torsional Deflection, deg/ft/in-lb	Ultimate Torsional Failure[3] Moment, in-lb	Recommended Maximum Torque $(T_{max})_{allow}$ Corresponding to Various Bend Radii,[4] in-lb							
					3	4	6	8	10	12	15	20
0.127	30,000	2.7	21.48	12	0.2	0.7	1.2	1.5	1.6	1.7	1.8	1.9
0.147	20,000	3.2	10.11	30		1.2	2.6	3.3	3.8	4.1	4.4	4.7
0.183	15,000	3.2	7.39	32		1.2	2.8	3.5	4.0	4.3	4.6	4.9
0.245	10,000	3.2	0.97	195			12.8	16.0	18.0	20.0	21.0	23.0
0.304	7,500	3.6	0.44	338			19.0	26.0	30.0	33.0	35.0	38.0
0.370	5,500	6.3	0.17	690				20.0	35.0	45.0	55.0	65.0
0.495	4,500	5.9	0.06	1230				45.0	70.0	86.0	103.0	120.0
0.620	4,000	6.7	0.019	2420				53.0	109.0	147.0	184.0	221.0
0.740	3,000	6.7	0.009	4370				96.0	198.0	265.0	332.0	400.0
0.990	2,500	8.4	0.003	9344					206.0	386.0	567.0	747.0

[1]From ref. 5, courtesy: S. S. White Technologies, Inc. A safety factor of approximately 4 has been embedded in these recommended allowable torque values. The methods of Chapter 5 may be utilized to adjust these allowable torque values if necessary. These values assume that the applied torque acts in the direction that tends to tighten the helical outer layer of wire.

[2]Many other shafts and variations are commercially available. See ref. 5, for example.

[3]Torque at which a flexible shaft will deform permanently or break.

[4]Listed bend radii are in inches.