

## Chains & cables: Lubricant function and composition



*Both lubricant quality and application effectiveness have a significant impact on chain and cable component life cycles.*

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### Article highlights:

- Basic components, failure modes and lubricant requirements of chains and cables.
- Tips for reducing chain replacements and improving process throughput.
- Examining four desirable properties for wire rope lubricants.

Chains and cables have been used in manufacturing, shipping, construction and many other applications since before the Industrial Age. The primary industrial application for chains is likely for use in power transmission between parallel shafts. One might argue that the largest single application for chains is the automotive timing chain. Wire ropes, similarly, have been used extensively since the early days of the Industrial Age, with the forerunners of the wire cable reaching back to the early days of man in the form of braided hemp and fiber ropes.

Chains and wire ropes/steel cables are plentiful in manufacturing and commercial applications, but the quantity of published literature supporting effective lubrication is slight in comparison to that of literature for other commonly occurring components (gears, bearings, engines, etc.). Based on personal experience within manufacturing facilities of all types, reliability engineers likely would find a solid financial return on a relatively low level of effort dedicated to improving

lubricant type and application effectiveness for these important and safety-critical components.

This article addresses the basic components and construction of the most common types of chains and cables, briefly reviews common failure modes and provides input on the lubricant characteristics that would be most helpful in improving performance for these types of components.

### Chains: The basics

A chain is a series of interconnected bushings/journal bearings driven by a gear or sprocket. In the March TLT we discussed journal bearing lubrication and noted that journal bearing components experience sliding surface interaction, creating a hydrodynamic type oil film when the appropriate degrees of speed, load and oil viscosity are present.

Three common types of chain construction are precision roller chain, inverted-tooth (silent) chain and engineering steel offset sidebar chain. These common types of chains are used in a variety of applications, including power transfer, transport/conveyance, control and lifting.<sup>1</sup>

Common chain dimensions include pitch, width and link or roller diameter. Common roller chain components include the pin link plate, roller link plate, bushing, roller and pin. (See Figures 1 and 2).

Figure 1. Oil (A) must be applied to the gaps between Rollers (C) and Roller Link Plates (D), and between the Link Plates and Pin Link Plates (E), to lubricate Rollers and Chain Pins (B).

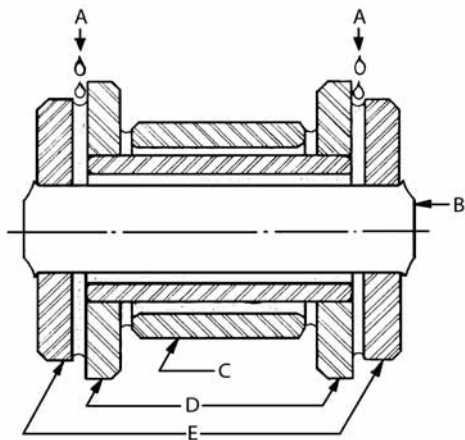
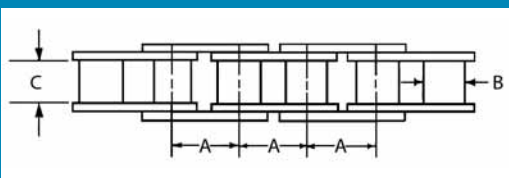


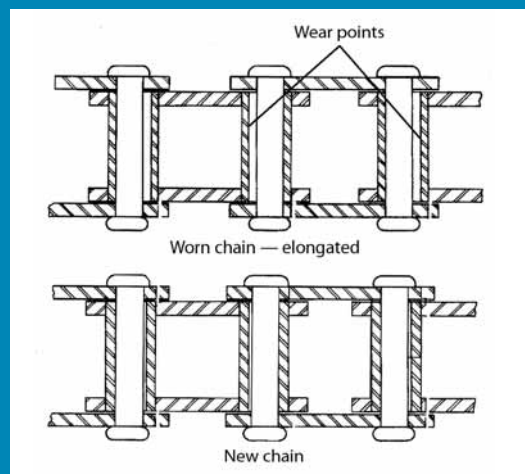
Figure 2. Principal dimensions of a roller chain: A, pitch; B, roller diameter; C, width.



Common failure modes include overloading (tensile failure), cyclic loading (fatigue failure) and wear.<sup>2</sup> Overloading failure occurs whenever the chain is exposed to static or dynamic loads beyond the material strength of the steel used to construct the chain. Component distortion typically accompanies overloading. Cyclic loading failure occurs over time from repeated application of unit loads above the chain's endurance limit.<sup>3</sup> Loads below the endurance limit may be sustained indefinitely. Fatigue failure is evidenced by link breakage without any deformation or distortion of the broken link.

Wear failure occurs gradually from repeated material removal from the loaded portion of the link. This mode gives the appearance of the chain stretching, when in fact the added chain length is the aggregation of the gaps created by wear at the pin and bushing contact points for multiple links. (See Figure 3).

Figure 3. Chain wear locations.



Chain wear is progressive. In Figure 4 (see page 30), Stage 1 represents the early operating state of a properly selected and installed chain. The rate of wear is high as the chain pins and bushings seat together.

Once seated, Stage 2 wear rates for a well-lubricated chain are steady and minimal. In the final stage, as the chain wear progresses through the hardened metal exterior and the underlying soft metal is exposed, the rate of wear increases, chain elongation increases and the chain rides inappropriately on the drive sprocket. Sprockets are designed to tolerate some degree of elongation (3% to 6%), but beyond this minimal amount the chain no longer fits the sprocket correctly, and the individual link becomes subjected to dramatic load increases.<sup>4</sup>

CONTINUED ON PAGE 30

Figure 4. Common chain wear rate profile.



Proper lubricant selection can slow the onset of progressive wear (Stage 3) and also help dampen the shock-loading forces that lead to cyclic fatigue failure. The type of lubricant selected is highly dependent on the chain application. Chain lubricants are category of products with a significant degree of specialization and sophistication, particularly for elevated temperature application.

As a general rule, chains with pitch sizes (the distance from one pin center to another) less than .75 inches have relatively tight clearances and warrant more fluid (lower viscosity) products that provide greater penetration to the pins and bushings. ISO 32 to 68 options are useful. As both the tem-

perature and load rises, the viscosities of the fluids should increase. Chain pitch ranges between .75 inches and 1.25 inches warrant ISO VG 68 to 100, and pitch ranges between 1.25 inches and 2.00 inches warrant ISO VG 150 to 220.

For chains that experience highly dusty environments, specialized lubricants with evaporative carriers and solid-film (moly and graphite) additives are ideal. Tackified lubricants are appropriate for wet environments. Large chains that experience heavy shock-loading operations would benefit from the use of EP compounds and the use of solid-film agents. Figure 5 provides general guidance for lubricant base oil types, viscosities and additive types for a variety of operating conditions.

Many lubricant suppliers manufacture high-performance lubricants and provide engineered-application support for high temperature ( $\geq 220$  C), high draft and high-speeds applications such as metal painting/drying ovens, wallboard and fiberglass manufacture, textile tenter frames and lithographic ovens. Reliability engineers must find useful ideas and assistance from specialty suppliers for product type and application methods selection improvements in support of reducing chain replacements and improving process throughput. We'll address lubricant application in a future article.

Figure 5. An overview of lubricant base oil types, viscosities and additive types for a variety of operating conditions.

Chain pitch	Operating temperature	Operating environment**	Base oil type**	Lubricant vis. @ 40°C	Additive type	Evaporation, % loss @ 8 hrs*
>0.75 inches	-10°C to 20°C	No dust/moisture	Mineral oil	ISO 22	Solid film AW	N/A
	-10°C to 20°C	Moisture present	Solvent/oil blend	ISO 22	Solid film AW	N/A
	20°C to 80°C	No dust/moisture	Mineral oil	ISO 68	Soluble AW	N/A
	20°C to 80°C	High dust	Solvent carrier	ISO 68	Solid film AW	N/A
	20°C to 80°C	High moisture	Tackified mineral oil	ISO 68	Soluble AW	N/A
	80°C to 220°C	No dust/moisture	Low residue synthetic	ISO 100	Soluble AW	± 50%
	80°C to 220°C	High dust	Low residue synthetic	ISO 100	Solid film AW	± 50%
	>220°C	No dust/moisture	Low residue synthetic	ISO 150	Soluble AW	± 50%
	>220°C	High dust	Low residue synthetic	ISO 150	Solid film AW	± 50%
0.75-1.25 inches	-10°C to 20°C	No dust/moisture	Mineral oil	ISO 32	Solid film AW	N/A
	-10°C to 20°C	Moisture present	Solvent/oil blend	ISO 32	Solid film AW	N/A
	20°C to 80°C	No dust/moisture	Mineral oil	ISO 100	Soluble AW	N/A
	20°C to 80°C	High dust	Solvent carrier	ISO 68	Solid film AW	N/A
	20°C to 80°C	High moisture	Tackified mineral oil	ISO 100	Soluble AW	N/A
	80°C to 220°C	No dust/moisture	Low residue synthetic	ISO 100	Soluble AW	± 50%
	80°C to 220°C	High dust	Low residue synthetic	ISO 100	Solid film AW	± 50%
	>220°C	No dust/moisture	Low residue synthetic	ISO 150	Soluble AW	± 50%
	>220°C	High dust	Low residue synthetic	ISO 150	Solid film AW	± 50%
>1.25 inches	-10°C to 20°C	No dust/moisture	Mineral oil	ISO 32	Solid film AW	N/A
	-10°C to 20°C	Moisture present	Solvent/oil blend	ISO 32	Solid film AW	N/A
	20°C to 80°C	No dust/moisture	Mineral oil	ISO 150	Soluble AW	N/A
	20°C to 80°C	High dust	Solvent carrier	ISO 68	Solid film AW	N/A
	20°C to 80°C	High moisture	Tackified mineral oil	ISO 100	Soluble AW	N/A
	80°C to 220°C	No dust/moisture	Low residue synthetic	ISO 220	Soluble AW	± 50%
	80°C to 220°C	High dust	Low residue synthetic	ISO 220	Solid film AW	± 50%
	>220°C	No dust/moisture	Low residue synthetic	ISO 320	Soluble AW	± 50%
	>220°C	High dust	Low residue synthetic	ISO 320	Solid film AW	± 50%

\*Volatility Testing: Thin Film Evaporation Loss, 220 oC, for 8-, 24-, 48-hour intervals.

\*\*High-speed chain operations require automatic application, may require lower viscosities and higher frequencies.

## Cables: The basics

Cables (i.e., wire ropes) are used for a wide variety of functions, including stationary lifting (stays), hoisting and dragging large loads. Wire ropes experienced a period of intense development in the 1830s in German mining applications. With the advent of higher quality steel and wire-forming operations, wire ropes became a mainstay in worldwide commercial, construction, mining and industrial services.

Wire ropes and cables operate in a variety of challenging conditions. Mining operations use ropes for hoisting and dragging. These ropes are exposed to abrasive and dust-drenched service. Shipping and dredging operations routinely submerge wire ropes in the water, routinely washing away the protective lubricant and exposing the rope to corrosive salt and freshwater. These types of environmental conditions degrade lubricant effectiveness rapidly and can lead to shortened lubrication intervals or shortened rope life cycles. Some applications, office building elevator service, for example, are relatively clean, dry and cool. Ropes in these services would be expected to function with better long-term lubrication effectiveness, leading to greater rope durability and longevity.

A wire rope is constructed by passing multiple individual wires through a wire-forming dry and spindle process to cause the wires to lie against a core, as shown in Figures 6<sup>5</sup> and 7<sup>6</sup>. Once the wires are fitted together they are called a strand. The core may be made of a natural or synthetic fiber or may be made from either a single-wire or another strand. The number of wires that make up a strand can vary but tend to run between seven and 37. The number of strands that make up a cable also varies but tends to run between six and 17 strands per rope.

Additional fibers per strand and additional strands per rope increase a rope's load limits. The orientation, or lay, of the fibers in the strands and orientation of the strand in the rope also influence the rope's bend radius, load-carrying ability and longevity. There are five ways to lay the wires and strands together to create a rope. Figure 8 shows the relative orientation of wires to strand and strands to rope.<sup>7</sup>

As depicted in Figure 7, wire ropes are bathed in a lubricant as they are manufactured.<sup>6</sup> This lubricant provides both dye lubrication/protection and corrosion protection during storage. Some wear-resistance characteristic is also imparted with this initial coating. As the wires fit together, the majority of the lubricant is displaced. If the core is composed of an absorbent material, the core will retain

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Figure 6. Wire rope construction.

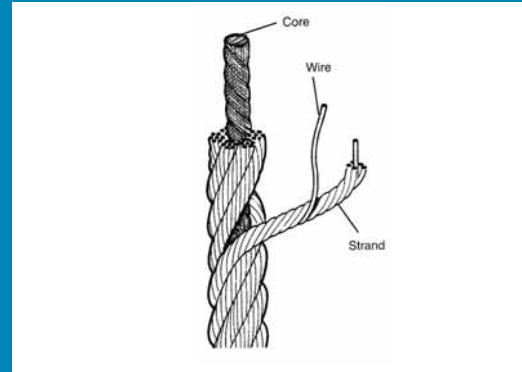


Figure 7. Wire-forming machines provide an initial protective lubricant coated during the wire-forming process.

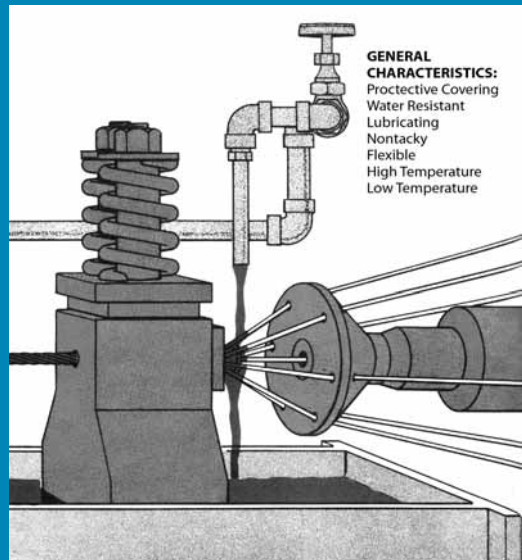
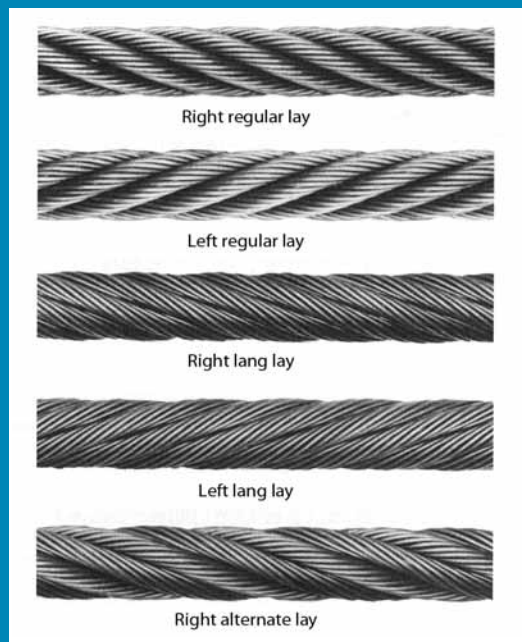


Figure 8. Five types of lay.



a reservoir of lubricant that begins to displace as soon as the wire is placed into service. The lubricant is intended to provide a protective coating from the time of manufacture to the time at which the lubricant is placed into service. Once in service, though, the original lubricant/corrosion inhibitor is displaced and must be periodically replenished.

Wire ropes have four dominant failure modes: fatigue, wear, corrosion and core failure.<sup>8</sup> In service each wire contacts multiple other wires—three additional wires at a minimum. When a load is applied and the rope travels around a capstan or wire drum, the line contacts widen as the wire plastically deforms under load. When in use the wires and strands move against one another under very high contact pressures. Repeated bending and tension stress causes individual wires to break from fatigue.

In addition, wear from contact friction causes individual strands to thin and weaken, accelerating fatigue. Also, as the lubricant dissipates, and the vacant spaces are subject to either moisture or corrosive process water and chemicals, the strand surfaces rust and corrode. This additional attack to the strand surface adds to fatigue and frictional wear. Lastly, when the core fiber has lost its reservoir of lubricant through normal use, the core must be refilled. Core collapse allows for increased contact and frictional stress inside the cable, which leads to internal breakage and loss of reliability.

Given common operating and failure modes, corrosion protection and frictional resistance are both

tremendously important properties that the lubricant must impart. Depending on the application, lubricated cables can fail from both the outside in and the inside out. There are four common product approaches to lubricating cables. Each type has benefits and drawbacks. Figure 9 lists a few of the more important properties and suggests some limits.

### Conclusion

Chains and cables are common components that play a significant role in the manufacturing, shipping and construction industries. Chains and cables have a relatively simple construction and share common failure modes.

Lubricant selection and replenishment are both important to overcoming common root causes of failure. Chain and cable lubricants must be applied in such a way that they coat the interior contact surfaces, provide a wear resistant and corrosion inhibiting layer and do so without drawing atmospheric dust into the critical contact areas.

Proper lubrication of chains and cables enables reliability engineers to reduce a significant amount of expenditures historically associated with chain and cable replacement. **TLT**

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Figure 9. Desirable properties for wire rope lubricants by lubricant type.

Desired Wire Rope Lubricant Properties					
Lubricant type	ASTM Method	Petrolatum	Asphaltic	Grease	Penetrating oil
Application viscosity		25 cPs @ 100°C	85 cPs @ 100°C	-	23-32 cSt @ 40°C
Operating viscosity		Semisolid @ 40°C	Semisolid @ 40°C	220 cSt	22-32 cSt @ 40°C
NLGI grade		-	-	#2	-
<b>Load protection</b>					
4 Ball EP values	D-2783				
Weld load limit			400 Kg		250 ± kg
Load wear index			50 ±		50 ±
<b>Corrosion resistance</b>					
Appearance	D665	Pass	Pass	Pass	Pass
Appearance	D1748	60 hrs	60 hrs	60 hrs	60 hrs
Dropping point, °C	D2265	80	80	80	N.A.

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