12

CHAPTER

Belts and Pulleys, Chains and Sprockets, Gears and Gearboxes

CHAPTER OUTLINE

LEARNING OBJECTIVES

After completing this chapter, you will be able to:

- ☐ Describe how belt drives transfer power.
- ☐ Summarize the various types of belts.
- ☐ Describe attachment and removal methods for sheaves.
- ☐ Describe how to tension a belt.
- ☐ Describe how to align sheaves.
- ☐ Summarize the proper storage of belts.
- ☐ Identify common factors that lead to belt wear and failure.
- ☐ Summarize the operation of a chain drive.
- ☐ Identify the various types of chains.
- ☐ Explain the function of sprockets.
- ☐ Describe how to tension a chain drive.
- ☐ Discuss the common lubrication methods for chain drives.
- ☐ Summarize the function of gears.
- ☐ Identify the common elements and measurements of gears.
- ☐ Discuss the differences between various types of gear.
- ☐ Explain how a worm drive operates.
- ☐ Discuss considerations for gear lubrication.
- ☐ Explain the purpose of backlash and axial runout measurements as part of gear maintenance.

TECHNICAL TERMS

addendum	pitch
backlash	pitch circle
belt	positive drive system
chain pitch	pressure angle
chordal action	pulley
circular pitch	sheave
clearance	sprocket
dedendum	static balance
diametral pitch (DP)	throating
dynamic balance	undercutting
gearbox	working depth
lead	worm
overhung load	worm drive
pinch point	worm gear

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Power transmission methods using belts, chains, and gears are highly engineered and have developed over many years, with improvements along the way. While the methods are highly reliable, proper installation, maintenance, and inspection are key to ensuring their reliability. From the smallest miniature gear drives on old clocks to the largest gears used on power trains aboard ships, these types of drives surround us. In this chapter, we will discuss the use and components of belt drives, chain drives, and gear drives, as well as the proper maintenance of each type of drive.

12.1 BELT DRIVES

Any power transmission system relies on the transfer of power from a driver, through an intermediary element, and to the driven machine. The intermediary element can be a coupling, belt, chain, shaft, or even fluid medium. Due to the design of these systems, safety issues, such as pinch points, are an inherent danger.

The following are some specific advantages of belts compared to other methods of power transmission:

- Belts typically involve less regular maintenance.
- Belts are usually easier to replace.
- When properly aligned, belts have a very long life.
- Belts can be used over a wide range of speeds and horsepower.
- Using timing belts is effective when exact mechanical speed is needed.

However, belt drives inherently have a unique set of disadvantages:

- Overtensioning a belt places excessive load on bearings.
- Exposure to environmental elements and other chemicals can significantly reduce belt life.
- If not properly applied and designed, a belt drive can induce vibration.
- Improperly storing belts can reduce their life.

Belt drives transfer power using the friction created between the belt and pulleys. **Figure 12-1** illustrates the details of a typical belt. The friction is developed through the contact of the sidewall (or edge) of the belt to the inside area of the pulley. Power is transferred through the tensile cords of the belt to the other pulley through friction. Anything that damages the friction surface of the pulleys, the contacting belt surface, or the belt's tension members will affect belt life. The top-band material provides rigidity to the belt to help prevent it from turning or rolling over. The molded notches increase the flexibility of the belt, increase the surface area, and help to dissipate heat developed from friction between the belt and pulleys.

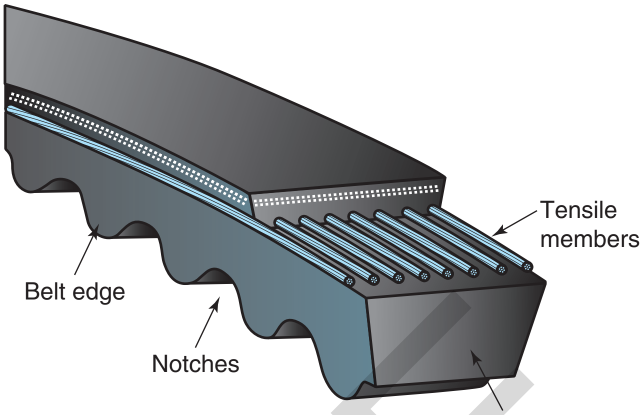

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Figure 12-1. Friction is developed through contact of the sidewall, or belt edge, with the inside area of the pulley. Molded notches increase belt flexibility and surface area and help dissipate heat.

> **SAFETY NOTE**
> **Pinch Points**
>
> ***Pinch points*** are places between moving parts or between a moving part and a stationary part within a machine where loose clothing and body parts can be caught. If not properly guarded, pinch points may cause serious bodily injury, in addition to damaging tools and clothing. Never operate a machine without the safety guards in place. Always reinstall the machine guards after maintenance and before starting any machine.

12.1.1 Belts

Belts are continuous bands used to transfer power from one pulley wheel to another. A wide range of belts are manufactured to match the variety of applications (**Figure 12-2**):

- **V-belts.** These are general-use belts made of rubber compounds, nylon, and various tensile members. The tapered sides of the belt contact the sheaves. Standard (classical) V-belts offer less contact area than narrow-groove (wedge) V-belts offer.

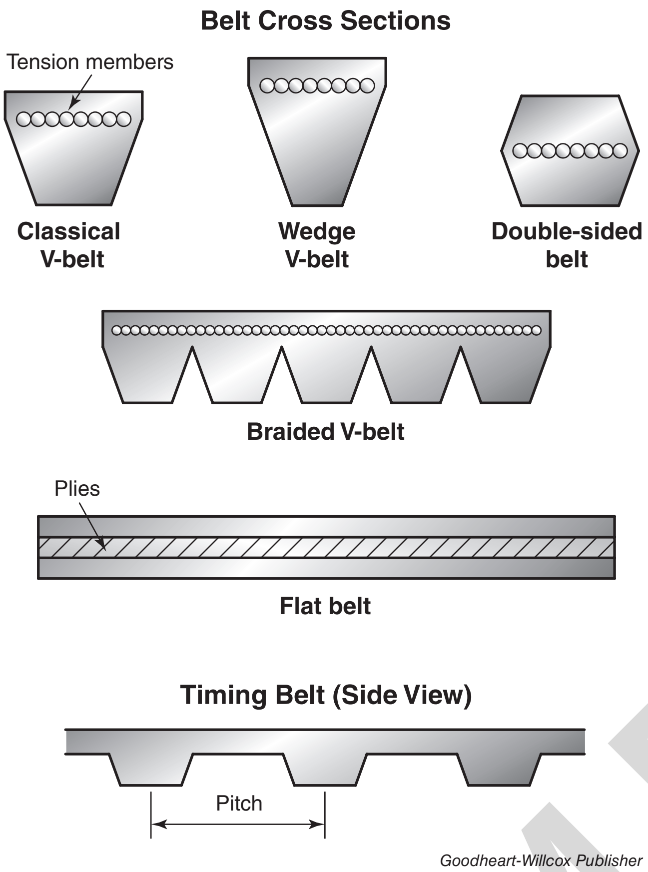

Figure 12-2. The type of belt used in a belt drive system depends on criteria such as system design, the forces and speeds of the drive system, the length of the belt, the available space, and environmental conditions.

- **Double-sided belts.** These belts are used for power transmission through multiple bidirectional loading sheaves. They can be octagonal, round, and double V-belt in design and are made of rubber compounds, nylon, and various tensile members.
- **Multiple belts.** These belts are used in industry for higher-horsepower applications. They are made with multiple layers, stronger tensile members, and a backing that prevents the belt from rolling and turning over. Multiple belts are also called *banded belts*.
- **Flat belts.** These belts are used with machinery that operates at lower speeds and can be a linked belt or truly flat. Belts may be made of leather, polyurethane, or other materials.
- **Timing belts.** These belts are used specifically with timing sheaves and are made of neoprene, nylon, and fiberglass.
- **Synthetic belts.** These belts are lighter, with a smaller cross section than other belts, and they can run at higher speeds. Synthetic belts can be made of a combination of materials, including polyurethane, nylon, rubber, fiberglass, neoprene, and others. They are also called *poly belts*.
- **Variable speed belts.** These belts are used with variable speed sheaves and are constructed of higher-strength nylon and rubber compounds.

TECH TIP

V-belts

A V-belt should ride high in the groove and not touch the bottom of the sheave.

Most belts have embedded tension members. These tension members transmit most of the power from the drive sheave to the driven sheave. When measuring a belt's length, ***pitch circle*** represents the length of a belt at the location of the tension members. For a timing belt, ***pitch*** is the distance between the same location on adjacent teeth.

The numbering system used for belts depends on the belt type and the manufacturer. There are some standard designations for belts, but the numbering and identification system used for some belts is manufacturer-specific. See **Figure 12-3**. Always refer to the manufacturer for details about belt size, use, construction, and compatibility. Keep in mind that while some belts may have a similar cross section, they are likely not rated to transfer the same power. For example, an "A" belt (conventional belt) has the same cross section as a 4L belt (fractional horsepower belt), but these belts have different ratings and cannot be interchanged. **Figure 12-4** offers more general guidance for reading belt numbers.

TECH TIP

Using a Single Belt Manufacturer

In industrial settings, there are benefits to sourcing all your belt needs to one company. Having numerous brands of belts operating various machines in a facility can increase the complexity of maintenance.

Belt Numbering and Identification	
Belt Type	**Designations**
V-belts	Fractional: FHP, 2L, 3L, 4L, 5L Standard or conventional: A, B, C, D Narrow V: 3V, 5V, 8V
Double-sided	Numbering depends on the manufacturer
Multiple	Standard sizes: 3V, 5V, 8V, A, B, C, D
Synthetic	Imperial sizes: J, K, L, M Metric sizes: 3, 5, 7, 11
Variable speed	Identified by top width of belt, angle of belt, OD, and length
Timing	Specified by pitch, pitch length, and width

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Figure 12-3. There are some common designations for belt numbering and identification, but always refer to the manufacturer for belt specifications and compatibility.

Clarification of Difference between Timing Belts and Poly Belts

Figure 12-5 illustrates poly belts and timing belts. Note that the timing belts have sharp molded edges, whereas the poly belts have a more rounded molded tooth profile. The sharp edges of the timing belt ensure complete engagement with the sheave (pulley), which has the same tooth profile. The poly belt sheaves also have an exact curved profile to properly engage with the curved teeth of the poly belt. These belts are not interchangeable.

12.1.2 Pulleys and Sheaves

A ***pulley*** is a simple machine consisting of a wheel and axle assembly used to transfer power through a belt or cable that sits along the edge of the wheel. A ***sheave*** is

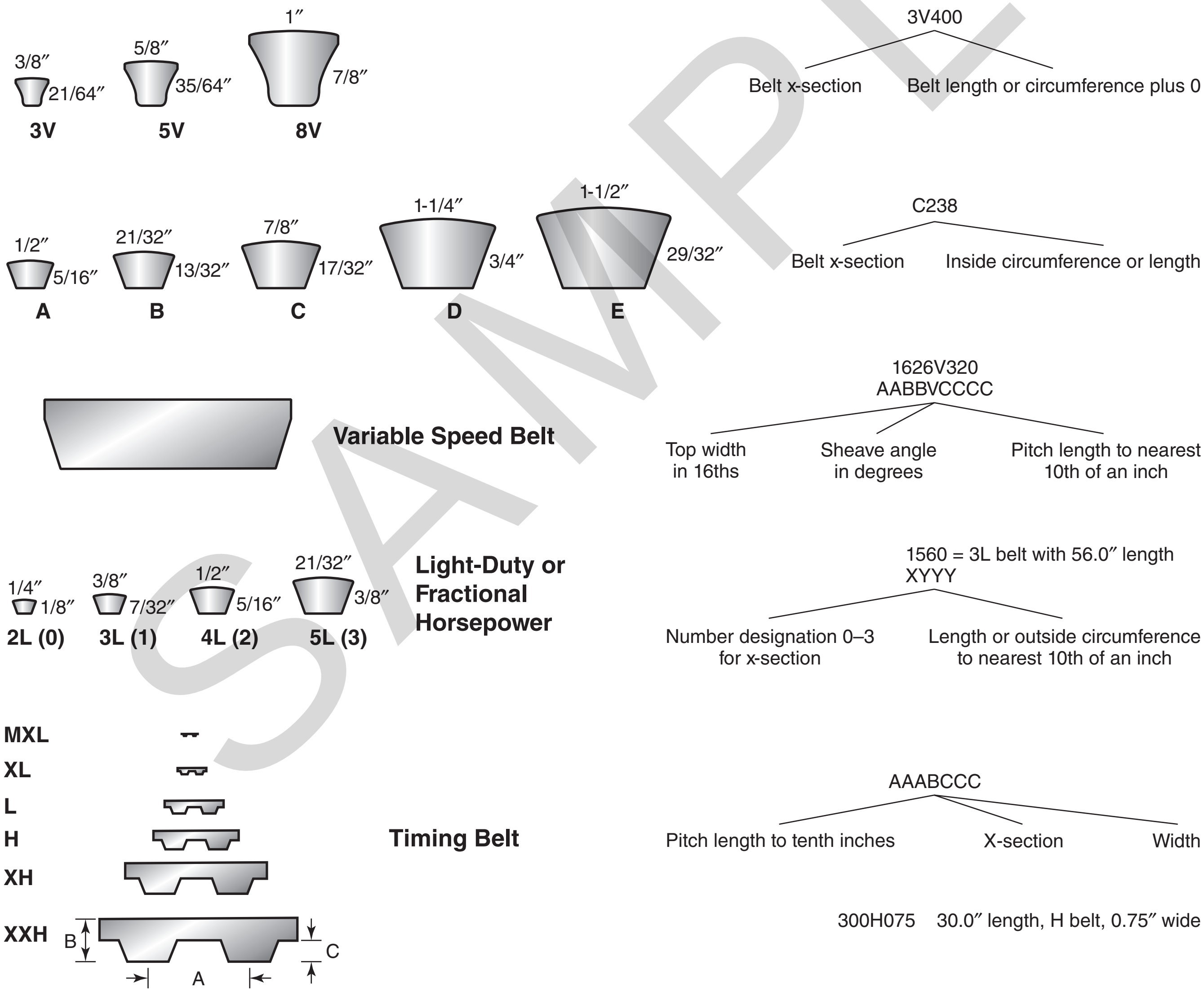

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Figure 12-4. Manufacturers often use unique numbering for their belts, but some general guidance for interpreting numbering is provided here.

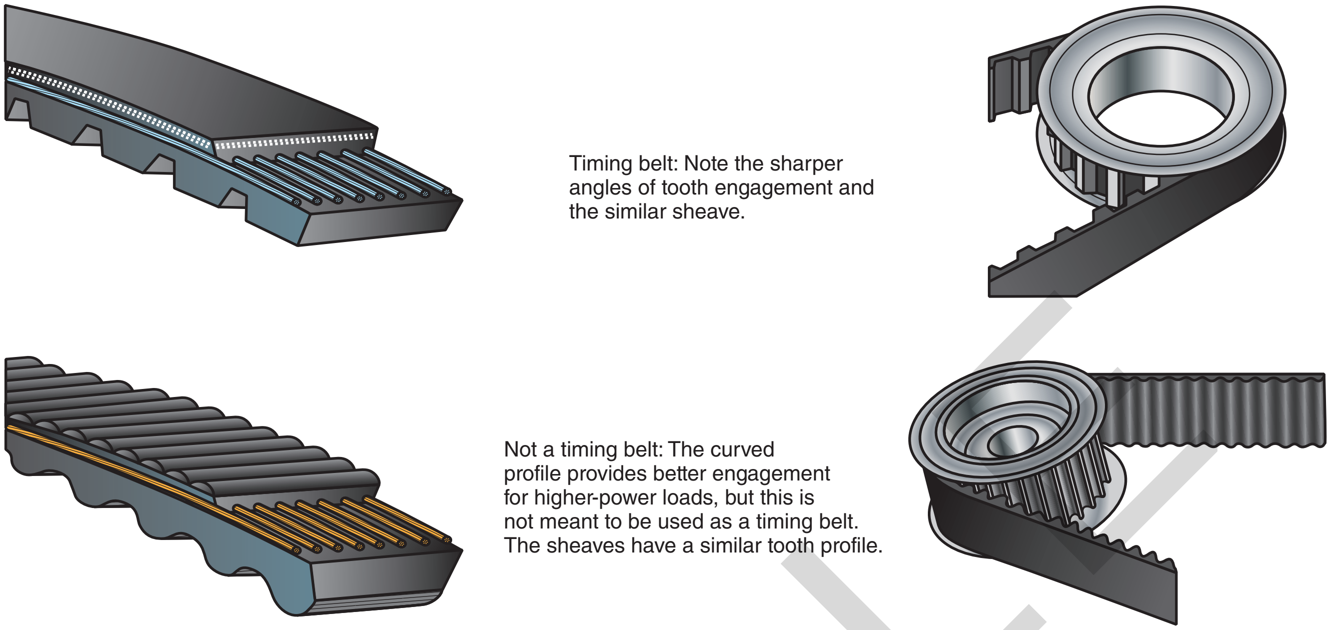

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Figure 12-5. Timing belts and sheaves have sharper angles that ensure complete tooth engagement.

the wheel component of a pulley that contains a groove or channel in which a belt or cable sits. Sheaves can be manufactured by casting, pressing, or machining and can be made of steel, stainless steel, polyethylene, cast iron, aluminum, or other materials. Categories include single-belt sheaves, multiple-belt sheaves, poly V-belt sheaves, and variable speed sheaves. See **Figure 12-6**.

Larger sheaves and those meant for higher speeds are typically dynamically balanced from the factory. ***Dynamic balance*** is the ability of an object to stay in balance while rotating. Many smaller sheaves and those limited in speed capability are static balanced. ***Static balance*** is the ability of an object to maintain balance while stationary on its axis.

> **TECH TIP**
> **Timing Belt Sprockets**
>
> Timing belt drive systems use sprockets rather than sheaves. Sprockets have teeth along their circumference that mesh with teeth on the timing belt. Sprockets are used in chain drive systems as well. When using a timing belt, the pitch of both sprockets must match that of the belt, just as two gears that mesh must have the same pitch. Timing belt drive systems are ***positive drive systems***, meaning no slip occurs between the belt and the sprocket.

Attachment Methods

Attaching a sheave to a shaft is typically accomplished by one of the following methods:

- One or more setscrews with a key
- Quick detachable (QD) bushing or split-taper bushing
- Taper-lock bushing

Setscrew attachment methods are normally used with lighter loads, while applications that have heavier or shock loads use one of the bushing methods. QD bushings and split-taper bushings are both flanged bushings. QD bushings have a single split through the bushing and the flange, while split-taper bushings have splits in the bushing but not the flange. Taper-lock bushings are flangeless bushings with a tapered outer surface and a split along their length. See **Figure 12-7**.

Bushings have threaded and non-threaded holes around the tapered surface. The non-threaded holes of the tapered hub are used with the threaded holes of the corresponding sheave. The threaded holes of the tapered hub are used to allow the fasteners to press against the sheave to allow development of force to separate and remove hubs and sheaves. With taper-lock bushings, the threaded hole is made up of the sheave *and* bushing, and exact alignment of the threads is important in order to tighten the fasteners.

QD and split-taper bushings are normally installed using conventional mounting, but some bushings can

Light-duty, spoke-type single-belt sheave

Variable pitch, light-duty, double-belt sheave

Photo courtesy TB Wood's–Altra Industrial Motion

Figure 12-6. These two types of sheaves are common in industry.

QD bushing

Taper-lock hub

Photo courtesy TB Wood's–Altra Industrial Motion

Figure 12-7. Both QD bushings and taper-lock hubs compress the hub onto the shaft to develop clamping force.

be installed using reverse mounting. In conventional mounting, bolts are inserted through the sheave and threaded into the bushing's flange. The assembly is installed on the shaft with the bushing's flange toward the motor. In reverse mounting, the bolts are inserted through the bushing's flange and threaded into the sheave. The assembly is then installed with the bushing's flange facing away from the motor. See **Figure 12-8**.

All of these bushings develop clamping power in similar ways. As the bolts are tightened, the tapered surfaces of the bushing and the sheave/hub are pressed together. This pressing action tightens the parts against one another and causes the bushing to tighten around the shaft as the split in the bushing is compressed.

12.1.3 Designing a Belt Drive

When properly designing a drive, the following conditions are taken into account:

- The application—both the type of loading and service time
- Speed of both the drive and driven machine
- Amount of horsepower being transferred
- Distance between the pulleys

Operations that involve higher power, longer running times, and more severe duty typically require larger

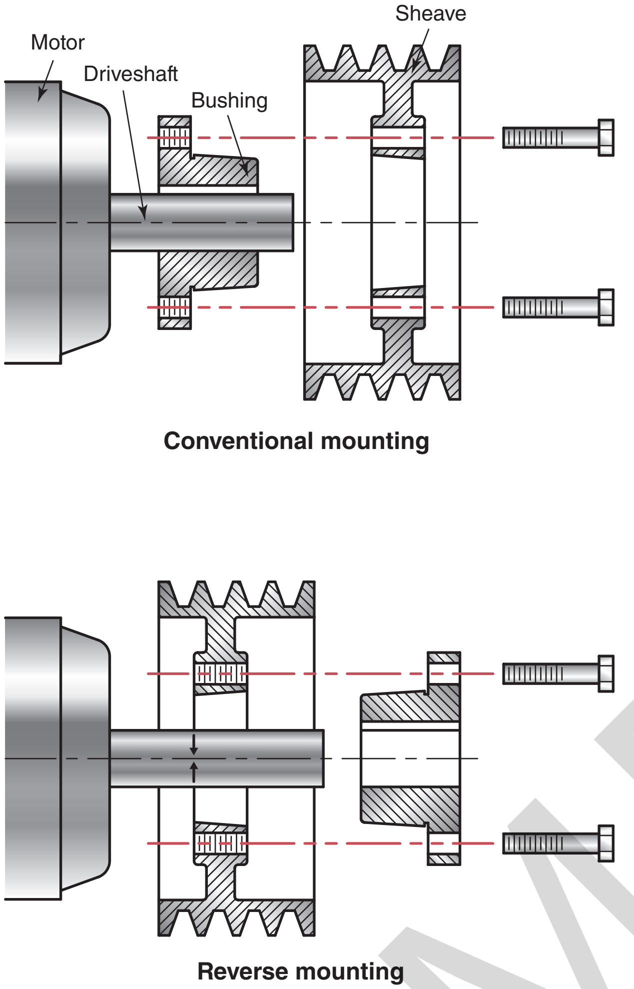

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Figure 12-8. Some bushings can be installed in the reverse mount position. Always check the manufacturer's information before using a reverse mount configuration.

belt cross sections or multiple belts. When designing drives with multiple shafts and sheaves, a detailed engineering analysis is performed to calculate belt lengths, idler positioning, and proper sheaves.

The speed of the drive and driven machine are important considerations when designing a drive. The following calculation is used to determine these speeds:

$$D_1 \times rpm_1 = D_2 \times rpm_2 \tag{12-1}$$

where

D_1 = diameter of driver sheave
rpm_1 = driver speed
D_2 = diameter of driven machine sheave
rpm_2 = speed of driven machine

Using this equation, knowing any three of the variables allows us to calculate the fourth variable. For example, if we know the driver speed (rpm_1), diameter of the driver sheave (D_1), and diameter of the driven machine sheave (D_2), we can calculate the speed of the driven machine (rpm_2). Note that the *rpm* of the driven machine does not affect the driver. The *rpm* of the driver is a fixed value, unless the motor is driven by a variable speed drive or other variable method.

TECH TIP

Tightening Bushings

When installing a sheave on a shaft, always torque the bolts to the value recommended by the manufacturer. When using flanged bushings, a gap remains between the face of the flange and the sheave/hub. The correct torque is critical in establishing a proper fit.

PROCEDURE

Installing a Sheave

Always refer to the manufacturer's installation instructions when installing bushings and sheaves. The following is a general procedure:

1. Inspect, clean, and deburr the seating area of the shaft, outside diameter (OD) and inside diameter (ID) of the bushing, ID of the sheave, and any threaded fasteners or their mating surfaces.
2. Decide on the sheave and bushing orientation. In some cases, the bushing and sheave may be assembled before being placed on the shaft. In other cases, the bushing and sheave are placed on the shaft before the connecting bolts are installed.
3. Install the bolts connecting the sheave/hub and bushing so they can be accessed from the side facing away from the motor. If the bushing is inserted into the sheave from the motor side, align the non-threaded holes in the sheave with the threaded holes in the bushing. Pass the fasteners through the non-threaded holes in the sheave and thread them into the bushing until hand tight. If using reverse mounting and the bushing's flange is facing out (away from the motor), align the

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non-threaded holes in the bushing with the threaded holes in the sheave. Install the bolts and hand tighten.

4. Position the assembly more precisely on the shaft and key, if needed.
5. Carefully tighten the threaded fasteners to the proper torque.
6. Tighten setscrews to the key.

TECH TIP

Lubrication and Anti-Seize Compounds

Do not use lubrication or anti-seize compound in any part of the assembly, including threaded fasteners. Using lubricant can result in excessive force being placed on the assembly and may cause damage. Lubricating fasteners lowers the allowable torque because they thread more easily. It can also cause damage or breakage, particularly with fine threaded fasteners.

PROCEDURE **Removing a Sheave**

To remove a sheave from a shaft, complete the following steps:

1. Remove all threaded fasteners.
2. Loosen all setscrews.
3. Insert threaded fasteners into the appropriate jacking positions.
4. Slowly apply equal force to all jacking screws until the assembly separates. Be mindful that the assembly may come apart quickly. Do not allow the assembly to fall and impact anything, which can easily damage cast sheaves.
5. Clean all mating surfaces, but do not apply lubricant.
6. If contamination is a concern, place components into a sealable plastic bag and seal a plastic bag over the shaft seating area with tape.

12.2 BELT DRIVE MAINTENANCE

The simplest type of drive consists of one drive pulley and one driven pulley, with no guides or tension members between them. As speed ratios increase, one pulley becomes substantially larger than the other. If the speed ratio becomes too high, the belt on the smaller pulley is more likely to slip, especially on start-up, due to decreased contact area.

An *idler pulley* guides or tightens a belt in a pulley arrangement. See **Figure 12-9**. When positioned to push in on a belt, the idler pulley can alleviate some slippage by increasing contact area. However, this positioning reduces belt life because the belt is forced out of its normal bend it experiences traveling around the sheaves. An idler pulley can guide and provide tension when positioned to push out on a belt. This positioning does not reduce belt life, but it does decrease the contact area on both the drive and driven pulleys.

12.2.1 Belt Tensioning

The most common method of belt tensioning is to allow 1/64″ of belt deflection per inch of span, measured center to center, between the sheaves. This should include the proper amount of force placed at the center span on the belt.

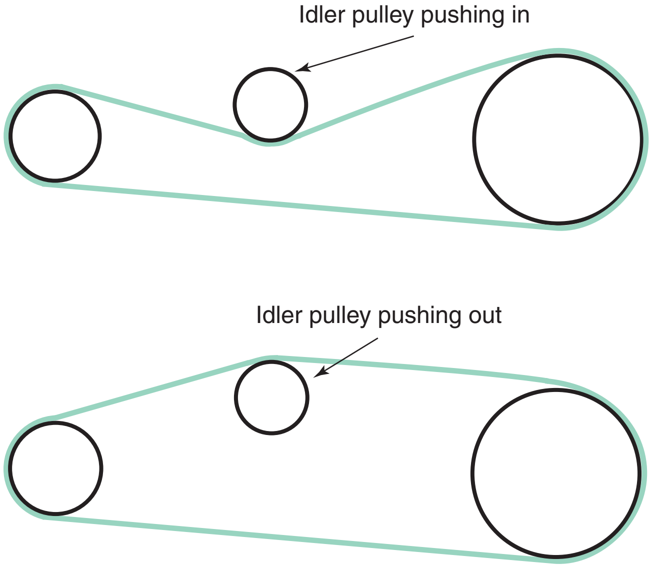

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Figure 12-9. An idler pulley can alleviate slippage and provide tension when properly placed in a pulley arrangement.

PROCEDURE **Belt Installation**

For the initial installation of a belt, perform the following:

1. Move one of the machines to reduce the span distance to a point where the belt(s) may be easily placed on the sheave without stretching or prying. Prying a belt over a sheave to reduce the time to install can easily damage the tensile members of the belt and result in early failure. The damage to the tensile members is not readily observed.
2. Find the proper force deflection amount using the manufacturer's tables.
3. Slowly and evenly move the machines apart while rotating the belt through the sheaves by hand. This will help seat the belts within the sheaves.
4. Align the sheaves before maximum tension is reached.
5. With sheaves aligned, increase tension to the proper amount to achieve belt deflection.
6. Recheck alignment.
7. After 24 hours of run time, recheck and readjust belt tension, if needed.

On larger drives, proper tension may be difficult to achieve without specialized measuring instruments. Belt suppliers have several belt tension instruments that can be used to very accurately measure deflection, force, and distance.

TECH TIP **Belt Tension**

Timing belts and poly belts typically need less tension than conventional V-belts. Check with manufacturers to determine the exact recommended tension force and deflection.

Some belts may slip at start-up, especially those that immediately accelerate to full speed (across-the-line starters) with high-torque loads. Belt slippage at start-up may be inevitable, and excessive tension force should not be used to try to prevent it. Excessive tension force places further load on bearings because of the overhung load. An ***overhung load*** is any load perpendicular to the shaft that is applied beyond the outermost bearing of the shaft.

Belt tension may need to be adjusted as a belt wears in and seats in the groove of the sheave. Also, the drive will develop a tight and slack side depending on the rotational direction of the driver. It is perfectly normal for this to happen.

12.2.2 Sheave Alignment

Prior to alignment, check the radial and axial runout of the sheave with a dial indicator. Excessive runout affects operation and could induce vibration. Radial runout should be limited to 0.010″ total indicator reading (TIR), and the axial runout limit is 0.005″ TIR. If runout checks of the sheave reveal excessive runout, check shaft runout to ensure the shaft is not bent. **Figure 12-10** summarizes these concepts.

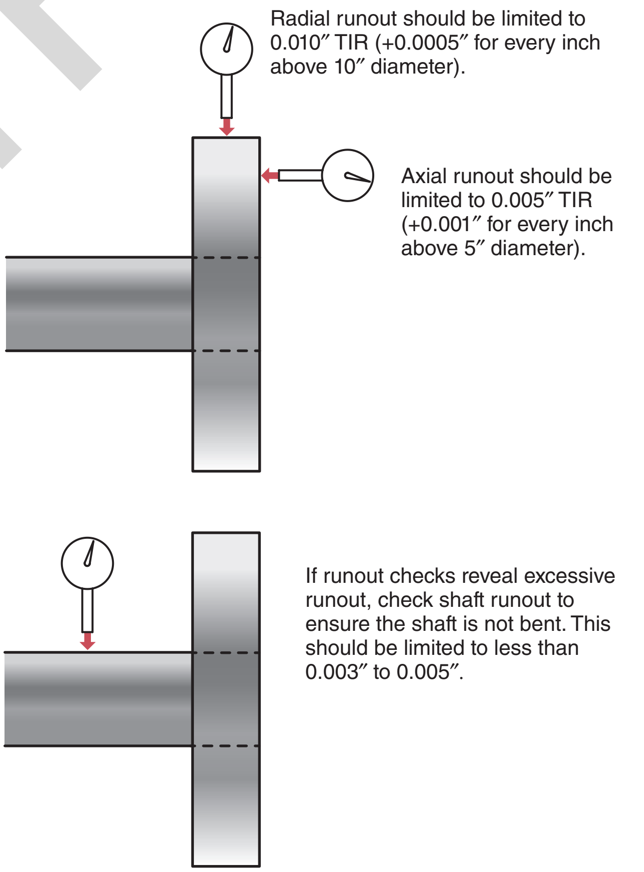

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Figure 12-10. Use a dial gauge to check radial and axial runout between shafts and sheaves.

Under optimal circumstances, both the drive and driven shafts are parallel to the baseplate. Misalignment is typically a combination of both angular and parallel discrepancies, which are illustrated in **Figure 12-11**. Misalignment can result in sheave and belt wear and shortened belt life. The usual method is to align the faces of sheaves with a straightedge, but the ultimate purpose of the alignment process is to align the centers of the sheave grooves. The straightedge should touch four points on the two sheaves when checking alignment.

TECH TIP
Allowance for Face Thickness

If the faces of the sheave are of different thickness, make an allowance to offset the alignment to align the sheave grooves.

PROCEDURE **Sheave Alignment**

The following is a general procedure to achieve sheave alignment:

1. Make both shafts parallel to the baseplate, if possible.
2. If shafts are vertical, check them with a machinist's level.
3. Using the driven machinery as the stationary item, use a straightedge to project to the motor sheave.

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4. Move the motor until one edge of the sheave contacts the straightedge. Depending on the motor base, shims may be needed.
5. Pivot the motor until both edges of the sheave contact the straightedge. Shims may be needed again, depending on the orientation of the motor shaft.
6. Evaluate the need for offset if dealing with a variable sheave or sheaves with different face thicknesses.

Note: Normally, the motor or driver is easier to move into proper alignment. Once the shafts are parallel, evaluate whether it is easier to move the driver into final alignment or, if possible, to reposition sheaves on the shaft to reduce offset. Parallel misalignment should be limited to less than 1/2 degree, which is approximately 1/10″ of parallel offset per foot of shaft distance. In the end (if sheaves are similar), a straightedge should touch each sheave at two points (four points total).

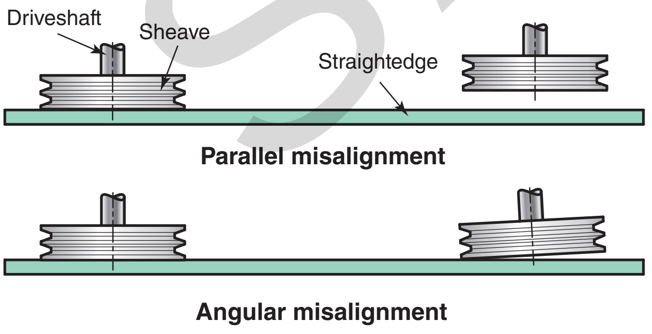


Figure 12-11. Sheaves should be aligned on both the parallel and angular planes. Parallel misalignment should be limited to less than 1/2°.

SAFETY NOTE
Drive Guards

Always ensure drive guards are back in place before starting the drive.

12.2.3 Troubleshooting Belt Drives

The most common cause of drive failure is a lack of or improper maintenance. Become fully familiar with the belt manufacturer's publications and recommendations to ensure a proper life span for the drives. Regularly scheduled drive inspections are an important step in increasing machinery reliability.

Properly storing belts will help maintain their integrity until they are needed for operation. Consider the following when storing belts:

- Store belts in a temperature-controlled area, away from sunlight and sources of heat.
- Keep belts in the original box if possible, and do not place excess weight on top of the box.
- Hang belts, if needed, with the full radius of the belt hanging unobstructed in its natural shape.

- Store belts away from ozone-producing machinery, such as brushed motors.

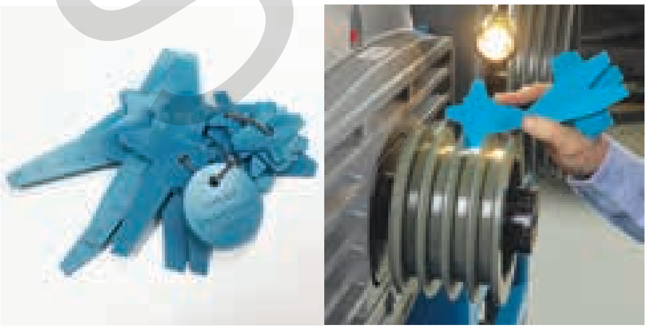
Belt wear and failure can be caused by some common factors, including misalignment, improper tensioning, high ambient temperatures, and worn sheaves. Broken belts or tensile members are the result of immediate loading or improper installation. Remember that prying a belt over or onto the sheave is not an acceptable practice. Worn belt edges point to alignment problems. Belt wear can also occur if the belt does not properly match the sheave. Top belt wear can result in idler bearing failure and the idler pulley sliding, instead of pushing, against the belt. Belt cracks and flaking can be caused by exposure to environmental factors and volatile compounds.

Check sheaves for wear each time a belt is replaced. Excessive sheave wear is often visible as polished sheave walls. Belt manufacturers may provide sheave gauges to check for groove wear, **Figure 12-12**. Dished, cupped, or worn sheaves will leave a gap between the gauge and sidewall of the sheave. A gap larger than 1/32″ calls for sheave replacement. Sheave grooves should be clean, dry, and free of debris and lubricant. Variable speed sheaves may need lubricant on the threads that allow the sheave to expand and contract. Do not overlubricate the threads. If lubricant from the threads is deposited on the belt, it will reduce belt life.

TECH TIP

Do Not Hammer a Sheave

Never use a hammer on a sheave. Hammering a cast sheave or pulley can result in unseen cracks, which can cause it to fail when at speed and under load.



Sheave gauges Checking a sheave

Timken Belts

Figure 12-12. Checking sheaves for wear is just as important as checking belts for wear.

12.3 CHAIN DRIVES

Chain drives are designed to lock into the sprocket of both the drive and driven machinery, which provides a definite speed ratio. Chains are used in various forms for applications such as conveyor systems, agricultural machines, escalators, bulk material handling, automotive applications, and industrial power transmission. Industrial power transmission chains are typically made from sheet steel by punching, stamping, and forming operations, followed by heat treatment.

GREEN MAINTENANCE

Recycling Steel

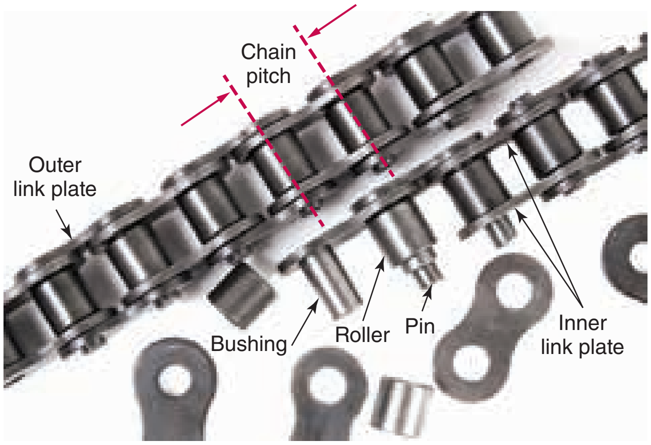
Steel is the most recycled resource in the world. The rate of steel recycling in the United States is around 85 percent. In addition to this high recycling rate, steel offers eco-friendly benefits throughout its life cycle. For example, wastewater and waste material from steel manufacturing sites can be recovered and reused in other applications. A facility can reduce its environmental footprint by contributing to steel recycling programs. When tools and steel machine components fail or are at the end of their service life, collect and recycle them.

12.3.1 Chains

Using chain drives for industrial purposes provides several advantages. Chain drives are typically used for slower-speed drives, but they can transfer more horsepower than a similarly sized belt drive. A chain drive is a positive drive that maintains an exact speed ratio. Since chains can be broken at any spot, or a master link is included, maintenance is less time consuming. Once the drive is aligned, it rarely needs to be realigned. Additionally, chains are more resistant to environmental conditions than belts.

Types and Design

Standard roller chain is made from two different subassembly links. The first link contains the bushings, rollers, and inside side bars. The second link connects these together with pins and outside side bars. Pins may be hardened, depending on the chain's intended use. **Figure 12-13** shows the components of standard roller chain.



Bayurov Alexander/Shutterstock.com

Figure 12-13. To assemble a link of standard roller chain, a pin is inserted through the link plate and both a bushing and roller slide onto the pin. A link plate is fastened onto the end of the pin to complete the link assembly.

metwo/Shutterstock.com

Figure 12-14. The offset ends of chain fit together to create continuously connected links.

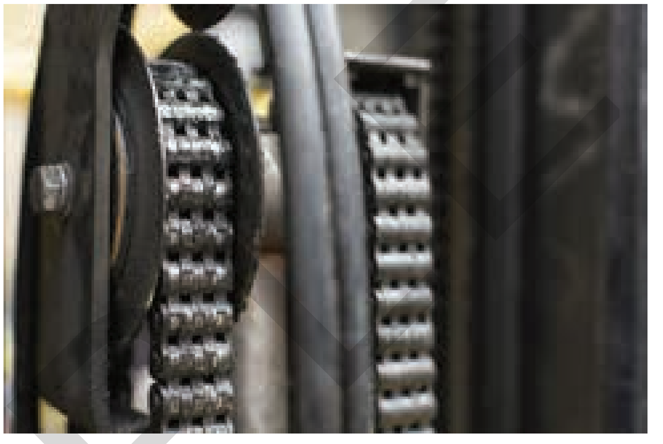


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Figure 12-15. Leaf chain is often used in lifting applications, such as on forklifts.

Roller chain is identified using a common standard that generally consists of a two-digit number. The first digit in the chain identification number represents the chain pitch. ***Chain pitch*** is the distance between the centers of the pins on each link. The first digit is the number of eighths of an inch (1/8″) in the chain pitch. For example, a chain with the number 80 would have a pitch of 1″ (eight one-eighths, or 8 × 1/8″).

The second digit indicates the type of chain: 0 for standard, 1 for light-duty, and 5 for rollerless. Multi-strand chains are numbered in a similar manner but include the number of strands in the designation. A 40-2 chain is composed of two side-to-side strands and has a pitch of 1/2″.

Single-strand chain strength, or ANSI average strength, is approximately the pitch squared and multiplied by 2.25 lb. Drives are typically designed so that a safety ratio of strength-to-load is 5:1 or 6:1. Heavy chain is labeled with a standard number followed by the letter *H*. Heavy chain is approximately 120 percent stronger than standard chain, having heavier link plates and induction-hardened pins.

In addition to the standard types of chain, other types commonly used in industry include offset, leaf, and silent chain. *Offset chain*, **Figure 12-14**, comes in a variety of standard pitch lengths. The side bars on each link of offset chain are offset to create a narrow end and a wide end when the side bars are paired. A bushing fits between the narrow side bars, which are then fit between the wide side bars and secured with a pin.

Leaf chain, **Figure 12-15**, is composed of heavier links with multiple side plates and strands to increase its strength rating. Leaf chain link plates are thicker than those in standard chain with the same pitch. The numbering system for leaf chain begins with the letters *BL* followed by three numbers that indicate the pitch and the number of plates. For example, a BL 823 chain has a pitch of 1″ and follows a pattern of 2 × 3 plates.

Silent chain is widely used in conveying applications and power transmission where higher speeds are needed. These chains are similar in appearance to leaf chains, but the profile of the links includes two included angles of 60°, as shown in **Figure 12-16**. Driving links connect the flank links, and guide links ensure proper alignment and mesh with sprockets. Silent chain is available with several forms of guide links, including center, double, or outside guides. Other forms of guide links are manufactured specifically for conveyor applications. These types can transfer power on both sides of the chain (duplex) and may not mesh with standard SC-type of silent-chain sprockets. Always refer to and follow the manufacturer's recommendations.

Standard pitches of silent chain are available, but measuring pitch on silent chain is different from measuring pitch on standard chain. The pitch of silent chain should be measured across three centers, or pins, and then divided by two. An example of how

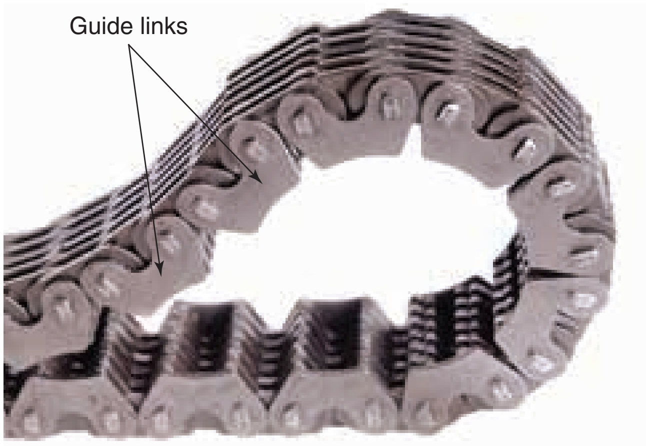

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Figure 12-16. The guide links on silent chain may be located on the outside edges of the chain or in the center of the row of links.

power transmission silent chain is labeled is shown in **Figure 12-17**. A matching sprocket to this chain would use the same number, followed by an additional number showing the number of teeth on the sprocket (SC 8 10-33).

Silent chain has less chordal action, and therefore less noise and vibration, than standard chain. ***Chordal action*** refers to the action that occurs when a straight chain enters and revolves around a sprocket. As the chain enters the sprocket, it engages a tooth and then is displaced vertically, or tilted, as the sprocket turns through a revolution until the chain leaves the sprocket. This change in the link angle, as compared to the straight links, changes the velocity of the link and promotes noise and vibration.

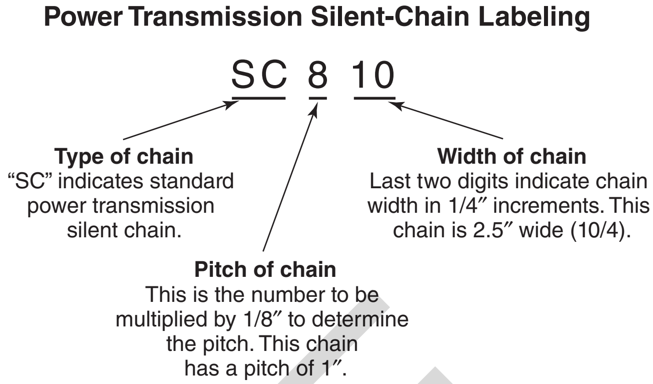

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Figure 12-17. The labeling of power transmission silent chain indicates the chain type, pitch, and width.

12.3.2 Sprockets

A ***sprocket*** is a gear or wheel with teeth that mesh with a chain in a chain drive system. In a chain drive system, the sprocket drives the chain to transmit rotary motion. A simple example of a chain drive system is a bicycle. The pedals drive a sprocket that moves the chain, which transmits rotary motion to sprockets that drive the rear wheel of the bicycle.

Sprockets are manufactured using machined steel, cast iron, or synthetic materials and are then hardened, depending on the application. They are classified into four different types: A, B, C, and D. Sprocket types are illustrated in **Figure 12-18**. Type A sprockets have no hub and are flange-mounted using threaded fasteners, or they may sometimes be welded. Type B sprockets have a hub on one side and are mounted using a keyway and setscrew for a plain bore, or using a tapered bushing with a tapered bore. Type C sprockets have a hub on

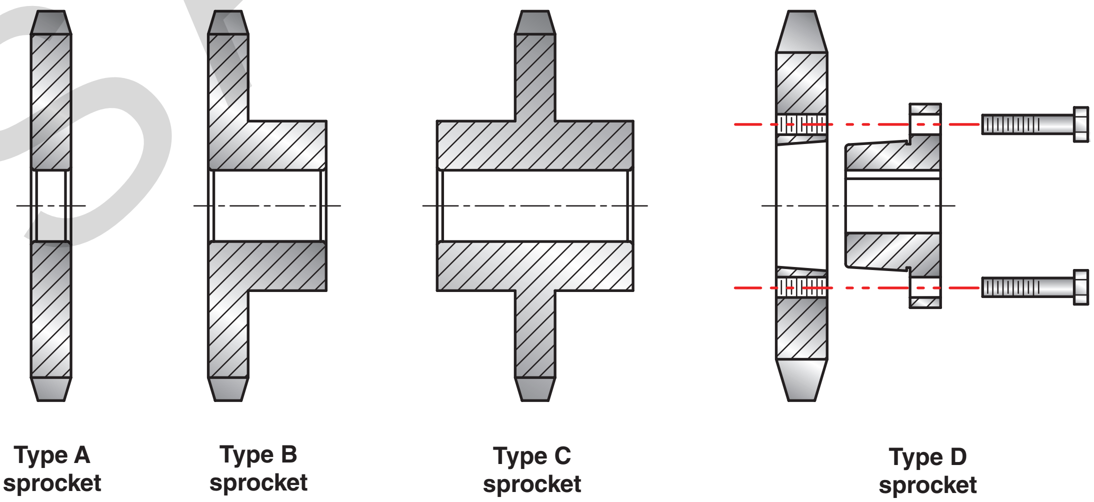

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Figure 12-18. Common types of sprockets may have no hub, a hub on one side, or hubs on both sides. Others may have a detachable hub/bushing.

both sides and can be mounted with either a straight or tapered bore. Type D sprockets are typically larger split sprockets, which allows for easier installation and maintenance.

The process of installing a sprocket on a shaft is identical to the process of installing a sheave, described earlier in this chapter. Always follow the manufacturer's installation procedures.

TECH TIP
Use Appropriate Sprockets

Silent chain meshes only with SC sprockets. Standard roller chain with multiple strands requires a specific sprocket with a corresponding number of rows of teeth.

12.4 CHAIN DRIVE MAINTENANCE

The two most common causes of chain drive failure are lack of lubrication and improper alignment. Both lubrication and alignment checks are regular tasks that should be familiar to all technicians. In addition, placing a chain drive in an environment for which it was not designed will impact the chain and sprocket life.

SAFETY NOTE
Lockout/Tagout

Never work on a chain drive unless it is locked out and tagged out. Always replace guards when maintenance is completed.

12.4.1 Tensioning and Initial Installation

On the initial installation of a chain, check the runout of the shaft and sprocket. Radial runout should be less than 0.004″ TIR. Face runout on machined sprockets should be limited to 0.010″ on sprockets up to 10″ in root diameter, adding an additional 0.001″ of runout for every additional inch in root diameter. For example, a sprocket with an 18″ root diameter would have a limit of 0.018″ for face runout.

Both the drive and driven shafts of a machine must be relatively parallel. This alignment can be performed before or after sprockets are installed, using similar methods to aligning sheaves. The more accurate the alignment, the less the wear on the chain and sprocket.

When placing the chain on the sprockets, it is usually easier if the connection is made on the top of the larger sprocket. The connection link depends on the manufacturer and size of the chain. Common methods of connecting links include using riveted pins, spring clips, retaining clips, and cotter pins. Spring clips and retaining clips, **Figure 12-19**, connect links using a flat clip that secures the pins to hold the link assembly of inside side bars, pins, and outside side bars together. Cotter pins, **Figure 12-20**, are inserted into the ends of each link pin to connect links and hold the link assembly together.

Figure 12-19. Spring clips and retaining clips are commonly used to connect links of drive chain.

Figure 12-20. A cotter pin can be used only with a drive chain pin that has been machined with a slot or hole specifically for a cotter pin.

Initial chain tension should result in approximately 2 percent play on one side of the center-to-center distance of the shafts. This is approximately 1/4″ of sag for every foot of shaft separation.

PROCEDURE

Checking Chain Tension

Tension should be checked using the following steps:

1. Place all slack on one side of the chain by slightly rotating sprockets in opposite directions.
2. Lay a straightedge across the top of the chain from one sprocket to another.
3. Apply pressure in the center of the span and measure the sag.
4. Adjust the center distance to reduce sag while maintaining alignment.
5. Check chain tension after 100 hours of run time following initial installation. Subsequent periodic maintenance should include a tension check.

12.4.2 Wear

Wear on standard roller chain is not linear. As a chain enters and leaves a sprocket, material gradually wears away from the surfaces of the pins and bushings, causing elongation, or stretch. The pitch length on the links with the bushings typically will not show much elongation. Elongation can be measured using a longer section of the chain and an accurate tape measure. Some manufacturers provide plastic rulers with indentations to check chain wear. Elongation should be limited to 3 percent. When the increase in a chain's pitch is greater than 2 percent, it is practical to start planning its replacement.

To correct a worn chain, replace the chain. Do not remove a link of the chain to eliminate elongation. Chain drives are designed for a certain chain pitch. Removing a link (or links) of the chain does not correct the wear and elongation of the remaining chain. The chain is still worn and stretched—you just made it shorter. The chain will continue to wear the sprockets.

TECH TIP

Measuring Chain Elongation

To measure a chain for elongation, pick an easy-to-use number of pitches. For instance, for a 1/2″ pitch chain, using 20 pitches should yield a measurement of 10″. The chain should be replaced if elongation reaches 3 percent, or just over a 1/4″ in this example. If 20 pitches measure over 10 1/4″, it is time to replace the chain.

12.4.3 Lubrication

Proper lubrication involves the proper amount of lubrication, proper method, proper lubricant selection, and proper replacement schedule. There are four main methods of lubrication for a chain:

- Drip
- Oil bath
- Oil flinger
- Forced lubrication

Using the *drip method*, lubricant is dripped onto the lower chain before entering a sprocket. This allows some time for the lubricant to penetrate into the bushings and pins. Drip rates can range from 5 to 20 or more drops per minute, depending on the speed of the chain. The drip method is acceptable for slower speeds, but higher speeds require more lubrication.

In an *oil bath*, the lower span of chain is submersed into oil at a depth of at least 1/2″. Only a small part of the chain needs to be submersed, preferably prior to engaging a sprocket on the lower side. This method works well for low or medium speeds.

An *oil flinger* disc is attached to the lower shaft and rotates with it. As the disc turns, it spins through the lubricant and flings it onto the chain using centrifugal force. The flinger disc may be used if a drive cannot be designed to incorporate an oil bath.

Forced lubrication uses a small pump and motor to pressurize the lubricant and spray it onto the chain. Use of this method adds a mechanical maintenance item to the technician's routine checks to ensure proper operation of the pump and motor.

Follow recommendations from the manufacturer regarding the type and viscosity of lubricant to use. The operating environment, load, speed, and temperature all factor into the proper lubricant for the application.

TECH TIP

Inspect the Lubricant

When changing the lubricant for a chain drive, inspect it for any excessive metallic particles. Lubricant should be clean and bright. If the lubricant is contaminated, determine what changes need to be made to better protect the drive from environmental elements, such as dust, grinding, and salt.

12.5 GEARS AND GEARBOXES

Gears transmit power between machines while changing rotation, speed, and torque. Gears can also change rotational movement to linear movement through the use of a rack and pinion. Basic gears have been used for a long time. However, modern advancements in engineering and manufacturing methods have allowed the use of internal gears, planetary gearing, and larger herringbone gears. In this section, we will examine the basic concepts of gear power transmission and maintenance concerns with gearboxes.

12.5.1 Gears

While gears come in a wide variety of sizes, there are common elements and measurements critical to their operation. Knowledge of these commonalities is important to understand how a gear works and what to do when troubleshooting system problems. Refer to **Figure 12-21** for common terms and dimensions related to gears.

On a gear, the *pitch circle* is a diameter measurement that includes only the portion of the gear that would make smooth contact with another gear. Typically, this includes the entire diameter of the gear below the ***addendum***, or the top half of the gear tooth. The ***dedendum*** is the length of a gear tooth below the pitch circle. The ***working depth*** is the entire length of the tooth, addendum plus dedendum, minus the clearance. When gears mesh, there is a certain amount of space between the top of the tooth on one gear and the bottom of the mating space on the opposite gear. This space is called ***clearance***. With the correct center-to-center distance between meshed gears, the gear pitch circles are tangent to one another.

In order to mesh, gears must have the same diametral pitch and pressure angle. ***Diametral pitch (DP)*** is the number of teeth per inch of length on the pitch circle. A large diametral pitch measurement indicates that a gear has small teeth. ***Pressure angle*** is the angle at which gear teeth surfaces mesh together. It is typically 14.5° or 20°. Meshing teeth must also have the same circular pitch. ***Circular pitch*** is the distance between a point on the face of one tooth to the same point on the next tooth, measured along the pitch circle.

During operation, it is expected that gears will operate smoothly. To ensure gear teeth do not bind when meshing, backlash is considered in the machine's design. ***Backlash*** is the side-to-side clearance between mating teeth, or the difference between the thickness of the tooth and the tooth space, as shown in **Figure 12-22**. The smaller the amount of backlash, the more precisely gear teeth mesh. When determining the optimal amount of backlash, engineers must consider thermal expansion and room for lubricant between the gear teeth. If the amount of backlash becomes too great, damage to gear teeth and vibration in the system can result.

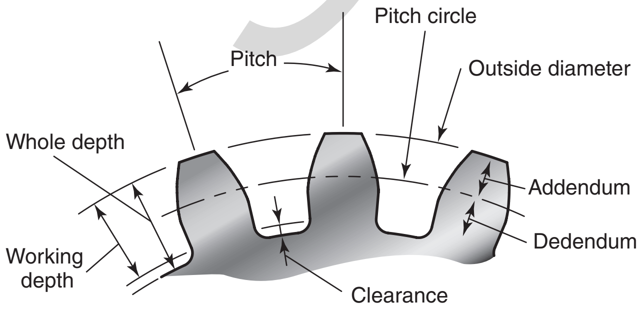

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Figure 12-21. Technicians should become familiar with common gear nomenclature.

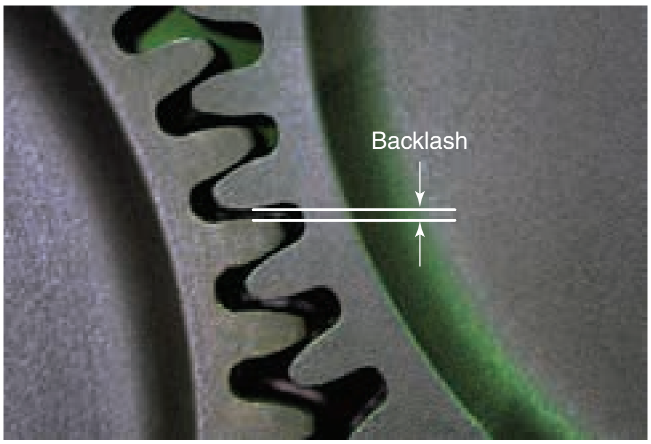

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Figure 12-22. Having adequate backlash prevents gears from binding when meshing.

Gear Ratio

The gear ratio is calculated by dividing the number of teeth of the driving gear by the number of teeth of the driven gear:

$$\text{gear ratio} = \frac{\text{number of teeth on driving gear}}{\text{number of teeth on driven gear}} \qquad (12\text{-}2)$$

For example, a gear ratio of 1:2 tells you the driven wheel does two full revolutions for every one revolution of the driver wheel.

Gear Types

The *external spur gear*, **Figure 12-23**, is the most basic type of gear. External spur gears are used in offset parallel shafting. In order for gears to mesh, they must have the same diametral pitch and tooth pressure angle. An angle of 20° tends to be strong and results in less undercutting. ***Undercutting*** is wear on the lower part of the dedendum. It can occur as a tooth enters the gap to mesh with another gear. When two spur gears are used, the shafts run in opposite directions. Using an intermediary idler gear between the input and output shafts causes the output shaft to rotate in the same direction as the input shaft.

An *internal spur gear*, **Figure 12-24**, is used for parallel shafting. Either a pinion or a spur gear is used as the input. In this case, both the input and output turn in the same direction. This combination is used in planetary gear sets because of its close centers, parallel shafting, and high output torque.

The *rack and pinion*, **Figure 12-25**, is used to convert rotational movement to linear movement. In this case, the rack is movable and the pinion is held stationary. As the pinion rotates, the rack develops linear movement. An example of this can be seen in positioning systems, such as a manual lathe. Since spur gears are straight-cut gears, they can develop thrust if not properly aligned. Shafts must be close to parallel in order to not develop thrust.

Helical gears have teeth that are cut on a straight angle, or *helix angle*, as shown in **Figure 12-26**. The "hand" of a helical gear indicates the directional angle of the teeth. Helical gears may be right-hand or left-hand gears. The helix angle allows several teeth to engage at the same time, which reduces noise, produces smoother

Photo courtesy Boston Gear–Altra Industrial Motion

Figure 12-23. Notice the completely straight tooth profile on these external spur gears.

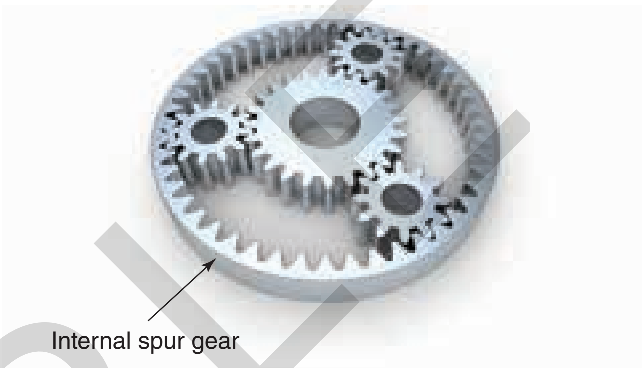

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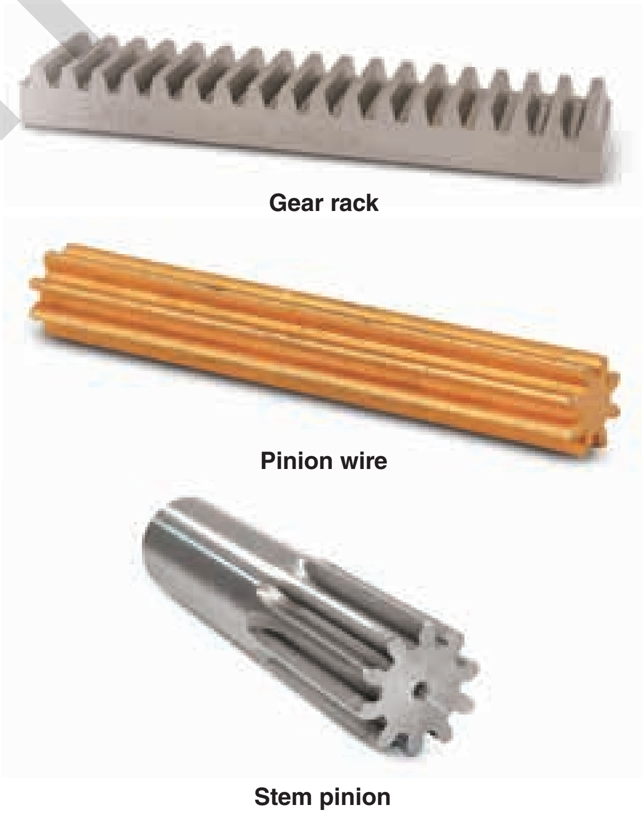
Figure 12-24. This internal spur gear is part of a planetary gear set.



Photos courtesy Boston Gear–Altra Industrial Motion

Figure 12-25. The gear rack is used to convert rotary motion into linear motion. Pinion wire can be bored and fitted for specific applications. Stem pinions mate with external spur gears.

Photo courtesy Boston Gear–Altra Industrial Motion

Figure 12-26. The angle of helical gear teeth allows several teeth to engage at the same time.

operation, and can handle higher speeds. Helical gears with opposite hands can mesh on parallel shafting and produce opposite rotation. The helix angle results in axial thrust, so appropriate bearings must be used. If rotation of the input shaft is reversed, thrust will also be changed to the opposite direction.

Double-helical gears, **Figure 12-27**, are used in applications where axial thrust needs to be minimized. Since a double-helical gear has two opposite-handed helical gears on the same shaft, the thrust is canceled. This type of gear is used for high-torque applications, such as those found in power generation and shipboard use.

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Figure 12-27. A double helical gear is manufactured on the same hub, with a space between the sets of teeth.

The *herringbone gear*, **Figure 12-28**, is similar to the double-helical gear, but it does not have space between the opposite hands. Herringbone gears are used in transmissions and high-torque applications. The lack of a center gap makes manufacturing herringbone gears more difficult and costly.

Bevel gears come in several forms and are used for shafts transferring power at 90° intersections. Straight bevel gearing made of sets of the same gear are called *miter gears*, **Figure 12-29**. These gears have a one-to-one speed ratio and only change the direction (90°) of rotation. Bevel gears are specified by pitch diameter, pitch angle, diametral pitch, and outside diameter.

The most common forms of bevel gear are the straight bevel gear and spiral bevel gear, but zerol and hypoid bevel gears are also available. See **Figure 12-30**. *Zerol bevel gears* have teeth that are curved, not angled. These gears run smoother than straight bevel gearings with less noise, and they do not produce thrust. The *hypoid bevel gear* and crown are offset. For this

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Figure 12-28. Larger herringbone gears are used in the power-generation industry.

Photo courtesy Boston Gear–Altra Industrial Motion

Figure 12-29. Miter gears change the direction of rotation by 90°.

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Figure 12-30. Zerol and hypoid gears are engineered for specific applications.

arrangement, the pinion may be larger and stronger than regular bevel gearing, which can allow high speed ratios and torque transfer.

12.5.2 Gearboxes

A ***gearbox*** is a set or system of gears that may or may not be contained within a casing. Gearboxes range from very small and lightweight, single-speed reduction gearboxes to large, high-horsepower, multispeed reduction units. A common type of gearbox is a single-speed reduction unit in the 0.5–25 hp range made of worm gears.

A ***worm drive*** is used to transmit power between two shafts and change the direction of rotation by 90°. Worm drive gearboxes contain two types of gear: a worm and a worm gear, as shown in **Figure 12-31**. The ***worm***, or *worm screw*, is a section of threaded rod that is the driving element of a worm drive. The ***worm gear***, or *worm wheel*, is a wheel-shaped gear with meshing teeth that is the driven element of a worm drive. Worms are classified by diametral pitch, material of construction, and thread type (single-start thread, double-start thread, or quad-start thread). Both the worm and worm gear can be right- or left-handed. Looking at either the worm or worm gear with the shaft pointing vertically, a left-handed gear will have teeth that slant up and to the left. Turning the gear or worm over will not change this.

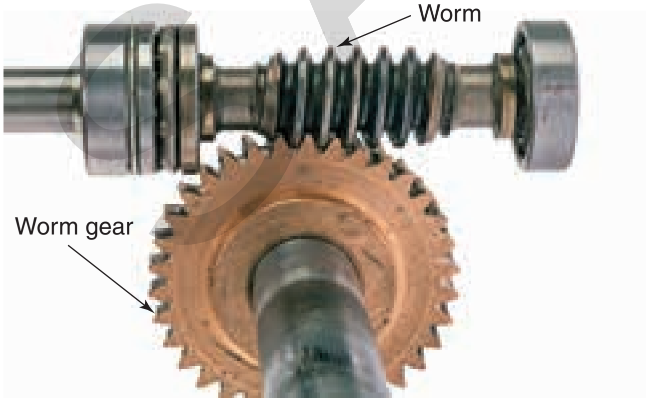

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Figure 12-31. In a worm drive, the worm drives the worm gear to transmit power between shafts.

Pitch and *lead* are both important terms related to the operation of worm drives. On a worm drive, *pitch* refers to the center-to-center distance of threads on a worm. ***Lead*** is the number of starts on a worm multiplied by the pitch. A single-threaded worm, or single-start thread, has a higher gear ratio than a quad-start thread. The gear ratio of a worm drive is calculated using the following equation:

$$\text{gear ratio} = \frac{\text{number of teeth on the worm gear}}{\text{number of starts on the worm}} \qquad (12\text{-}3)$$

Since the input is into the worm, output speed and torque are calculated using the speed ratio. For example, if the number of teeth on a worm gear is 40 and the worm is a double-start thread, the ratio is 20:1. The output speed is the input speed divided by 20.

How a worm transmits force to the worm gear depends on the classification of both gears. If neither is throated, force is transmitted to the worm gear through all teeth in contact. ***Throating*** describes an additional manufacturing and design method that brings the worm in closer contact to the worm gear. Most worm drives are single throated. **Figure 12-32** shows both single- and double-throated worm drives. The single-throated design curves the teeth of the worm wheel so that closer contact is made between the gears. The double-throated design also includes a redesigned worm. The worm's teeth are cut on a radius, so more teeth contact the worm gear and can transmit force.

Since the teeth of a worm gear are at an angle and the worm is a screw thread, contact between the two gears depends on the radial alignment of the worm as compared to the worm gear. If the worm drive is always turned in the same direction, contact will always take place on the same side of all the worm gear teeth. If the drive is reversed, contact (and wear) will take place on the opposite side of the teeth. From an initial start-up, the worm should contact the worm gear at the leaving side of the gear. As wear takes place, contact will increasingly fall back toward the center of the worm gear tooth, as shown in **Figure 12-33**.

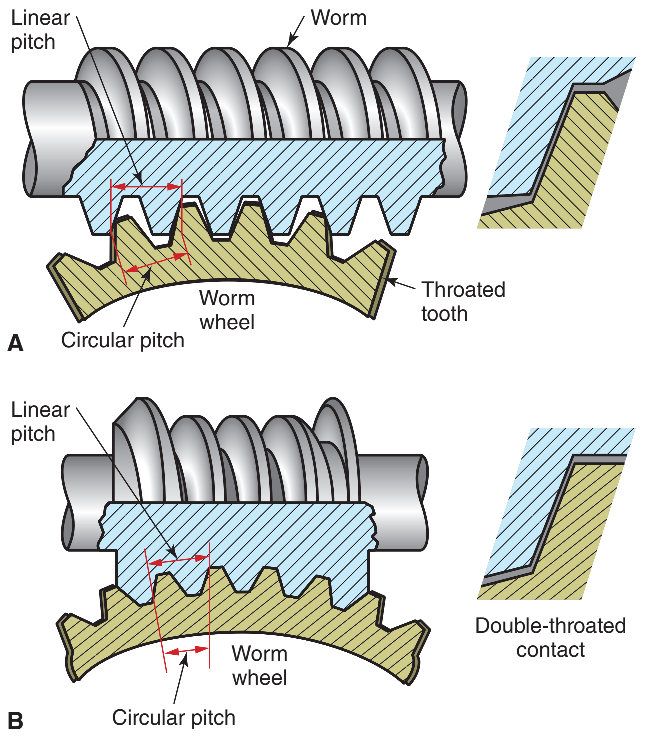

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Figure 12-32. These illustrations detail single-throated (A) and double-throated (B) worm gears. Notice the worm diameter change across the length of the double-throated gear, allowing a match to the circular pitch.

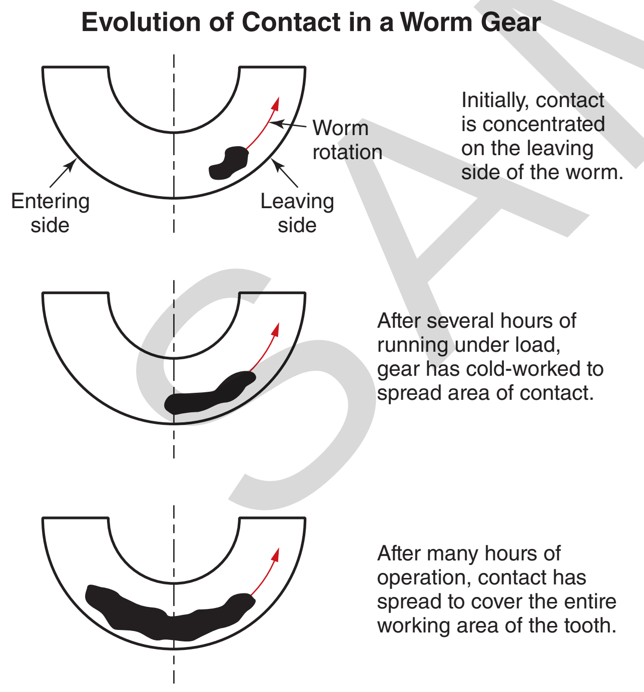

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Figure 12-33. As wear takes place, contact increasingly falls back toward the center of the worm gear tooth.

TECH TIP

Bluing

Machinist dye or blue can be applied to gears to determine where mating gears are making contact in order to aid in alignment.

In general, worm drives are somewhat self-locking. Because of the high lead angle between the worm teeth and worm gear teeth, it is unlikely that a load on the output shaft will be able to reverse the rotation of the worm when it is not powered. Manufacturers warn to not rely on this for a safety measure. If the lead angle is less than 5° (which is determined by diametral pitch and starts on the worm), the drive should be self-locking.

12.6 GEAR MAINTENANCE

Ensuring proper lubrication is a key maintenance item with gears. At some point, you may have to disassemble a gear drive to investigate an issue. However, current drives do not have many adjustments a technician can perform. Always refer to the manufacturer's manuals for specific maintenance.

TECH TIP

Check Sight Glass

Check the oil level sight glass when the gearbox is not running for the most accurate reading.

12.6.1 Lubrication

Proper lubrication depends on the speed of the gears, load, type of gearing, and temperature of both the lubricant and environment. Some slower gears may work well with grease, while faster gearing works better with mineral-based oil. Systems rely on drip, splash, or pressurized lubrication. Follow the manufacturer's recommendations for the type of oil or grease to be used. Both oil and grease should be regularly changed and should be included as a regularly scheduled maintenance item. Oils in the range of SAE 80–90 viscosity are recommended for splash systems.

TECH TIP
Manufacturer's Recommendations

Review the manufacturer's recommendations on additives. EP greases and lubricants are not recommended with bronze gears.

Higher-speed gear drives usually require that the lower gear be somewhat covered in lubricant. This can range from submerging part of the lower gear to completely covering the lower gear. When changing lubricant, check for abnormal wear. This is typically indicated by excessive metallic particles in the lubricant. If you see any larger pieces of metal in the lubricant, immediately investigate to find the source.

TECH TIP
Replacing Gaskets

Make sure you have the appropriate gaskets prior to opening a gearbox. Always replace the gaskets and "soft" parts when performing maintenance.

12.6.2 Adjustments

Backlash is maintained by the center distance between the gears and typically cannot be adjusted in the field. However, taking a reading of backlash provides a comparison to manufacturer specifications and may predict possible issues.

PROCEDURE **Backlash Measurement**

To take a proper backlash measurement, perform the following steps:

1. Open the gearbox.
2. Hold one gear stationary.
3. Mount a dial indicator at a 90° angle to one of the opposing teeth faces.
4. Rock the movable gear back and forth to read total indicator displacement.

If backlash is beyond what the manufacturer specifies, it may be due to tooth wear or bearing wear. Some backlash is desired for lubricating purposes. Depending on the application, excessive backlash may not interfere with the operation of the drive.

Axial runout is another measurement that may indicate bearing concerns. Axial runout is the movement of the shaft and gear in parallel direction with the shaft. Excessive axial runout can point to bearing wear and may affect wear patterns and how gears mesh. Always check with the manufacturer for runout specifications on each drive.

PROCEDURE **Axial Runout Measurement**

Perform the following to take an axial runout measurement:

1. Hold other shafts stationary (one or more).
2. Set a dial indicator at one end of the shaft to be measured.
3. Jack the shaft in one direction; then set the indicator to zero.
4. Jack the same shaft back while keeping pressure on it.
5. Note the indicator reading.

Replacing worn lubricant seals is a typical maintenance task on older drives. If the drive is not to be completely disassembled and only the seals are to be replaced, couplings must be removed in order to remove the oil seals. You may also need to drain lubricant, depending on the level of the lubricant.

PROCEDURE **Removing and Installing Oil Seals**

The following is a general procedure for removing and installing oil seals:

1. Cover the shaft by tightly wrapping a thin plastic sheet around it and securing the plastic with tape.

(Continued)

2. Carefully remove the oil seals by drilling two or three small holes in the face of the seal and insert screws. Use the screws to gently and evenly pry the seal free and off the shaft.
3. Completely clean the mating surface of the seal to the housing.
4. If necessary, apply an additional light coating of sealant to the outside of the seal and inside the housing seating area, depending on the roughness of the housing.
5. Lightly lubricate the plastic sheeting.
6. Gently push the seal over the plastic sheeting until it starts to seat in the housing.
7. Use a wooden drift and hammer to evenly seat the seal into the housing.
8. Wipe off any excess sealant.
9. Remove the plastic sheeting.

CHAPTER WRAP-UP

Basic maintenance procedures, or the lack of, can greatly influence the life of a power transmission system. Consistent lubrication schedules, proper installation, and sound judgment go a long way to improve the reliability of machinery. When in any doubt, always research and verify proper methods and specifications with the manufacturer. Always have the proper information on-hand when performing any type of maintenance task.

Chapter 12 Review

SUMMARY

- Power transmission systems rely on the transfer of power through an intermediary element. Due to the design of these systems, safety issues, such as pinch points, are an inherent danger. Never operate a machine without the safety guards in place.
- Belt drives transfer power using the friction created between the belt and pulleys. A variety of belts are available. Most belts have embedded tension members that transmit power from the drive sheave to the driven sheave.
- A pulley is a simple machine that transfers power through a wheel and a belt or cable. A sheave is the wheel component of a pulley where the belt or cable sits.
- Attaching a pulley to a shaft is accomplished using setscrews with a key, a tapered bore and bushing, or taper-lock sheaves and bushings.
- The most common method of belt tensioning is to allow 1/64″ of belt deflection per inch of span, measured center-to-center, between the sheaves. Belt tension may need to be adjusted as belts wear in and seat in the groove of the sheave.
- Under optimal circumstances, both the drive and driven shafts are parallel to the baseplate. Misalignment can result in sheave and belt wear and shortened belt life.
- Properly storing belts will help maintain the integrity of the belts until they are needed for operation. Sheaves should be checked for wear each time a belt is replaced.
- Chain drives are designed to lock into the sprocket of both the drive and driven machinery. A chain drive is a positive drive that maintains an exact speed ratio.
- In addition to standard roller chain, other types commonly used in industry include offset, leaf, and silent chain.
- In a chain drive system, the sprocket drives the chain to transmit rotary motion.
- The two most common causes of chain drive failure are lack of lubrication and improper alignment. More accurate alignment between the drive and driven shafts results in less chain and sprocket wear.
- Initial chain tension should result in approximately 2 percent play on one side of the center-to-center distance of the shafts. Check chain tension after 100 hours of run time after initial installation.
- As a chain wears, the chain links with the pins wear and stretch. Chains should be replaced when elongation is 3 percent or greater.
- The four main methods of lubrication for a chain are drip, oil bath, flinger, and forced lubrication.
- Gears transmit power between machines while changing rotation, speed, and torque. Gears can also change rotational movement into linear movement. In order to mesh, gears must have the same diametral pitch and pressure angle.
- The most basic type of gear is the external spur gear. However, a technician may encounter several other types, including internal spur gears, rack and pinions, helical gears, herringbone gears, and bevel gears.
- A worm drive is used to transmit power between two shafts and change the direction of rotation by 90°. It is comprised of a worm that drives a worm gear.
- Ensuring proper lubrication is a key maintenance item with gears. Oil and grease should be changed regularly as part of scheduled maintenance. Follow the manufacturer's recommendations for the type of oil or grease to be used.
- When backlash readings are compared to manufacturer specifications, they can reveal tooth wear or bearing wear. Excessive axial runout can point to bearing wear and may affect wear patterns and how gears mesh.

REVIEW QUESTIONS

Answer the following questions using the information provided in this chapter.

Know and Understand

1. Belt drives transfer power using _____ created between the belt and the pulleys.
   A. friction
   B. torque
   C. heat
   D. All are correct.
2. Use a _____ belt when an exact mechanical speed is needed.
   A. double-sided
   B. poly
   C. timing
   D. V-
3. *True or False?* A sheave is a component of the pulley.
4. *True or False?* Chain drives can transfer more horsepower than a similarly sized belt drive.
5. A _____ transfers torque from a shaft to a chain.
   A. pulley
   B. sheave
   C. coupling
   D. sprocket
6. *True or False?* When placing a chain on sprockets, it is generally easier if the connection is made on the top of the smaller sprocket.
7. The _____ method of chain lubrication uses a disc and centrifugal force.
   A. forced
   B. flinger
   C. drip
   D. bath
8. Gears transmit _____ between machines while changing rotation, speed, and torque.
   A. movement
   B. teeth
   C. power
   D. load
9. *True or False?* For gears to mesh properly, they must have the same diametral pitch and pressure angle.
10. _____ is the distance between a point on the face of one gear tooth to the same point on the next tooth.
   A. Circular pitch
   B. Diametral pitch
   C. Working depth
   D. None are correct.
11. The helix angle in a helical gear allows _____.
   A. higher operating speeds
   B. smoother operation
   C. noise reduction
   D. All are correct.
12. Splash lubrication systems for gears typically use _____ viscosity.
   A. SAE 80–90
   B. SAE 90–100
   C. SAE 100–110
   D. SAE 120
13. *True or False?* Depending on the application, excessive backlash may *not* interfere with the operation of the drive.
14. The limit of face runout on a 12″ sprocket is _____.
   A. 0.010″
   B. 0.012″
   C. 0.014″
   D. 0.018″

Apply and Analyze

1. What is a *sheave*?
2. Explain the orientation of a sheave and QD bushing in a reverse mounting application.
3. Explain the function of a sprocket.
4. Describe why lubricants are not used on sheaves, bushings, and their fasteners.
5. Calculate the driven speed of a machine if the driver pulley is 4″ in diameter with an rpm of 1800, and the driven pulley is 12″ in diameter.
6. Explain how to tension a chain drive.
7. Describe how the oil flinger method lubricates a chain.
8. Describe a chain with the designation of 61-3.
9. Identify some advantages that helical gears provide.
10. Name the four factors to consider when lubricating gears.

Critical Thinking

1. Describe the most common method of belt tensioning.
2. Identify common factors that lead to belt wear and failure.
3. Describe some of the advantages and disadvantages of belt drives.
4. How is silent chain different from standard chain?
5. Why is it important to measure axial runout?

Questions for Class Discussion

1. Look up a manufacturer of industrial power synchronous belts. Summarize the different belt types offered.
2. Look up a supplier of laser alignment tools for belt drives. Summarize the types offered and price range.
3. Look up Ramsey chain "silent-chain basics" and pick one of the seven basics to summarize.
4. Visit the *Power Transmission Engineering* magazine website. Read an article in the magazine or a newsletter and summarize the article's major concepts.

NIMS CREDENTIALING PREP QUESTIONS

The following questions will help you prepare for the NIMS Industrial Technology Maintenance (ITM) Mechanical Systems Smart Credential exam.

1. A _____ belt is used for power transmission through multiple bidirectional loading sheaves.
   A. flat
   B. double-sided
   C. timing
   D. V-
2. The _____ represents the length of a belt at the location of the tension members.
   A. pitch
   B. chordal action
   C. pitch circle
   D. elongation
3. The first digit in the two-digit chain identification number represents the _____.
   A. strength
   B. length
   C. type of chain
   D. chain pitch
4. Which type of chain is composed of heavier links with multiple side plates and strands to increase its strength rating?
   A. Roller chain
   B. Offset chain
   C. Leaf chain
   D. Silent chain
5. Type _____ sprockets have a hub on one side and are mounted using a keyway and setscrew for a plain bore, or a tapered bushing for a tapered bore.
   A. A
   B. B
   C. C
   D. D
6. The number of teeth per inch of length on the pitch circle of a gear is the _____.
   A. diametral pitch
   B. working depth
   C. circular pitch
   D. clearance
7. For what purpose is some amount of backlash desired in gear operation?
   A. Elongation
   B. Alignment
   C. Tensioning
   D. Lubrication