CHAPTER 32

CHAIN DRIVES

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NOTATION

BD	Bottom diameter, in
C	Center distance, in chain pitches
CD	Caliper diameter, in
CCD	Chain clearance diameter, in
D	Roller outside diameter, in
D_p	Gauge pin diameter, in
G	Maximum guide groove diameter, in
H	Maximum chain height, in
HP	Horsepower
K_f	Constant for link plate fatigue
K_r	Constant for roller and bushing impact
L	Chain length, in chain pitches
MHD	Maximum hub or groove diameter, in
MUTS	Minimum ultimate tensile strength, lb
n	Number of chain strands
N	Number of sprocket teeth
N_1	Number of teeth on small sprocket
N_2	Number of teeth on large sprocket

OD	Sprocket outside diameter, in
OGD	Over-gauge diameter, in
P	Chain pitch, in
PD	Sprocket pitch diameter, in
R	Sprocket speed, r/min
T	Thickness of link plate or sidebar, in
W	Chain (roller) width, in

32.1 TYPES, USES, AND CHARACTERISTICS

32.1.1 Chain Drives Compared

Three major types of chain are used for power transmission: roller, engineering steel, and silent. Roller chains are probably the most common and are used in a wide variety of low-speed to high-speed drives. Engineering steel chains are used in many low-speed, high-load drives. Silent chains are mostly used in high-speed drives. Other types of standard chains, and many types of special chains for unique applications, may be found in manufacturers' catalogs.

Chains can span long center distances like belts, and positively transmit speed and torque like gears. For a given ratio and power capacity, chain drives are more compact than belt drives, but less compact than gear drives. Mounting and alignment of chain drives does not need to be as precise as for gear drives. Chain drives can operate at 98 to 99 percent efficiency under ideal conditions. Chain drives are usually less expensive than gear drives and quite competitive with belt drives.

Chain drives can be dangerous. Provide proper guarding to prevent personnel from coming in contact with, or being caught in, a running drive. Any chain can break from unexpected operating conditions. If a chain breaks at speed, it can be thrown off the drive with great force and cause personal injury and property damage. Provide adequate guarding to contain a broken chain or to prevent personnel from entering an area where they might be struck by a broken chain. A broken chain can sometimes release a load and cause personal injury and property damage. Provide an adequate brake or restraint to stop and hold the load in case of a chain breakage.

32.1.2 Roller Chains

Standard Roller Chains. A portion of a typical roller-chain drive is shown in Fig. 32.1. The American National Standards Institute (ANSI) has standardized limiting dimensions, tolerances, and minimum ultimate tensile strength for chains and sprockets of 0.25 to 3.0 in pitch [32.1]. The chain pitch is the distance between successive roller, or bushing, centers, and is the basic dimension for designating roller chains. The standard includes both standard and heavy series chains.

Multiple-Strand Roller Chains. Multiple-strand roller chain consists of two or more parallel strands of chain assembled on common pins. They also are standardized [32.1].

Double-Pitch Roller Chains. Double-pitch roller chains are standardized in Ref. [32.2]. Double-pitch chains have the same pin, bushing, and roller dimensions as cor-

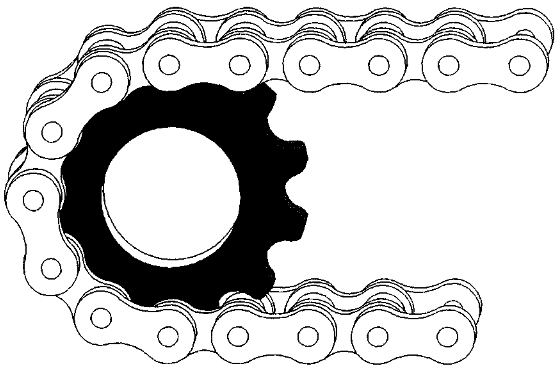


FIGURE 32.1 Typical roller chain on sprocket. *(Diamond Chain Company).*

responding chains in Ref. [32.1], but the pitch of the link plates is twice as long. The standard [32.2] covers chains of 1.0 to 4.0 in pitch.

Nonstandard Roller Chains. Many manufacturers offer high-strength, extra-clearance, sintered metal bushing, sealed-joint, and corrosion-resistant chains for special applications or adverse environments. These chains are not covered by any standard, but most are designed to run on standard sprockets.

Sprockets. Roller-chain sprockets have precisely designed, radiused pockets which smoothly engage the rollers on the chain and positively transmit torque and motion. Driver sprockets receive power from the prime mover and transfer it to the chain. Driven sprockets take power from the chain and transfer it to the selected machinery. Idler sprockets transmit no power; they are used to take up slack chain, increase the amount of chain wrap on another sprocket, guide the chain around other machine members, and reverse the normal direction of rotation of another sprocket.

32.1.3 Engineering Steel Chains

Standard Engineering Steel Chains. The engineering steel chains designated for power transmission are heavy-duty offset sidebar chains. Limiting dimensions, tolerances, and minimum ultimate tensile strength for chains and sprockets of 2.5 to 7.0 in pitch are standardized in Ref. [32.3].

Nonstandard Chains. Some manufacturers offer engineering steel chains in straight-sidebar and multiple-strand versions, and in pitches that are not included in Ref. [32.3]. Although these chains are not standardized, they are listed in manufacturers' catalogs because they are used extensively in special applications.

Sprockets. Machine-cut engineering-steel-chain sprockets look much like roller-chain sprockets, but they have pitch line clearance and undercut bottom diameters to accommodate the dirt and debris in which engineering-class chain drives often operate.

32.1.4 Silent Chain

Standard Silent Chains. Silent (inverted-tooth) chains are standardized in Ref. [32.3] for pitches of 0.375 to 2.0 in. Silent chain is an assembly of toothed link plates interlaced on common pins. The sprocket engagement side of silent chain looks much like a gear rack. Silent chains are designed to transmit high power at high speeds smoothly and relatively quietly. Silent chains are a good alternative to gear trains where the center distance is too long for one set of gears. The capacity of a given pitch of silent chain varies with its width. Standard widths of silent chain range from 0.5 to 6.0 in for 0.375-in pitch, and from 4.0 to 30.0 in for 2.0-in pitch.

Nonstandard Silent Chains. Some manufacturers offer silent chains with special rocker-type joints. These chains generally transmit higher horsepower more smoothly and quietly than the standard joint designs. However, they generally require sprockets with special tooth forms.

Sprockets. Silent-chain sprockets have straight-sided teeth. They are designed to engage the toothed link plates of the chain with mostly rolling and little sliding action.

32.2 ROLLER CHAINS: NOMENCLATURE AND DIMENSIONS

32.2.1 Standard Roller-Chain Nomenclature

Roller Chain. Roller chain is an assembly of alternating roller links and pin links in which the pins pivot inside the bushings, and the rollers, or bushings, engage the sprocket teeth to positively transmit power, as shown in Fig. 32.1 and the illustration with Table 32.1.

Roller Links. Roller links are assemblies of two bushings press-fitted into two roller link plates with two rollers free to rotate on the outside of each of the bushings.

Pin Links. Pin links are assemblies of two pins press-fitted into two pin link plates.

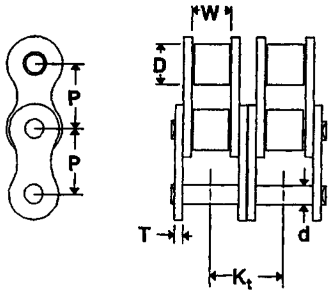
Connecting Links. Connecting links are pin links in which one of the pin link plates is detachable and is secured either by a spring clip that fits in grooves on the ends of the pins or by cotters that fit in cross-drilled holes through the ends of the pins. Illustrations of connecting links may be found in Ref. [32.1] or [32.4] or in manufacturers' catalogs.

Offset Links. Offset links are links in which the link plates are bent to accept a bushing in one end and a pin in the other end. The pin may be a press fit in the link plates, or it may be a slip fit in the link plates and be secured by cotters. Illustrations of offset links may be found in Ref. [32.1] or [32.4] or in manufacturers' catalogs.

32.2.2 Roller-Chain Dimensions and Numbering

Standard Chain Dimensions. The three key dimensions for describing roller chain are pitch, roller diameter, and roller width. The pitch is the distance between adjacent bushing centers. The roller diameter is the outside diameter of the chain rollers.

TABLE 32.1 Roller Chain Dimensions



(Dimensions in inches; MUTS in lbf)

ANSI chain no.	Chain pitch, P	Roller diameter, D	Roller width, W	Pin diameter, d	Link plate thickness, T		Transverse pitch, K_t	
					Std.	Heavy	Std.	Heavy
25	0.250	0.130*	0.125	0.0905	0.030	—	0.252	—
35	0.375	0.200*	0.188	0.141	0.050	—	0.399	—
41**	0.500	0.306	0.250	0.141	0.050	—	—	—
40	0.500	0.312	0.312	0.156	0.060	—	0.566	—
50	0.625	0.400	0.375	0.200	0.080	—	0.713	—
60	0.750	0.469	0.500	0.234	0.094	0.125	0.897	1.028
80	1.000	0.625	0.625	0.312	0.125	0.156	1.153	1.283
100	1.250	0.750	0.750	0.375	0.156	0.187	1.408	1.539
120	1.500	0.875	1.000	0.437	0.187	0.219	1.789	1.924
140	1.750	1.000	1.000	0.500	0.219	0.250	1.924	2.055
160	2.000	1.125	1.250	0.562	0.250	0.281	2.305	2.437
180	2.250	1.406	1.406	0.687	0.281	0.312	2.592	2.723
200	2.500	1.562	1.500	0.781	0.312	0.375	2.817	3.083
240	3.000	1.875	1.875	0.937	0.375	0.500	3.458	3.985

* Bushing diameter. Chain is rollerless.
** Lightweight chain
Illustration courtesy of Diamond Chain Company.

The roller width actually is the inside distance between roller link plates. These and other selected dimensions are shown in Table 32.1.

Ultimate Tensile Strength. The minimum ultimate tensile strength (MUTS) for standard chains is given in Ref. [32.1]. The value is estimated from the equation

$$\text{MUTS} = 12\,500P^2n$$

Chain Numbering. A standard numbering system is described in Ref. [32.1]. The right digit indicates the type of chain: 0 for a standard roller chain, 5 for a rollerless bushing chain, and 1 for a light-duty roller chain. The left one or two digits designate the chain pitch in eighths of an inch; for example, 6 indicates $\frac{6}{8}$, or $\frac{3}{4}$-in pitch. An H immediately following the right digit designates heavy series chain. Multiple-strand chain is designated by a hyphen and one or two digits following the right digit or letter. In Ref. [32.2], 2000 added to the chain number designates a double-pitch chain.

32.2.3 Roller-Chain Sprockets

Definitions and Types. Four styles of sprockets are standardized in Ref. [32.1]. Style A is a flat plate with no hub extensions. Style B has a hub extension on one side of the plate (flange). Style C has hub extensions on both sides of the flange. The extensions do not have to be equal. Style D has a detachable hub. The style D hub is normally attached to the flange with bolts. Most sprockets have a central bore with a keyway and setscrew to mount them on a shaft. Many other configurations of sprocket hubs and bores may be found in manufacturers' catalogs.

Tooth Form. The tooth form and profile dimensions for single- and multiple-strand roller-chain sprockets are defined in Ref. [32.1].

Sprocket Diameters. There are five important sprocket diameters defined in Ref. [32.1]. They are pitch, outside, bottom, caliper, and maximum hub diameters. The equations for those diameters, shown in Fig. 32.2, are

$$\text{PD} = P/\sin(180/N) \qquad \text{OD} = P[0.6 \cot(180°/N)]$$

$$\text{BD} = \text{PD} - D \qquad \text{CD} = \text{PD} \cos(90°/N) - D$$

$$\text{MHD} = P[\cot(180°/N) - 1] - 0.030$$

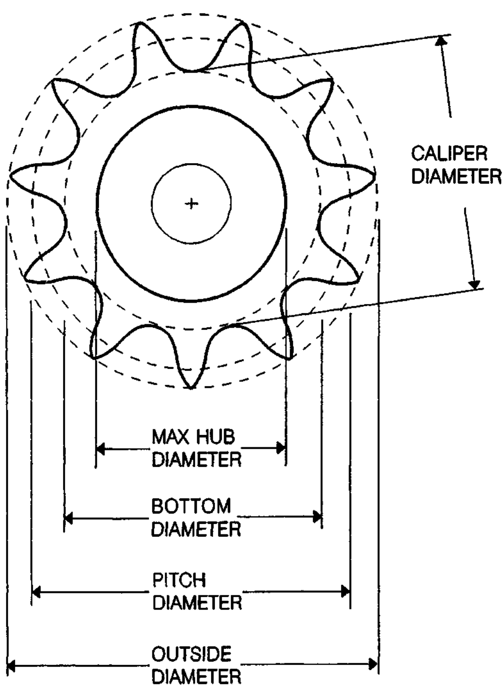


FIGURE 32.2 Roller chain sprocket diameters. *(Diamond Chain Company).*

32.3 SELECTION OF ROLLER-CHAIN DRIVES

32.3.1 General Design Recommendations

The following are only the more important considerations in roller-chain drive design. For more detailed information, consult Ref. [32.5] or manufacturers' catalogs.

Chain Pitch. The most economical drive normally employs the smallest-pitch single-strand chain that will transmit the required power. Small-pitch chains generally are best for lighter loads and higher speeds, whereas large-pitch chains are better for higher loads and lower speeds. The smaller the pitch, the higher the allowable operating speed.

Number of Sprocket Teeth

Small Sprocket. The small sprocket usually is the driver. The minimum number of teeth on the small sprocket is limited by the effects of chordal action (speed variation), as shown in Fig. 32.3. Lower speeds will tolerate more chordal action than higher speeds. The minimum recommended number of teeth on the small sprocket is

Slow speed	12 teeth
Medium speed	17 teeth
High speed	25 teeth

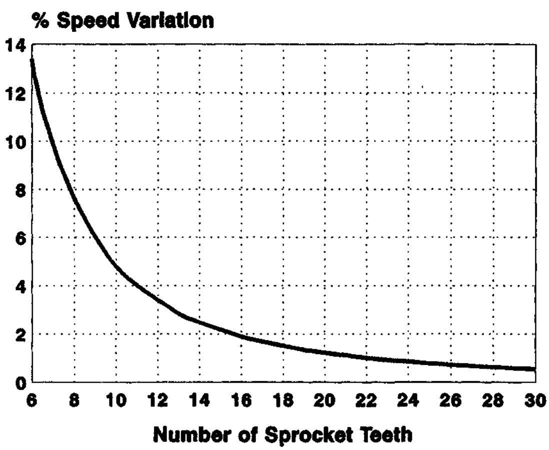


FIGURE 32.3 RC velocity variation versus number of teeth.

Large Sprocket. The number of teeth on the large sprocket normally should be limited to 120. Larger numbers of teeth are very difficult (expensive) to manufacture. The number of teeth on the large sprocket also limits maximum allowable chain wear elongation. The maximum allowable chain wear elongation, in percent, is $200/N_2$.

Hardened Teeth. The fewer the number of teeth on the sprocket, the higher the tooth loading. Sprocket teeth should be hardened when the number of teeth is less than 25 and any of the following conditions exist:

1. The drive is heavily loaded.
2. The drive runs at high speeds.
3. The drive runs in abrasive conditions.
4. The drive requires extremely long life.

Angle of Wrap. The minimum recommended angle of wrap on the small sprocket is 120°.

Speed Ratio. The maximum recommended speed ratio for a single-reduction roller-chain drive is 7:1. Speed ratios up to 10:1 are possible with proper design, but a double reduction is preferred.

Center Distance. The preferred center distance for a roller-chain drive is 30 to 50 times the chain pitch. At an absolute minimum, the center distance must be at least one-half the sum of the two sprocket outside diameters. A recommended minimum center distance is the pitch diameter of the large sprocket plus one-half the pitch diameter of the small sprocket. The recommended maximum center distance is 80 times the chain pitch.

The center distance should be adjustable to take up chain slack caused by wear. Adjustment of at least 2 pitches is recommended. If a fixed center distance must be used, consult a chain manufacturer.

Chain Length. Required chain length may be estimated from the following approximate equation:

$$L \doteq 2C + \frac{N_1 + N_2}{2} + \frac{N_2 - N_1}{4\pi^2 C} \tag{32.1}$$

Equation (32.1) will give chain length accurate to within ±½ pitch. If a more precise chain length is required, an equation for the exact chain length may be found in Ref. [32.5] or in manufacturers' literature.

The chain length must be an integral number of pitches. An even number of pitches is preferred. An odd number of pitches requires an offset link, and offset links reduce the chain's capacity.

Wear and Chain Sag. As a chain wears, it elongates. Roller-chain sprocket teeth are designed to allow the chain to ride higher on the teeth as it wears, to compensate for the elongation. Maximum allowable wear elongation normally is 3 percent. Where timing or smoothness is critical, maximum allowable elongation may be only 1.5 percent. The size of the large sprocket may also limit allowable elongation, as noted earlier.

As a chain elongates from wear, the excess length accumulates as sag in the slack span. In long spans, the sag can become substantial. It is important to design sufficient clearance into the drive to accommodate the expected amount of chain sag. For a drive with an approximately horizontal slack span, the required sag allowance for a particular amount of elongation is shown in Fig. 32.4. The drive centers should be adjusted periodically to maintain sag at 2 to 3 percent of the center distance.

Idlers. When the center distance is long, the drive centers are near vertical, the center distance is fixed, or machine members obstruct the normal chain path, idler

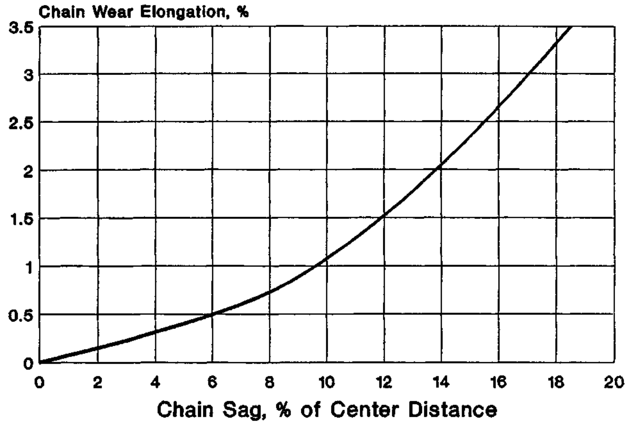


FIGURE 32.4 Chain sag versus center distance.

sprockets may be required. Idler sprockets should engage the chain in the slack span and should not be smaller than the small sprocket. At least 3 teeth on the idler should engage the chain, and there should be at least 3 free pitches of chain between sprocket engagement points.

Multiple-Strand Chain. Multiple-strand chain may be required when the load and speed are too great for a single-strand chain, or when space restrictions prevent the use of large enough single-strand sprockets.

Drive Arrangements. A number of recommended, acceptable, and not recommended drive arrangements are shown in Fig. 32.5.

32.3.2 Selection Procedure

Obtain Required Information. It is very important to obtain all the listed information before making a selection.

1. Source of input power
2. Type of driven equipment
3. Power to be transmitted
4. Speed and size of driver shaft
5. Speed and size of driven shaft
6. Desired center distance and drive arrangement
7. Means of center distance adjustment, if any
8. Available lubrication type
9. Space limitations
10. Adverse environmental conditions

Check for any unusual drive conditions, such as

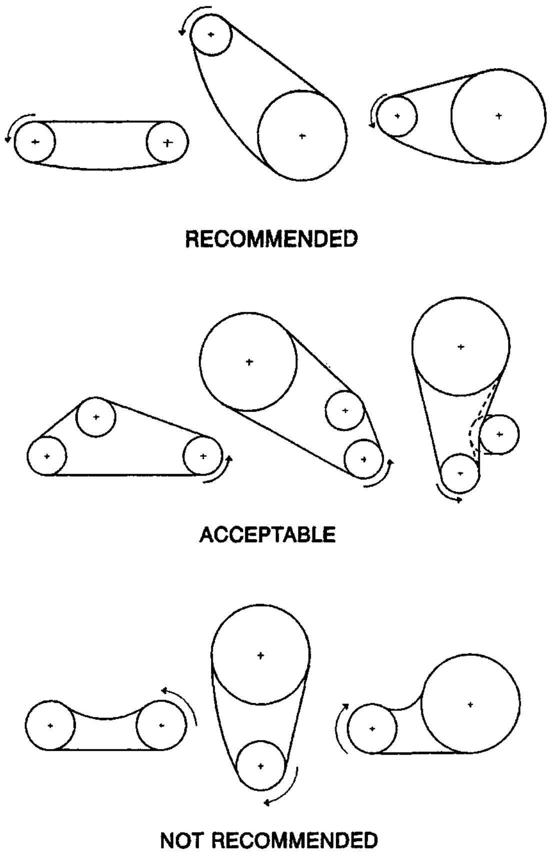


FIGURE 32.5 Drive arrangements.

- Frequent stops and starts
- High starting or inertial loads
- Temperatures above 150°F or below 0°F
- Large cyclic load variations in a single revolution
- Multiple driven shafts

If any of these, or any other unusual drive condition, is found, consult a chain manufacturer for help with the selection.

Determine Service Factor. The average required power for a drive usually is given. The peak power may be much greater than the average, depending on the power source and the driven equipment. A service factor, obtained from Table 32.2, accounts for the peak loads. The load classification for various types of driven equipment may be found in Ref. [32.1] or [32.5] or in manufacturers' catalogs.

Calculate Design Power. Obtain the design power by multiplying the average power times the service factor from Table 32.2.

TABLE 32.2 Service Factors for Roller Chain Drives

	Type of input power		
Type of driven load	Internal combustion engine with hydraulic drive	Electric motor or turbine	Internal combustion engine with mechanical drive
Smooth	1.0	1.0	1.2
Moderate shock	1.2	1.3	1.4
Heavy shock	1.4	1.5	1.7

Make Preliminary Chain Selection. Enter the chart, Fig. 32.6, with the design power and the speed of the small sprocket to select a preliminary chain. If no single-strand chain will transmit the design power at the required speed, or if space is restricted, multiple-strand chain may be required. If multiple-strand chain is to be selected, divide the design power by the multiple-strand factor, from Table 32.3, before entering the selection chart. Note that optimally the drive will operate near the peak of the rating curve. If the speed and power are low to moderate and the center distance is long, double-pitch chain may be acceptable. A selection procedure for double-pitch chains is given in Ref. [32.2].

TABLE 32.3 Roller Chain Multiple Strand Factors

Number of strands	Multiple strand factor
2	1.7
3	2.5
4	3.3

Select Small Sprocket. Refer to the horsepower tables in Ref. [32.1], [32.2], or [32.5] or in manufacturers' catalogs to select the small sprocket. Again, if multiple-strand chain is being considered, the design power must be divided by the proper multiple-strand factor from Table 32.3. Several different combinations of chain and sprocket sizes may be satisfactory for a given drive. Study the tables to see if increasing the number of teeth on the small sprocket might allow use of a smaller-pitch chain, or if decreasing the number of teeth on the small sprocket might allow use of a larger-pitch single-strand chain instead of a multiple-strand chain.

Consult sprocket manufacturers' catalogs to ensure that the sprocket bore capacity is adequate for the shaft. If it is not, select a larger sprocket.

Select Large Sprocket. Determine the number of teeth required on the large sprocket by multiplying the number of teeth on the small sprocket by the speed ratio. Ensure that the selected large sprocket will fit within any space restrictions and clear all obstructions. If there is an interference, a smaller-pitch, multiple-strand chain might be needed.

Make Final Chain Selection. Choose the most suitable drive from the alternatives selected earlier. The final choice may be based on economics, performance, effi-

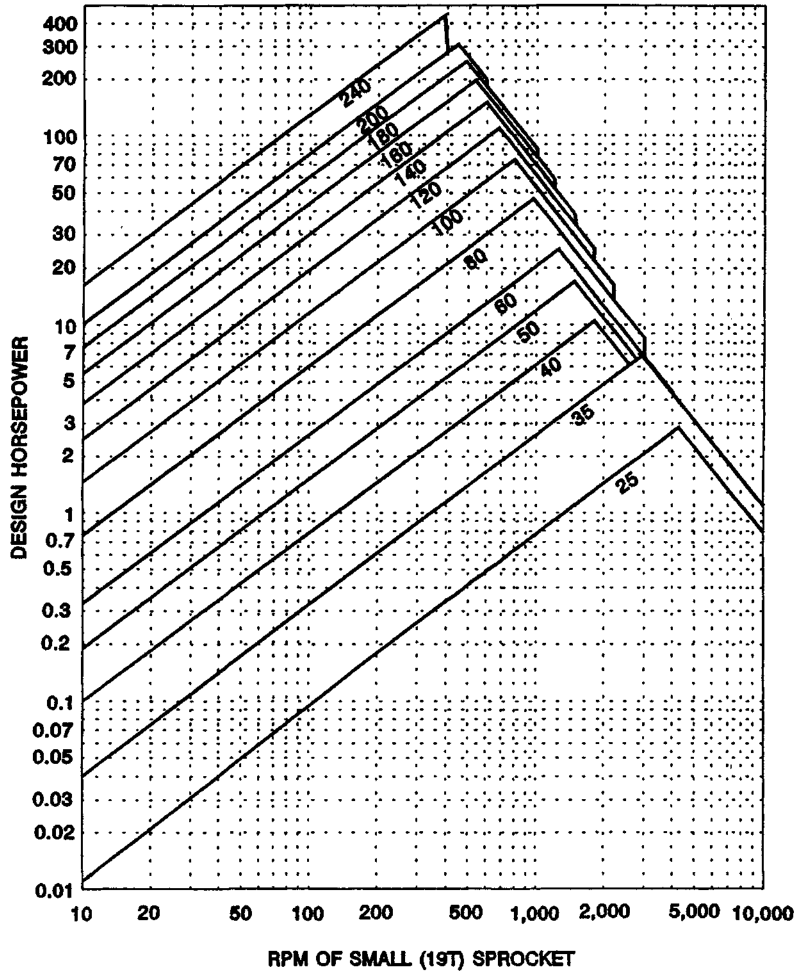


FIGURE 32.6 Roller chain selection chart.

ciency, space utilization, or a number of other considerations. Computer programs are available that automate the preliminary selection process and analyze the alternatives based on parameters provided by the designer.

Calculate Chain Length. For a two-sprocket drive, the approximate chain length may be estimated by Eq. (32.1). A more accurate chain length may be calculated by equations found in Ref. [32.5] or in manufacturers' catalogs. For three or more sprocket drives, the chain length may be estimated by graphic techniques, geometric layouts, computer programs, or certain CAD packages.

Determine Lubrication Type. The type of lubrication required may be obtained from the horsepower tables in Refs. [32.1] or [32.5], manufacturers' catalogs, or Sec. 32.4. It is very important to provide adequate lubrication to a roller-chain drive. Selecting an inferior type of lubrication can drastically reduce the life of the drive.

32.3.3 Power Ratings of Roller-Chain Drives

Conditions for Ratings. The roller-chain horsepower ratings presented in this section are based on the following conditions:

1. Standard or heavy series chain listed in Ref. [32.1]
2. Service factor of 1
3. Chain length of 100 pitches
4. Use of the recommended lubrication method
5. A two-sprocket drive, driver and driven
6. Sprockets properly aligned on parallel, horizontal shafts and chains
7. A clean, nonabrasive environment
8. Approximately 15 000 hours service life

Horsepower Rating Equations. When operating under the above conditions, the maximum horsepower capacity of standard roller chains is defined by the equations shown. Depending on speed and the number of teeth on the smaller sprocket, the power capacity may be limited by link plate fatigue, roller and bushing impact fatigue, or galling between the pin and the bushing. The power capacity of the chain is the lowest value obtained from the following three equations at the given conditions.

1. Power limited by link plate fatigue:

$$\mathrm{HP}_f = K_f N_1^{1.08} R^{0.9} P^{(3.0\,-\,0.07P)} \tag{32.2}$$

   where $K_f = 0.0022$ for no. 41 chain, and 0.004 for all other numbers.

2. Power limited by roller and bushing impact fatigue:

$$\mathrm{HP}_r = (K_r N_1^{1.5} P^{0.8})/R^{1.5} \tag{32.3}$$

   where $K_r = 29\,000$ for nos. 25 and 35 chain, 3400 for no. 41 chain, and 17 000 for nos. 40 through 240 chain.

3. Power limited by galling:

$$\mathrm{HP}_g = (\mathrm{RPN}_1/110.84)(4.413 - 2.073P - 0.0274N_2) - [\ln(R/1000)](1.59 \log P + 1.873) \tag{32.4}$$

The loci of these equations are presented in Fig. 32.6.

32.4 LUBRICATION AND WEAR

In all roller and engineering steel chains, and in many silent chains, each pin and bushing joint essentially is a traveling journal bearing. So, it is vital that they receive adequate lubrication to attain full potential wear life. Even silent chains with rocking-type joints are subject to some sliding and fretting, and so they also need good lubrication to obtain optimum wear life.

32.4.1 Purpose of Chain Lubrication

Effective lubrication aids chain performance and life in several ways:

1. By resisting wear between the pin and bushing surfaces
2. By flushing away wear debris and foreign materials
3. By lubricating the chain-sprocket contact surfaces
4. By dissipating heat
5. By cushioning impact loads
6. By retarding rust and corrosion

32.4.2 Lubricant Properties

General Lubricant Characteristics. Chain lubrication is usually best achieved by a good grade of nondetergent petroleum-base oil with the following properties:

- Low enough viscosity to penetrate to critical surfaces
- High enough viscosity to maintain an effective lubricating film at prevailing bearing pressures
- Free of contaminants and corrosive substances
- Able to maintain lubricating properties in the full range of operating conditions

Additives that improve film strength, resist foaming, and resist oxidation usually are beneficial, but detergents or additives to improve viscosity index normally are not needed.

Recommended Viscosities. The oil must be able to flow into small internal clearances in the chain, and so greases and very high-viscosity oils should not be used. The recommended viscosity for various ambient temperature ranges is shown in Table 32.4.

32.4.3 Application of Lubricant to Chain

Application Location and Flow Direction. It is vital to adequately lubricate the pin and bushing surfaces that articulate under load. It also is important to lubricate the surfaces between the roller and the bushing in roller and engineering steel chains. Oil should be applied to the upper link plate edges in the lower chain span just before the chain engages a sprocket. This places the oil where it can pass between the link plate faces and enter the critical bearing area. It also permits

TABLE 32.4 Recommended Oil Viscosity for Various Temperatures

Recommended grade	Temperature, °F
SAE 5	−50 to +50
SAE 10	−20 to +80
SAE 20	+10 to +110
SAE 30	+20 to +130
SAE 40	+30 to +140
SAE 50	+40 to +150

Source: Adapted from Ref. [32.6], p. 8, by courtesy of American Chain Association.

gravity and centrifugal force to aid the flow of oil in the desired direction. The extra oil that spills over the edges of the link plates should be adequate to lubricate the bearing surfaces between the rollers and the bushings in roller and engineering steel chain. It is important to supply oil uniformly across the entire width of silent and multiple-strand roller chains. For more information, see Refs. [32.5] and [32.6].

Flow Rates. When chain drives are transmitting large amounts of power at high speeds, oil-stream lubrication generally is required. The oil stream must cool the chain and carry away wear debris as well as lubricate the drive. A substantial oil flow rate is needed to accomplish all of that. The minimum flow rate for the amount of horsepower transmitted is shown in Table 32.5.

TABLE 32.5 Oil Flow Rates vs. Horsepower

Transmitted horsepower	Minimum flow rate, gal/min
50	0.25
100	0.50
150	0.75
200	1.00
250	1.25
300	1.50
400	2.00
500	2.25
600	3.00
700	3.25
800	3.75
900	4.25
1 000	4.75
1 500	7.00
2 000	10.0

Source: Adapted from Ref. [32.6], p. 12, by courtesy of American Chain Association.

32.4.4 Types of Chain Lubrication

All three types of chain drives—roller, engineering steel, and silent—will work with three types of lubrication system. The type of lubrication system used is dependent on the speed and the amount of power transmitted. The three types of chain drive lubrication systems are

Type 1. Manual or drip
Type 2. Oil bath or slinger disk
Type 3. Oil stream

A description of each type of lubrication follows.

Manual. Oil is manually applied periodically with a brush or spout can. The time period between applications is often 8 hours, but it may be longer if this is proven adequate for the particular conditions.

Drip. Oil is dripped between the link plate edges from a lubricator with a reservoir. Rates range from 4 to 20 drops per minute; 10 drops per minute is equal to about one ounce per hour. A distribution pipe is needed to direct oil to all the rows of link plates in multiple-strand chain, and a wick packing in the pipe will ensure uniform distribution of oil to all the holes in the pipe. Windage may misdirect the oil droplets. If that occurs, the lubricator must be relocated.

Oil Bath. A short section of chain runs through the oil in the sump of a chain casing. The oil level should not be higher than the pitch line of the chain at its lowest point in operation. Long sections of chain running through the oil bath can cause foaming and overheating. If that occurs, slinger disc–type lubrication should be considered.

Slinger Disk. The chain runs above the oil level while a disk on one shaft picks up oil from the sump and slings it against a collector plate. The oil is then directed into a trough which applies it to the upper edges of the chain link plates in the lower span of the chain. The disk diameter should be sized so that the disk runs at a rim speed of 600 to 8000 ft/min. Slower speeds will not effectively pick up the oil. Higher speeds can cause foaming and overheating.

Oil Stream. A pump sends a stream or spray of oil under pressure onto the chain. The oil must be applied evenly across the entire width of the chain, and it must be directed onto the lower span from the inside of the chain loop. Excess oil is collected in the sump and returned to the pump reservoir. The oil stream both lubricates and cools the chain when high power is transmitted at high speeds (Table 32.5). The oil may be cooled by radiation from the external surfaces of the reservoir or, if power is very high, by a separate heat exchanger.

32.4.5 Chain Casings

Chain casings provide a reservoir for the oil, contain excess oil slung off the drive, and prevent contaminants from contacting the drive. Chain casings usually are made of sheet metal, and are stiffened by embossed ribs or metal angles. Chain casings generally have doors or panels to allow access to the drive for inspection and maintenance.

Oil-retaining casings have single lap joints and single oil seals at each shaft opening. They are adequate for drip or oil bath types of lubrication. They are relatively inexpensive, but they will allow some oil to escape and some dust and dirt to enter the casing. Oil- and dustproof casings have double lap joints and double oil seals at the shafts. They are strongly recommended for slinger disc and pressure stream types of lubrication. They are more expensive, but they virtually eliminate oil leakage and prevent contaminants from reaching the drive.

Sizing for Clearance. Sufficient clearance between the chain and the casing is essential if maximum potential wear life from the chain is to be obtained. At least 3 in clearance is needed around the periphery of the chain and ¾ in on each side of the chain. Additional clearance must be provided in the bottom of the casing to accommodate chain sag from wear elongation. The required allowance for chain sag may be obtained from Fig. 32.4.

Sizing for Heat Dissipation. A chain casing also may need sufficient surface area for heat dissipation. The oil temperature should not exceed 180°F (total of ambient temperature and temperature rise). The temperature rise for a given chain casing may be estimated from Eq. (32.5), which presumes 98 percent chain drive mechanical efficiency.

$$\Delta T_h = \frac{50.9\ \mathrm{HP}}{AK_h} \tag{32.5}$$

where ΔT_h = temperature rise, °F
HP = transmitted horsepower
A = exposed casing area, ft^2
K_h = overall film coefficient of heat transfer, BTU/(h · ft^2 · °F)
K_h = 2.0 for still air, 2.7 for normal circulation, and 4.5 for rapid circulation

The equation may be rearranged to obtain the required surface area of the casing:

$$A = \frac{50.9\ \mathrm{HP}}{\Delta T_h K_h} \tag{32.6}$$

If a casing with the required surface area is too large for the available space, a separate oil cooler may be needed.

This short section gives only the rudiments of designing a chain casing. More information may be found in Refs. [32.5] and [32.6], machine design textbooks, or manufacturers' literature.

32.4.6 Specific Lubrication Recommendations

Roller Chain. The required type of lubrication is directly related to the speed of a roller-chain drive. The limiting speeds for standard sizes of roller chain are shown in Table 32.6. More detailed information may be found in Refs. [32.5] and [32.6] or in manufacturers' literature.

Engineering Steel Chains. The required type of lubrication for an engineering steel drive is related to speed, but the relationship is more complex than for a roller-chain drive. The approximate limiting speeds for standard sizes of engineering steel chain, on 12-tooth sprockets only, are shown in Table 32.7. The values in the table are for general guidance only. When designing a drive, consult Ref. [32.5] or manufacturers' literature.

TABLE 32.6 Roller Chain Speed Limits by Lubrication Type

	Limiting speed, fpm												
ANSI No.	25	35	40	50	60	80	100	120	140	160	180	200	240
Type 1	480	350	300	250	215	165	145	125	110	100	90	80	75
Type 2	3250	2650	2200	1900	1750	1475	1250	1170	1050	1000	935	865	790
Type 3	At all speeds higher than for Type 2												

TABLE 32.7 Offset Sidebar Chain Speed Limits by Lubrication Type

	Limiting speed, rpm of 12-tooth sprocket only							
ANSI No.	2010	2512	2814	3315	3618	4020	4824	5628
Type 1	33	33	33	32	29	30	35	38
Type 2	300	200	160	115	100	85	65	N/A
Type 3	At all speeds higher than for Type 2							

Silent Chains. The required type of lubrication is related to speed for silent-chain drives also, but again, the relationship is more complex than for roller-chain drives. The approximate limiting speeds for standard sizes of silent chain are shown in Table 32.8. The values in the table are for general guidance only. When designing a drive, consult Refs. [32.4] and [32.5] or manufacturers' literature.

32.5 ENGINEERING STEEL CHAINS: NOMENCLATURE AND DIMENSIONS

The engineering steel chains that are specifically designated for power transmission are heavy-duty offset sidebar chains, standardized in Ref. [32.3].

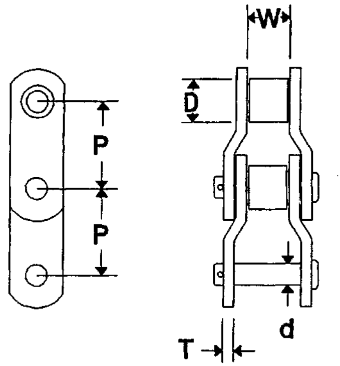
32.5.1 Offset Sidebar Chain Nomenclature

In offset sidebar chain, each link is the same. Each link consists of a pair of offset-bent sidebars with a bushing assembled in one end of the pair of sidebars and a pin assembled in the other end. A roller that is free to rotate is assembled on each bushing. The pin is assembled into, and is free to pivot inside of, the bushing of the adjacent link, as shown in the illustration with Table 32.9.

TABLE 32.8 Silent Chain Speed Limits by Lubrication Type

	Limiting speed, FPM					
	Number of teeth on small sprocket					
	21	25	29	35	42	50
Type 1	1220	1250	1270	1290	1320	1350
Type 2	2400	2500	2650	2800	3000	3200
Type 3	At all speeds higher than for Oil Bath					

TABLE 32.9 Offset Sidebar Chain Dimensions



(Dimensions in inches, MUTS and F_w in lbf)

ANSI chain no.	Chain pitch, P	Roller width, W	Roller diameter, D	Pin diameter, d	Sidebar thickness, T	Minimum ultimate tensile strength, MUTS	Maximum allowable working load, F_w
2010	2.500	1.50	1.25	0.625	0.31	57 000	4 650
2512	3.067	1.56	1.62	0.750	0.38	77 000	6 000
2814	3.500	1.50	1.75	0.875	0.50	106 000	7 600
3315	4.073	1.94	1.78	0.938	0.56	124 000	10 000
3618	4.500	2.06	2.25	1.100	0.56	171 000	12 000
4020	5.000	2.75	2.50	1.250	0.62	222 500	17 500
4824	6.000	3.00	3.00	1.500	0.75	287 500	23 600
5628	7.000	3.25	3.25	1.750	0.88	385 000	60 500

Illustration courtesy of Diamond Chain Company.

32.5.2 Offset Sidebar Chain Dimensions and Data

Offset Sidebar Chain Dimensions. Just as for roller chain, the three key dimensions for describing offset sidebar chain are pitch, roller diameter, and roller width. These, other selected dimensions, minimum ultimate tensile strengths, and maximum working loads for standard offset sidebar chains are shown in Table 32.9.

Offset Sidebar Chain Numbering. A four-digit numbering system for designating standard offset sidebar chains is given in Ref. [32.3]. The left two digits denote the number of ⅛-in increments in the pitch. The right two digits denote the number of $\frac{1}{16}$-in increments in the pin diameter. For example, chain no. 2814 designates a standard offset sidebar chain with 3.5-in pitch and ⅞-in pin diameter.

32.5.3 Sprockets

Machine-cut sprockets for offset sidebar chain look much like sprockets for roller chain. The standard (Ref. [32.3]) defines only tooth form, profile section, and important diameters. It does not define styles of sprockets because a great variety of styles and materials are offered by manufacturers. When designing a drive, consult manufacturers' literature to select sprockets that will be appropriate for the application.

Tooth Form. The tooth form and profile dimensions for offset-sidebar-chain sprockets are defined in Ref. [32.3].

Sprocket Diameters. There are four important sprocket diameters defined in Ref. [32.3]. They are pitch, root, bottom, caliper, and chain clearance diameters. The equations for those diameters, shown in Fig. 32.7, are

$$\mathrm{PD} = P/\sin\,(180/N) \qquad \mathrm{RD} = \mathrm{PD} - D \qquad \mathrm{BD} = \mathrm{RD} - C_b$$

$$\mathrm{CD} = \mathrm{BD}[\cos\,(90/N)] \qquad \mathrm{CCD} = P[\cot\,(180/N) - 0.05] - H$$

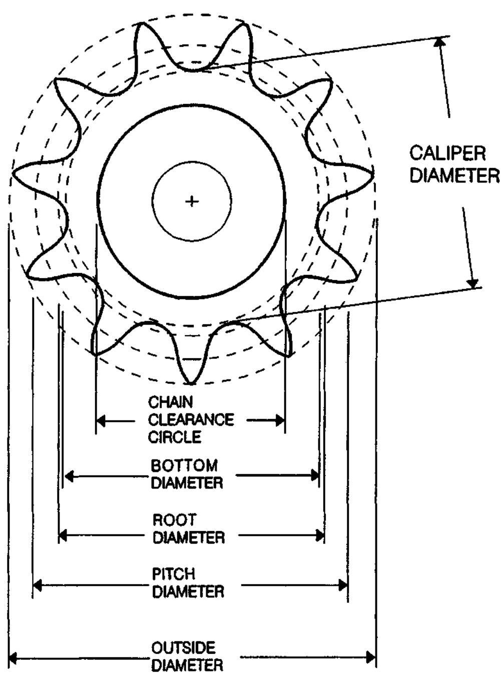


FIGURE 32.7 Engineering steel chain sprocket diameters. *(Diamond Chain Company).*

32.6 SELECTION OF OFFSET-SIDEBAR-CHAIN DRIVES

32.6.1 General Design Recommendations

Some of the general guidelines for offset-sidebar-chain selection are similar to those for roller-chain selection, but many are different. The selection of offset-sidebar-chain drives will be covered fully, even though there may be some repetition.

Chain Pitch. Generally, the smallest-pitch chain that will transmit the required power at the required speed provides the most economical drive.

Number of Sprocket Teeth

Small Sprocket. A small sprocket with 12 teeth is normally recommended. If the speed ratio is high or space is restricted, a small sprocket with 9 teeth is acceptable. If the speed ratio is low, center distance is long, and space is not limiting, a small sprocket with 15 teeth is suggested.

Large Sprocket. The size of the large sprocket is limited by available space, maximum allowable chain wear elongation, and manufacturing feasibility. Large sprockets with more than 66 teeth are not desirable because they limit maximum allowable chain wear elongation to less than 3 percent. Some manufacturers list their maximum-size stock sprockets at 50 teeth or less.

Angle of Wrap. The minimum recommended angle of wrap on the small sprocket is 135°, or three teeth engaging the chain.

Speed Ratio. The maximum recommended speed ratio for a single-reduction drive is 6:1. That is done so as to keep sprocket sizes within reasonable bounds and to obtain reasonably good chain wear life.

Center Distance. The preferred center distance is from 30 to 50 times the chain pitch. The center distance should be adjustable to compensate for chain wear elongation. The minimum adjustment should be equal to at least one chain pitch.

Chain Length. The required chain length may be estimated from Eq. (32.1). This will give chain length accurate to within ±½ chain pitch. If a more precise length is required, consult Ref. [32.5] or manufacturers' literature.

Wear and Chain Sag. Maximum allowable wear elongation for offset sidebar chains is determined by component size and hardness. Most offset sidebar chains are designed to provide 5 to 6 percent wear elongation. Wear elongation may be limited by the number of teeth on the large sprocket. For that case, the maximum allowable chain elongation, in percent, is $200/N_2$.

In a drive on approximately horizontal centers, chain wear elongation accumulates as sag in the slack span. The expected amount of sag for various amounts of wear elongation is shown in Fig. 32.4. The drive centers should be adjusted periodically to maintain sag at 2 to 3 percent of horizontal center distance.

Idlers. When the center distance is long, the drive centers are more than 45° from horizontal, or machine members obstruct the normal chain path, an idler sprocket may be required. Idler sprockets should engage the chain in the slack span and should not be smaller than the small sprocket in the drive. At least 3 teeth on the idler should engage the chain, and there should be at least 3 pitches of free chain between engagement points.

Drive Arrangements. A number of recommended, acceptable, and not recommended drive arrangements are shown in Fig. 32.5.

32.6.2 Selection Procedure

Obtain Required Information. Before an offset-sidebar-chain drive is selected, it is essential to obtain all the listed items of information. Note that the first 10 items are the same as for roller chain.

1. Source of input power
2. Type of driven equipment
3. Power to be transmitted
4. Speed and size of driver shaft
5. Speed and size of driven shaft
6. Desired center distance and drive arrangement
7. Means of center distance adjustment, if any
8. Available lubrication type
9. Space limitations
10. Adverse environmental conditions
11. Operating hours per day

In addition, check for any unusual drive conditions, such as

- Higher than listed speeds
- Inadequate lubrication
- Very heavy shock loads
- Corrosive or very abrasive conditions
- More than one driven shaft
- Other than precision-cut sprockets

When any of these, or any other unusual drive condition, is present, consult a chain manufacturer for assistance with the drive selection.

Determine Service Factor. The combined service factor SF is calculated by multiplying the three individual factors from Tables 32.10, 32.11, and 32.12:

$$SF = (SF_1)\ (SF_2)\ (SF_3)$$

The load classification for various types of driven equipment may be found in Ref. [32.5] or in manufacturers' literature.

TABLE 32.10 Service Factors for Offset-Sidebar-Chain Drives; Load Type, SF_1

	Type of input power		
Type of driven load	Internal combustion engine with hydraulic drive	Electric motor or turbine	Internal combustion engine with mechanical drive
Smooth	1.0	1.0	1.2
Moderate shock	1.2	1.3	1.4
Heavy shock	1.4	1.5	1.7

TABLE 32.11 Service Factors for Offset-Sidebar-Chain Drives; Environment, SF_2

Environmental conditions	Factor
Relatively clean, moderate temperature	1.0
Moderately dirty, moderate temperature	1.2
Very dirty, abrasive, exposed to weather, mildly corrosive, relatively high temperature	1.4

TABLE 32.12 Service Factors for Offset-Sidebar-Chain Drives; Operating Time, SF_3

Daily operating hours	Factor
8 to 10 hr/day	1.0
10 to 24 hr/day	1.4

Calculate Design Power. Obtain the design power by multiplying the average power times the combined service factor.

Make Preliminary Chain Selection. Enter the chart, Fig. 32.8, with the design power and the speed of the small sprocket to make a preliminary chain selection.

Select Small Sprocket. Refer to the horsepower tables in Ref. [32.5] or manufacturers' catalogs to select the small sprocket. Check the tables to see if increasing the number of teeth on the small sprocket might allow use of a smaller-pitch, more economical chain.

Consult sprocket manufacturers' catalogs to ensure that the sprocket bore capacity will accommodate the shaft. If it will not, a larger sprocket must be selected.

Select Large Sprocket. Determine the number of teeth required on the large sprocket by multiplying the number of teeth on the small sprocket by the speed ratio. Ensure that the selected large sprocket will fit within the available space and clear all obstructions. If there is an interference, a different chain and sprocket combination may have to be selected.

Make Final Chain Selection. Choose the most suitable drive from the alternatives selected earlier. The final choice may be based on economics, performance, efficiency, space utilization, or a number of other considerations. Computer programs are available that automate the preliminary selection process and analyze the alternatives based on parameters provided by the designer.

Calculate Chain Length. Calculate the chain length from Eq. (32.1). More accurate chain length may be calculated using equations in Ref. [32.5] or manufacturers' literature. For drives with more than two sprockets, the chain length may be obtained using graphical techniques, geometric layouts, computer programs, and certain CAD packages.

Determine Lubrication Type. The required lubrication type may be obtained from horsepower tables in Ref. [32.5], manufacturers' literature, or Sec. 32.4. It is very

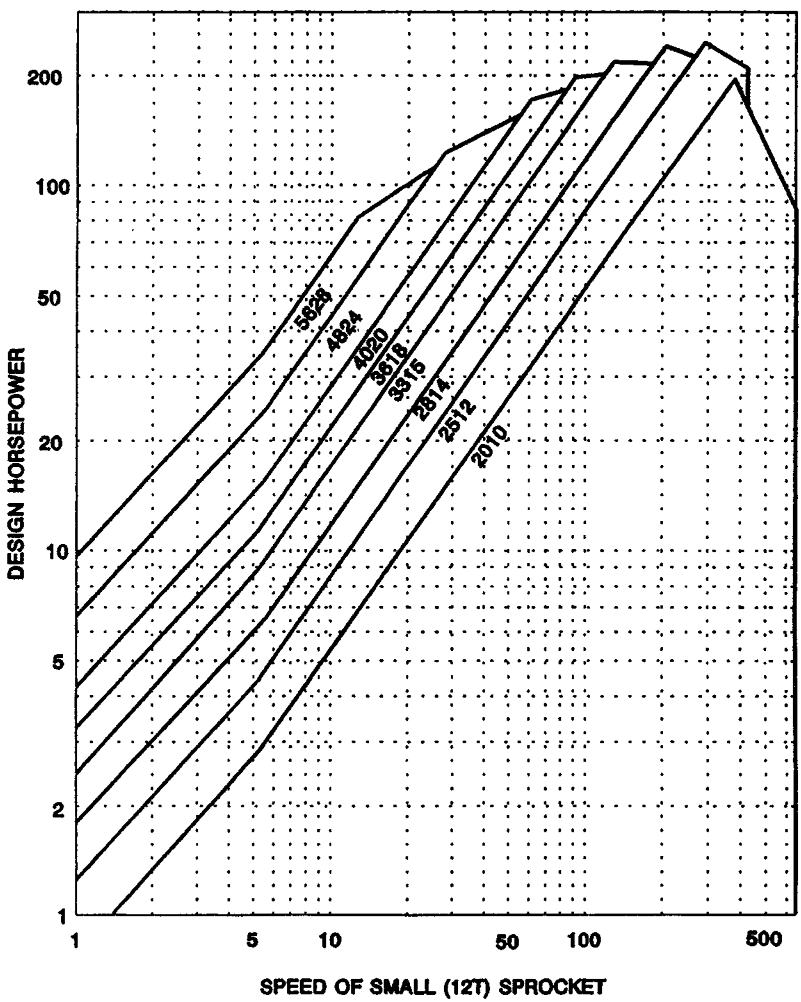


FIGURE 32.8 Engineering steel chain selection chart.

important to provide adequate lubrication to a chain drive. Selecting an inferior type of lubrication can drastically reduce the life of the drive.

Direction of Chain Travel. The wear life of an offset sidebar chain can be affected by its direction of travel. To obtain greater wear life, in a drive with other than a one-to-one ratio, the narrow or roller end of the links in the taut span should face the smaller sprocket. It may be helpful in many cases for the drive designer to specify the direction in which the chain is to be installed. A complete explanation of this phenomenon may be found in Ref. [32.5].

32.6.3 Horsepower Ratings of Offset Sidebar Chains

Conditions for Ratings. The offset sidebar chain ratings presented here and in Ref. [32.5] are based on the following conditions:

1. Standard chain listed in Ref. [32.3]
2. Service factor of 1
3. Chain length of 100 pitches
4. Use of the recommended lubrication method
5. A two-sprocket drive, driver and driven
6. Sprockets well aligned on parallel, horizontal shafts
7. Precision-machined tooth sprockets
8. A clean, nonabrasive environment
9. Approximately 15 000 hours service life

Horsepower Ratings. The ratings for offset sidebar chains on 12-tooth sprockets are shown on the chart in Fig. 32.8. The rating equations for offset sidebar chains are much more complex than those for roller chains, and they are not generally published.

32.7 SILENT CHAINS: NOMENCLATURE AND DIMENSIONS

32.7.1 Silent-Chain Nomenclature

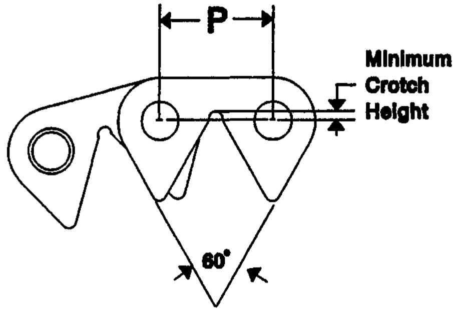
Silent chain is a series of toothed links alternately interlaced on joint components so that the joint between each pitch articulates essentially as shown in the illustration with Table 32.13. The joint components may be any combination of pins, bushings, or specially configured components that cause the toothed links to engage a standard sprocket so that the joint centers lie on the pitch circle. In addition to the toothed links and joint components, silent chain has guide links (not toothed) that run either on the sides of the sprocket or in circumferential grooves in the sprocket to control the chain laterally.

Silent chains do not have discrete strands as roller and engineering steel chains do. Silent chain may be assembled in an almost infinite number of "strands" because of the way the toothed links are alternately interlaced on the joint components, as shown in Fig. 32.9. Silent chain is produced in standard widths, in inches, designated in Ref. [32.4].

32.7.2 Silent-Chain Dimensions and Data

Silent-Chain Dimensions. The standard for silent chain (Ref. [32.4]) defines the sprockets in more detail than the chains. A silent chain is a standard silent chain if it functions properly on a standard sprocket. The only standardized chain dimensions are those shown in Table 32.13.

TABLE 32.13 Silent Chain Dimensions



Dimensions in inches

ANSI chain no.	Chain pitch	Min. crotch height	Standard chain widths
SC3	0.375	0.0232	.5, .75, 1, 1.25, 1.5, 1.75, 2, 2.25, 2.5, 3, 4, 5, 6
SC4	0.500	0.0310	.5, .75, 1, 1.25, 1.5, 1.75, 2, 2.25, 2.5, 2.75, 3, 4, 5, 6, 8
SC5	0.625	0.0388	1, 1.25, 1.5, 1.75, 2, 2.5, 3, 4, 5, 6, 7, 8, 10
SC6	0.750	0.0465	1, 1.25, 1.5, 2, 2.5, 3, 3.5, 4, 5, 6, 7, 8, 9, 10, 12
SC8	1.00	0.0620	2, 2.5, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16
SC10	1.25	0.0775	2.5, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 20
SC12	1.50	0.0930	3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 22, 24
SC16	2.00	0.1240	4, 5, 6, 7, 8, 10, 12, 14, 16, 18, 20, 22, 24, 30

Illustration courtesy of Diamond Chain Company.

Silent-Chain Numbering. A standard numbering system is described in Ref. [32.4]. Chain numbers begin with the two letters SC. They are followed by one or two digits that designate the chain pitch in increments of ⅛ in. The pitch designators are then followed by two or three digits that designate the chain width in increments of ¼ in. For example, chain number SC836 is a standard silent chain with a pitch of 1 in and a width of 9 in.

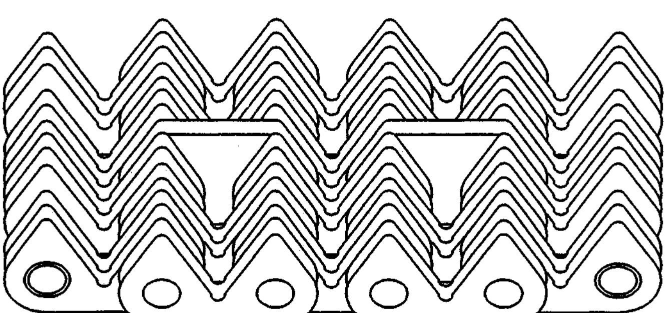


FIGURE 32.9 Typical silent chain. *(Diamond Chain Company).*

32.7.3 Silent-Chain Sprockets

Tooth Form. The tooth form, profile, and guide groove width and profile dimensions are defined in Ref. [32.4].

Sprocket Diameters. There are five important sprocket diameters defined in Ref. [32.4]. They are pitch, outside, over-gauge, maximum guide groove, and maximum hub diameters. The equations for those diameters, shown in Fig. 32.10, are

$$\text{PD} = P/\sin\,(180/N) \qquad D_p = 0.625P$$

$$\text{OD (for rounded teeth)} = P[\cot\,(180/N) + 0.08]$$

$$\text{OGD (for even number of teeth)} = \text{PD} - 0.125P\csc\,[30 - (180/N)] + D_p$$

$$\text{OGD (for odd number of teeth)} = [\cos\,(90/N)]\{\text{PD} - 0.125P\csc\,[30 - (180/N)]\} + D_p$$

$$G = P[\cot\,(180/N) - 1.16]$$

$$\text{MHD (for hobbed teeth)} = P[\cot\,(180/N) - 1.33]$$

$$\text{MHD (for straddle-cut teeth)} = P[\cot\,(180/N) - 1.25]$$

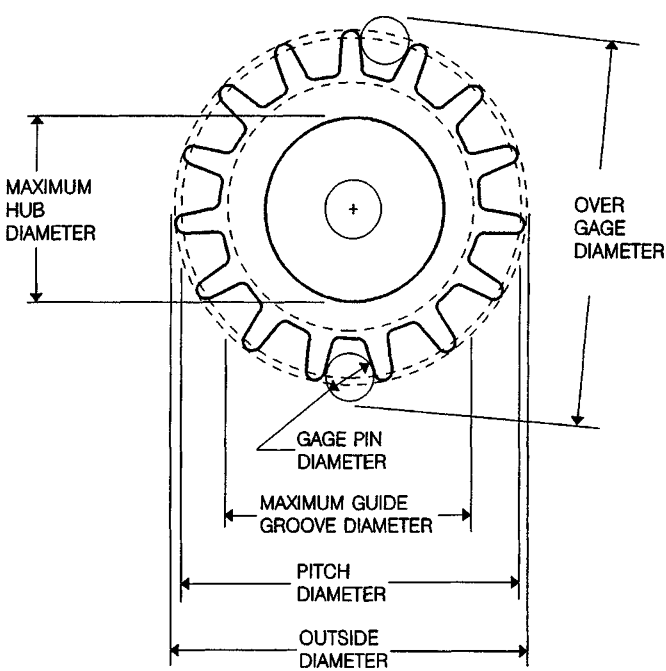


FIGURE 32.10 Silent chain sprocket diameters. *(Diamond Chain Company).*

32.8 SELECTION OF SILENT-CHAIN DRIVES

32.8.1 General Design Recommendations

The following guidelines are only the more important considerations in designing silent-chain drives. For more detailed information, consult Ref. [32.5] or manufacturers' literature.

Chain Pitch. It is very important to match the silent-chain pitch to the desired shaft speeds. Generally, the smaller the pitch, the greater the allowable speed.

Number of Sprocket Teeth

Small Sprocket. The absolute minimum number of teeth that a silent-chain sprocket can have is 12. However, the minimum recommended number of teeth on the small sprocket is much more than that:

Normal operation	21 teeth
Speed increasing (step-up)	23 teeth
High speed (over 1500 ft/min)	25 teeth

Large Sprocket. The number of teeth on the large sprocket normally should not exceed 120. The number of teeth on the large sprocket also limits maximum allowable chain wear elongation. The maximum allowable chain wear elongation, in percent, is $200/N_2$.

Hardened Teeth. The teeth on the small sprocket should be hardened when they are running at moderate to high speeds or transmitting nearly maximum rated power.

Angle of Wrap. The minimum recommended angle of wrap on the small sprocket is 120°.

Speed Ratio. The maximum recommended speed ratio is 8:1 for a single-reduction drive. Speed ratios of up to 12:1 are possible with proper design, but in such situations double-reduction drives are preferred.

Center Distance. The preferred center distance for a silent-chain drive is 30 to 50 times the pitch. The center distance should be adjustable to take up slack chain caused by wear. The center distance adjustment should be at least 2 pitches. If a fixed center distance must be used, consult a chain manufacturer.

Chain Length. The required chain length may be calculated from Eq. (32.1). It will give chain length accurate to within ±½ pitch. If a more precise chain length is needed, equations for exact chain length may be found in Ref. [32.5] or in manufacturers' literature.

Chain length must be an integral number of pitches. An even number of pitches is preferred. An odd number of pitches requires the use of an offset link, and offset links reduce the capacity of the chain.

Wear and Chain Sag. Silent chain elongates with wear just as other types of chain do. Silent-chain sprocket teeth are designed to allow the chain to run higher on the teeth as it wears, thus compensating for the elongation. The maximum allowable chain wear is limited by the number of teeth on the large sprocket, as noted earlier.

In a drive where the shaft centers are nearly horizontal, chain wear accumulates as sag in the slack span. The amount of sag for various amounts of wear elongation is shown in Fig. 32.4. The drive centers should be adjusted periodically to maintain chain sag at 2 to 3 percent of the center distance.

Idlers. In drives where the center distance is long, the shaft centers are near vertical, or the center distance is not adjustable, idler sprockets or guide shoes may be needed. Idler sprockets may be used when they engage the inside of the chain loop, but guide shoes with a large radius are advised for contact on the back of the chain. Idlers should have at least 17 teeth. They should have at least 3 teeth engaging the chain, and allow at least 3 pitches of free chain between engagement points. Guide shoes may be of wood, metal, or polymeric material. They should contact the back of the slack span near the small sprocket to increase the angle of wrap on the small sprocket.

Drive Arrangements. A number of recommended, acceptable, and not recommended drive arrangements are shown in Fig. 32.5. These apply to silent chain as well as roller chain, except that a radiused guide shoe should be used where idler sprockets contact the back side of the chain.

32.8.2 Selection Procedure

Obtain Required Information. Before a silent-chain drive is selected, it is essential to obtain all the listed items of information. Note that the first 10 items are the same as for roller chain.

1. Source of input power
2. Type of driven equipment
3. Power to be transmitted
4. Speed and size of driver shaft
5. Speed and size of driven shaft
6. Desired center distance and drive arrangement
7. Means of center distance adjustment, if any
8. Available lubrication type
9. Space limitations
10. Adverse environmental conditions
11. Operating hours per day

In addition, check for any unusual drive conditions, such as

- Frequent stops and starts
- High starting or inertial loads
- Multiple driven shafts
- Inferior lubrication type
- Corrosive or abrasive environment

If these or any other unusual drive conditions are present, consult a chain manufacturer for advice on the selection.

Determine Service Factor. Determine the service factor from Table 32.14. Load classifications may be obtained from Refs. [32.4] and [32.5] or from manufacturers' literature.

TABLE 32.14 Silent Chain Service Factors

Load classification	IC engine with fluid coupling or electric motor 10 hr/day	IC engine with fluid coupling or electric motor 24 hr/day	IC engine with mechanical drive 10 hr/day	IC engine with mechanical drive 24 hr/day	IC engine with torque converter 10 hr/day	IC engine with torque converter 24 hr/day
Very smooth	1.0	1.3	1.2	1.5	1.4	1.7
Mild shock	1.2	1.5	1.4	1.7	1.6	1.9
Moderate shock	1.4	1.7	1.6	1.9	1.8	2.1
Heavy shock	1.6	1.9	1.8	2.1	2.0	2.3

Calculate Design Power. Obtain the design power by multiplying the average power times the service factor from Table 32.14.

Make Preliminary Chain Selection. Enter the chart, Fig. 32.11, with design power and the speed of the small sprocket to make a preliminary chain selection. The solid lines on the chart represent the maximum horsepower per inch of width for each silent-chain size when operating on a 21-tooth small sprocket. The dashed lines represent the minimum and maximum recommended speeds for each silent-chain size.

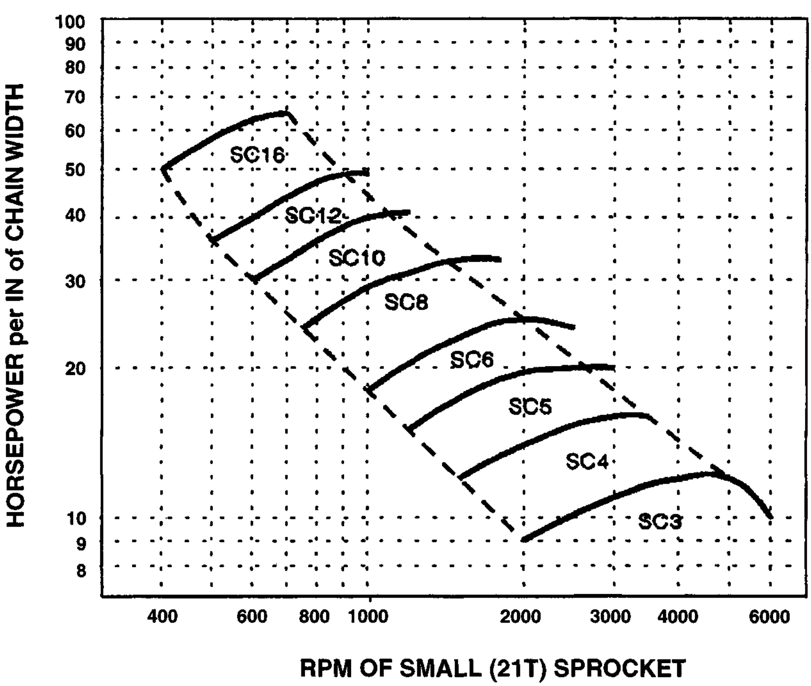


FIGURE 32.11 Silent chain selection chart.

Select Small Sprocket. Refer to the horsepower tables in Ref. [32.4] or [32.5] or in manufacturers' catalogs to select the small sprocket. Use an odd number of teeth in the small sprocket whenever possible. More than one selection will work well in most situations, so check the tables to see if changing the number of teeth might yield a more economical or more convenient selection.

Consult sprocket manufacturers' catalogs to ensure that the bore in the small sprocket will accommodate the shaft. If it will not, a larger sprocket must be selected.

Select Large Sprocket. Determine the number of teeth required on the large sprocket by multiplying the number of teeth on the small sprocket by the speed ratio. Ensure that the selected large sprocket will fit within the available space and clear any obstructions. If there is an interference, a different chain and sprocket combination may be necessary.

Make Final Chain Selection. Choose the most suitable drive from the alternatives selected earlier. The final choice may be based on economics, performance, efficiency, space utilization, or a number of other considerations. Computer programs are available that automate the preliminary selection process and analyze the alternatives based on parameters provided by the designer.

Calculate Chain Length. Calculate the chain length from Eq. (32.1). More accurate chain lengths may be obtained from equations in Ref. [32.5] or in manufacturers' literature. For drives with three or more sprockets, chain length may be obtained using graphical techniques, geometric layouts, computer programs, and certain CAD packages.

Determine Lubrication Type. Select the proper type of lubrication from the tables in Ref. [32.4] or [32.5], manufacturers' literature, or Sec. 32.4. It is extremely important to provide adequate lubrication to a silent-chain drive. Selecting an inferior type of lubrication can drastically reduce the life of the drive. In addition, because silent-chain drives generally operate at higher speeds than roller- or engineering steel–chain drives, inadequate lubrication can cause serious damage to the drive or to the machine in which it is used.

32.8.3 Horsepower Ratings of Silent-Chain Drives

Conditions for Ratings. The silent-chain power ratings presented here are based on the following conditions:

1. Standard chain listed in Ref. [32.4]
2. Service factor of 1
3. Chain length of 100 pitches
4. Use of recommended lubrication type
5. A two-sprocket drive, driver and driven
6. Sprockets properly aligned on parallel, horizontal shafts and chains
7. A clean, nonabrasive environment
8. Approximately 15 000 hours service life

Horsepower Ratings. Silent-chain power capacity ratings are stated in terms of horsepower per inch of chain width, and they vary with the chain pitch, number of teeth on the small sprocket, and speed of the small sprocket. The ratings consider fatigue strength of the chains, wear resistance of drive components, adequacy of lubrication, and effects of speed and chordal action. The equations for silent-chain ratings are not published, as those for roller-chain ratings are, but complete tables of power ratings for standard silent chains are shown in Ref. [32.4]. Figure 32.11 is a silent-chain quick-selection chart, using an abridged version of the ratings.

REFERENCES

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32.4 ANSI B29.2M-1982(1987), "Inverted Tooth (Silent) Chains and Sprockets," American Society of Mechanical Engineers, New York, 1982.

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