Roller Chain

Basic features of chain drives include *a constant ratio*, since no slippage or creep is involved; *long life*; and the ability to drive a number of shafts from a single source of power.

The pitch is the linear distance between the centers of the rollers. The width is the space between the inner link plates. These chains are manufactured in single, double, triple, and quadruple strands. The dimensions of standard sizes are listed in Table 17–19.

Figure 17–16

Portion of a double-strand roller chain.

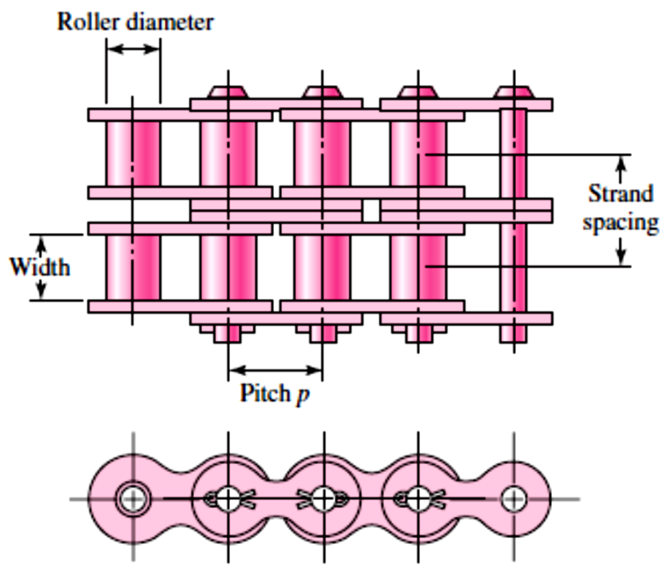


Figure 17–17 shows a sprocket driving a chain and rotating in a counterclockwise direction. Denoting the chain pitch by *p*, the pitch angle by γ, and the pitch diameter of the sprocket by *D*, from the trigonometry of the figure we see

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

Since γ = 360o/*N*, where *N* is the number of sprocket teeth, Eq. (*a*) can be written

$$D = \frac{p}{\sin(180^\circ/N)} \tag{17–29}$$

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)

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

$$V = \frac{Npn}{12} \qquad (17\text{–}30)$$

Where,

N = number of sprocket teeth

p = chain pitch, in

n = sprocket speed, rev/min

The ***maximum exit velocity*** of the chain is

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

where Eq. (*a*) has been substituted for the pitch diameter *D*. The *minimum exit velocity* occurs at a diameter *d*, smaller than *D*. Using the geometry of Fig. 17–17, we find

$$d = D\cos\frac{\gamma}{2} \qquad (c)$$

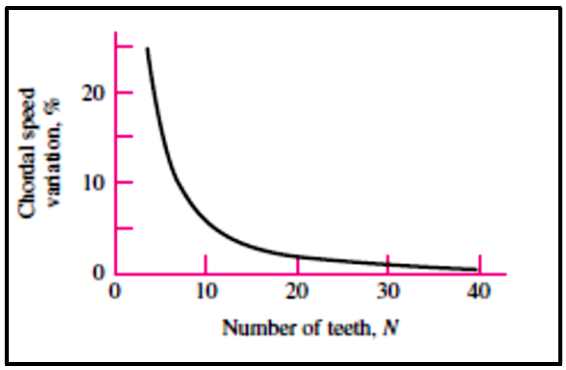
Thus the minimum exit velocity is

$$v_{min} = \frac{\pi d n}{12} = \frac{\pi n p}{12}\frac{\cos(\gamma/2)}{\sin(\gamma/2)} \qquad (d)$$

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

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

This is called the *chordal speed variation* and is plotted in **Fig. 17–18**. When chain drives are used to synchronize precision components or processes, due consideration must be given to these variations.



| Figure 17-18

- Usual case it is advantageous to obtain as small a sprocket as possible
- 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.
- Driven sprockets are not made in standard sizes over 120 teeth
- The most successful drives have velocity ratios up to 6:1
- Roller chains seldom fail because they lack tensile strength; *subjected to a great many hours of service;* wear of the rollers on the pins or to fatigue of the surfaces of the rollers.

The *horsepower capacity corresponding to a life expectancy of 15 kh for various sprocket speeds*. These capacities are tabulated in **Table 17–20** for 17–tooth sprockets.

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; type C′—type C, but this is a galling region; submit design to manufacturer for evaluation.

Table 17–21 displays available tooth counts on sprockets of one supplier.
Table 17–22 lists the tooth correction factors for other than 17 teeth.
Table 17–23 shows the multiple strand factors *K*2. The capacities of chains are based on the following:

The capacities of chains are based on the following:
- 15,000 h at full load
- Single strand
- ANSI proportions
- Service factor of unity
- 100 pitches in length
- Recommended lubrication
- Elongation maximum of 3 percent
- Horizontal shafts
- Two 17-tooth sprockets

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.

For single-strand chain, **the nominal power *H*1**, ***link-plate limited***, as

$$H_1 = 0.004 N_1^{1.08} n_1^{0.9} p^{(3-0.07p)} \quad \text{hp} \qquad (17\text{–}32)$$

and the **nominal power *H*2, *roller-limited***, as

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	$(N_1/17)^{1.08}$	$(N_1/17)^{1.5}$

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

$$H_2 = \frac{1000 K_r N_1^{1.5} p^{0.8}}{n_1^{1.5}} \quad \text{hp} \qquad (17\text{–}33)$$

where
$N1$ = number of teeth in the smaller sprocket
$n1$ = sprocket speed, rev/min
p = pitch of the chain, in
Kr = 29 for chain numbers 25, 35; 3.4 for chain 41; and 17 for chains 40–240
The constant 0.004 becomes 0.0022 for no. 41 lightweight chain.

The nominal horsepower in Table 17–20 is Hnom = min($H1$, $H2$). For example, for $N1$ = 17, $n1$ = 1,000 rev/min, no. 40 chain with p = 0.5 in, from Eq. (17–32),

$$H_1 = 0.004(17)^{1.08} 1,000^{0.9} 0.5^{[3-0.07(0.5)]} = 5.48 \quad \text{hp}$$

From Eq. (17–33),

$$H_2 = \frac{1,000(17)17^{1.5}\left(0.5^{0.8}\right)}{1,000^{1.5}} = 21.64 \quad \text{hp}$$

The tabulated value in Table 17–20 is *H*tab = min(5.48, 21.64) = 5.48 hp.

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

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

The center-to-center distance *C* is given by

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

Where,

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

The allowable power *Ha* is given by

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

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 *Hd* is given by

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

Equation (17–32) is the basis of the pre-extreme power entries (vertical entries) of Table 17–20, and the chain power is limited by link-plate fatigue. Equation (17–33) is the basis for the post-extreme power entries of these tables, and the chain power performance is limited by impact fatigue. The entries are for chains of 100 pitch

length and 17-tooth sprocket. For a deviation from this

$$H_2 = 1000\left[K_r\left(\frac{N_1}{n_1}\right)^{1.5} p^{0.8}\left(\frac{L_p}{100}\right)^{0.4}\left(\frac{15\,000}{h}\right)^{0.4}\right] \qquad (17\text{–}39)$$

where Lp is the chain length in pitches and h is the chain life in hours. Viewed from a deviation viewpoint, Eq. (17–39) can be written as a trade-off equation in the following form:

$$\frac{H_2^{2.5}h}{N_1^{3.75}L_p} = \text{constant} \qquad (17\text{–}40)$$

If tooth-correction factor $K1$ is used, then omit the term $N_1^{3.75}$. Note that $\left(N_1^{1.5}\right)^{2.5} = N_1^{3.75}$

In Eq. (17–40) one would expect the h/Lp term because doubling the hours can require doubling the chain length, other conditions constant, for the same number of cycles. Our experience with contact stresses leads us to expect a load (tension) liferelation of the form F^aL = constant. In the more complex circumstance of roller bus hing mpact, the Diamond Chain Company has identified a = 2.5. The ***maximum speed (rev/min)*** for a chain drive is limited by galling between the pin and the bushing. Tests suggest

$$n_1 \le 1,000\left[\frac{82.5}{7.95^p(1.0278)^{N_1}(1.323)^{F/1,000}}\right]^{1/(1.59\log p+1.873)} \quad \text{rev/min}$$

where F is the chain tension in pounds.

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 $C/p = 25$.

Solution *Function:* $H_{nom} = 90$ hp, $n_1 = 300$ rev/min, $C/p = 25$, $K_s = 1.3$
Design factor: $n_d = 1.5$

Sprocket teeth: $N_1 = 17$ teeth, $N_2 = 34$ teeth, $K_1 = 1$, $K_2 = 1, 1.7, 2.5, 3.3$
Chain number of strands:

$$H_{tab} = \frac{n_d K_s H_{nom}}{K_1 K_2} = \frac{1.5(1.3)90}{(1)K_2} = \frac{176}{K_2}$$

$K_1 K_2 \quad (1) K_2 \quad K_2$

Form a table:

Number of Strands	176/K2 (Table 17–23)	Chain Number (Table 17–19)	Lubrication Type
1	176/1 = 176	200	C′
2	176/1.7 = 104	160	C
3	176/2.5 = 70.4	140	B
4	176/3.3 = 53.3	140	B

Decision 3 strands of number 140 chain (H_{tab} is 72.4 hp).

Number of pitches in the chain:

$$\frac{L}{p} = \frac{2C}{p} + \frac{N_1 + N_2}{2} + \frac{(N_2 - N_1)^2}{4\pi^2 C/p}$$

$$= 2(25) + \frac{17 + 34}{2} + \frac{(34 - 17)^2}{4\pi^2(25)} = 75.79 \text{ pitches}$$

Decision Use 76 pitches. Then $L/p = 76$.

Identify the center-to-center distance: From Eqs. (17–35) and (17–36),

$$A = \frac{N_1 + N_2}{2} - \frac{L}{p} = \frac{17 + 34}{2} - 76 = -50.5$$

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

$$= \frac{p}{4}\left[50.5 + \sqrt{50.5^2 - 8\left(\frac{34 - 17}{2\pi}\right)^2}\right] = 25.104p$$

For a 140 chain, $p = 1.75$ in. Thus,

$$C = 25.104p = 25.104(1.75) = 43.93 \text{ in}$$

Lubrication: Type B

Comment: This is operating on the pre-extreme portion of the power, so durability estimates other than 15 000 h are not available. Given the poor operating conditions, life will be much shorter.

Lubrication of roller chains is essential in order to obtain a long and trouble-free life. Either a drip feed or a shallow bath in the lubricant is satisfactory. A medium or light mineral oil, without additives, should be used. Except for unusual conditions, heavy oils and greases are not recommended, because they are too viscous to enter the small clearances in the chain parts.