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CHAIN CHOKERS FOR SMALL-SCALE OPERATIONS

R.H. Ewing*

Abstract

With an appropriate mainline attachment, chain chokers are a viable alternative to conventional wire rope chokers, particularly for small-scale operations. This report provides users of tractor-mounted winches and cable skidders with technical information on chain chokers. The report covers types of steels, chain specifications and grades, and how to inspect chains for wear and elongation. The various components (e.g., sliding hooks, rings) used to assemble chain chokers are also discussed.

Introduction

In the past, logs were typically skidded using lengths of chain fitted with rings or hooks. These chain chokers were the most common means of choking logs in ground skidding, but began to lose favor in Canada with the advent of wheeled skidders and further development of wire rope chokers in the late 1950s. Today, wire ropes are the dominant choking system in North American forest operations. However, chain chokers still predominate in Europe and other parts of the world. In the eastern U.S., some contractors prefer chain chokers over wire chokers on skidder-based equipment.

In eastern Canada, small-scale contractors have used tractor-mounted winches equipped with chain chokers (Figure 1) successfully in many applications. FERIC has monitored such operations in selection harvesting, in commercial thinning in softwood and hardwood stands, and in firewood production. Over the past 15 years, approximately 4000 tractor-mounted winches have been sold in Canada (McCallum 1995). Originally manufactured in the Nordic countries, these winches were developed for use with chain chokers rather than wire rope chokers. With the increasing popularity of these winches on small-scale operations, the chain choker has re-established a niche.

Figure 1. A tractor-mounted winch equipped with chain chokers.

* Roderick H. Ewing is a Researcher, Small-scale Operations, Eastern Division.
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The purpose of this report is to present the use of chain chokers as an alternative to wire rope, and to guide potential and current users on proper chain and component selection. For example, the carbon and alloy steels currently used to produce chains and other components differ considerably. Low-carbon (e.g., Grade 30) steel chain is commonly available from hardware stores, and although it is suitable for light-duty operations such as towing, it is inadequate for more demanding operations such as winching and skidding. Most chain chokers supplied with tractor winches use high-carbon (Grade 70) steel or alloys (Grade 80). Alloys are generally more durable and more ductile than high-carbon steel of similar dimensions, and despite a higher cost, may thus be preferable for logging operations.

Wire rope chokers (Figure 2c) have inherent disadvantages that chain chokers can overcome. Chain chokers are more durable under normal operating conditions, are smoother and safer to handle (i.e., no wire burrs), rarely kink, and are compact and convenient to store. Corrosion and wear are easy to detect in chains, but are more difficult to detect in wire rope, since the damage is often internal. Moreover, if a chain choker should break, field repairs can be made easily using connector links. A chain's flexible link configuration also grips small-diameter logs or smooth-barked species more tightly; chains with a square link cross-section (popular in Europe) have an even tighter grip. Depending on log diameter, a chain's length can be adjusted using the mainline's keyhole slider to prevent log butts from contacting the ground during skidding. Depending on their configuration, an alternate set of chokers can also be easily detached from the machine and used to pre-choke logs while the tractor or skidder extracts the previous load.

However, chains also have drawbacks: they are more expensive than wire rope, better alloy chains and components may be unavailable locally, and chain chokers are easily lost. It can be difficult to insert chains under logs without a pull-through needle affixed to the free end, and a chain's free-end can detach from the keyhole slider in extreme cases. Alloy chain with the same breaking strength as wire rope will also weigh 30 to 40% more per unit length. These factors indicate that chain chokers are not necessarily better than wire-rope chokers; rather, they are an alternative choking system that has been used successfully with tractor-mounted winches.

Chain Choker Description

Chain chokers are short lengths of chain (1.5 to 3 m long) with a specialized sliding component (a hook or ring) at one end that secures the chain around a log. As the winch's mainline applies tension on the chain (via a keyhole slider), the sliding component tightens the chain loop against the log.

An efficient chain choker "system" has three primary components (Figure 2): the chain itself (including a free-end component such as a pull-through needle or a cross "T" end retainer), the sliding hook or ring component, and an attachment component on the mainline (e.g., a keyhole slider). Details on these components are provided later in this report.

Chain Types and Characteristics

Steels used to manufacture choker chain fall into two general categories: carbon steels and alloy steels. Most carbon and alloy steels are specified using a number such as C1008 based on a chemical analysis and standardized by the American Iron and Steel Institute (AISI) and the Society of Automotive Engineers (SAE) to ensure that a specific chemical content, manufacturing process and dimensional tolerance can be expected (Budinski 1992).

Carbon imparts hardness to steel. Carbon steels (Anon. 1984) have low, medium or high carbon content:

- Low-carbon (mild) steels (e.g., designation C1008) contain $<0.25\%$ carbon, and are usually "hot worked" and used in products such as wire or "I" beams. General-purpose chain designated Grade 30 is made from low-carbon steel, and is unsuitable for rigorous applications such as heavy-duty skidding (Table 1).

- Medium-carbon steels (e.g., designation C1030) contain 0.25 to 0.70% carbon, and are generally used for machine components that require high strength and good fatigue resistance (e.g., bolts and studs). Grade 40 chain generally falls into this category, which may be suitable for light-duty skidding (Table 1).

- High-carbon steels (e.g., designation C1080) exceed 0.70% carbon content, have properties such as high hardness and resistance to compressive or tensile loading, and are commonly used for coil springs or cultivation tines. Transport chain (Grade 70) may fall into this category (see Appendix).

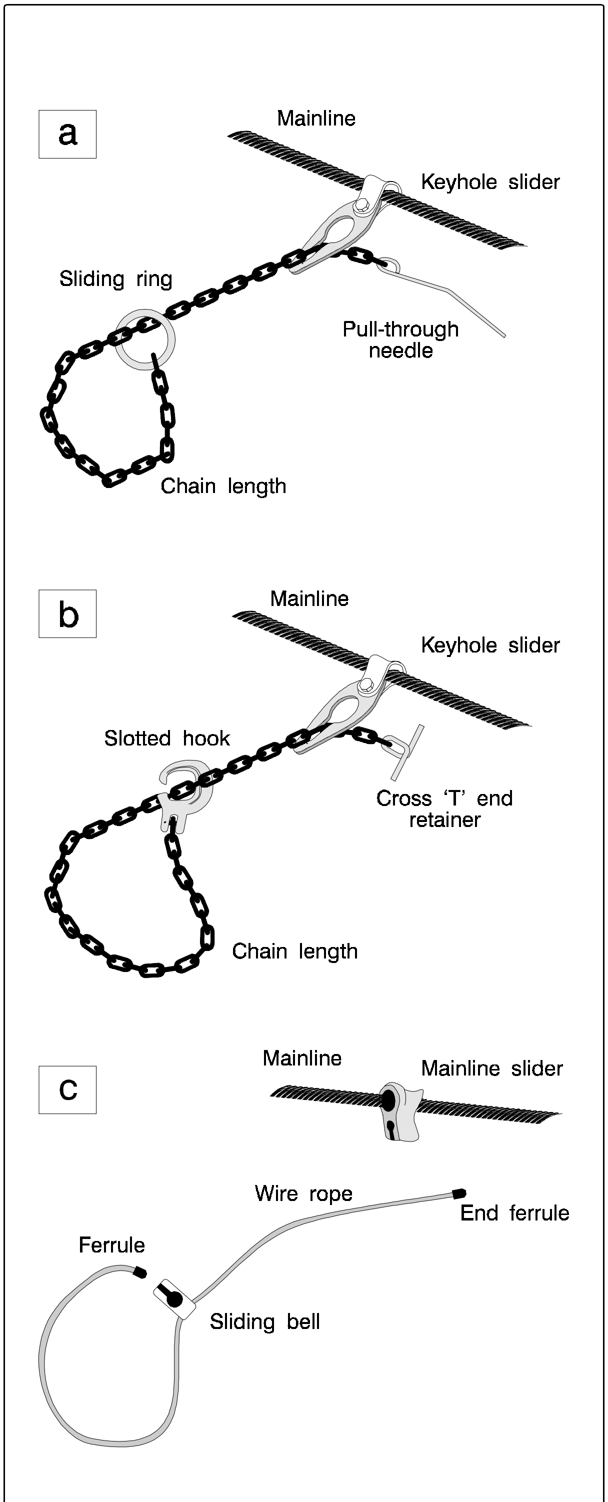

Figure 2. Components of chokers: chain chokers with (a) a sliding ring and (b) a slotted hook; (c) a wire rope choker.

Table 1. Chain selection based on estimated working load requirements

	Chain rod diameter (mm)		
Estimated load (kg)	Grade 30 (carbon)	Grade 40 (carbon)	Grade 80 (alloy)
<1000	10	7.1, 8.5, 10	7.1, 8.5, 10
<2000	---	10	8.5, 10
<3000	---	---	10

Alloy steels (e.g., designation 8620) are generally medium- or high-carbon steels with various exotic elements added, to a maximum of 5% of the total content (Avallone and Baumeister 1969). They contain elements such as molybdenum, nickel, boron or chromium that impart hardness, strength, shock resistance or corrosion resistance. These elements are often combined. For example, one commercially available choker chain uses chromium, nickel and molybdenum to increase wear and corrosion resistance, shock resistance and tensile strength compared with carbon steels. Chains designated Grade 80 (Table 1) or 100 use alloy steels, and are suitable for skidding or overhead hoisting applications.

Strength and Durability

Chain manufactured from carbon or alloy steels is normally heat-treated to relieve stresses created during manufacturing and to improve its strength and durability. This process includes heating, quenching and tempering, and imparts hardness, ductility and abrasion resistance. The manufacturer rates the chain's strength using the following definitions:

- The *working load limit* (in tonnes[1]), determined by the steel's tensile strength (the stress it can withstand without rupturing), is the *calculated* maximum load that a length of chain and its attachment are authorized to support in direct tension.

[1] Although kg and tonnes are units of mass, not force, these units are used in this report because of their familiarity.

- The *minimum breaking strength (ultimate load)* is the *actual* minimum load (tonnes) under which a new length of chain will break or rupture under direct tension. This is generally three to four times the working load limit. The chain's *design (safety) factor* represents its theoretical reserve capacity, and is determined by dividing the breaking strength limit (the ultimate load) by the working load limit. The result is expressed as a ratio (e.g., 4:1).

- The *proof test* is the final quality-control process before shipping the chain. The chain is fed along a test bench, and is progressively stretched over a short length (up to 1 m) with increasing tension to ensure that any defects are detected. The proof test factor is typically twice the working load limit. Links are then hallmarked (embossed) with the company logo and the steel's grade.

For further technical specifications on chain grade, size, weight and capacities, see the Appendix.

Most tractor-mounted winches have line capacities ranging from 3.5 to 6.0 tonnes. If the tractive effort exceeds this rating during winching (e.g., when the load hangs on an obstruction), the clutch is designed to slip, preventing damage to the chain, components and mainline. The ultimate breaking strength of chain chokers should equal or slightly exceed the winch's capacity (e.g., a 6.0-tonne chain choker is provided with a 5.6-tonne winch, a 4.0-tonne chain choker with a 3.5-tonne winch). If an inappropriately strong chain is used and a severe shock load occurs during skidding, the chain or its components may not rupture, and this may cause the tractor to rear up or the mainline to break and lash back at the operator. For safety, the recommended chain choker capacities outlined by the winch manufacturer should not be exceeded when purchasing a new choker.

Shock and Static Loads

Under normal operating conditions, chain chokers are subjected to both static and shock loads. The continuous tension on a chain choker during winching generates a static load. However, if a log hangs on an obstacle during skidding, the abrupt impact generates a shock load that can increase stresses on a choker and mainline by as much as 100% (Anon. 1976). During *winching*, static and shock loads are generally insufficient to break chains and their components; thus, the working load limit is an adequate measure of chain capacity. However, shock loads are more frequent and variable during *skidding*, and may be sufficient to damage equipment. Thus, the chain's minimum breaking strength is a better measure of its capacity.

Determining the appropriate size and capacity of a chain choker for an average logging application is difficult. Factors such as the winch capacity, the weight of the logs, the coefficient of friction (skidding coefficient), and ground conditions such as obstacles, soil moisture and slope contribute to the forces on the chokers and mainline. Table 1 suggests suitable chain sizes and grades for various working load requirements to help determine the type of chain required for a particular range of estimated loads.

If chain chokers fail, they are likely to break at the "weakest link"; depending on the chain choker configuration, this failure could occur at the mainline connection, at the connection between the sliding component and the chain, or at the chain itself.

Wear and Elongation

Most chain will eventually show signs of wear if used continuously, so periodic visual inspection of each link is recommended to determine when it must be replaced. Wear falls into two categories: wear between links, and abrasion or corrosion. Interlink wear occurs at the contact points between links. If wear is detected, measure the link with a caliper and compare the result with the manufacturer's "wear allowance" chart to determine if the chain remains usable (e.g., for one alloy, 1.98 mm of wear is the maximum permissible for 10-mm chain). Abrasion occurs along the exterior of the "barrel" of each link as chains drag on the ground. Replace any section of chain that exhibits obvious wear.

Elongation or stretch results from overloading. Steels are ductile and allow a certain degree of deformation, which provides a visible warning of overloading and impending failure. Most chain has a built-in elongation factor of 15%, but some alloy chain (Grade 100) has an elongation factor of 20%. Alloy chains must be used (by law) for overhead hoisting because of this characteristic. Link failures other than deformations generally occur in the shoulder area of the link (Figure 3).

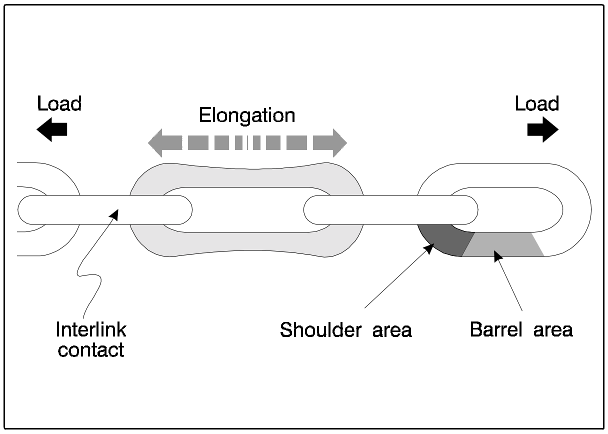

Figure 3. Elongation of a chain link.

Component Types and Characteristics

Components used in chain chokers (Figure 2) are made of carbon or alloy steels similar to those used in chain. Most components are formed by drop forging (e.g., hooks) or by shaping heated rod (e.g., rings). As with chains, heat treatment imparts hardness, ductility and impact resistance. The working load rating of all components should equal or exceed that of the choker chain. For instance, one commercially available alloy choker chain (7-mm diameter) with a working load limit of 2.7 tonnes uses a slotted hook with a working load limit of 2.9 tonnes.

Welding components onto a chain changes the steel's microstructure around the weld and may create weak points. Connector links (e.g., a Hammerlok™, discussed later in this report) provide more dependable connections between a chain and its components.

Slotted Hooks

Most slotted hooks look similar, but there are significant differences, particularly around the entry slot in the hook. This narrow opening only permits a chain link to be inserted sideways and thus prevents inadvertent release of the chain under a load. Chain chokers should be attached to logs with the hook's entry slot facing away from the direction of pull. A typical slotted hook should have a removable load pin secured with a retaining pin to permit direct connection to the choker chain and eliminate the need for additional connector links (Figure 4a). A variant of this hook incorporates the connector eye into the forged body of the hook (Figure 4b), with a connector link used to connect the chain to the hook. A third variant (Figure 4c) has a more intricate entry slot to minimize the risk of inadvertent detachment by further restricting the chain's ability to exit.

A possible forerunner to these hooks is a forged or heat-formed ring with a portion cut out to create an entry slot (Figure 4d). The entry slot's location, adjacent to the chain's connector eye, may reduce premature detachment since the line pull is on the opposite side of the ring. This simple sliding hook attaches to a length of chain using a connector link through its welded eye. Homemade hooks can be modified from existing components such as an anchor chain link (Figure 5a) or formed from heated rod (Figure 5b). Although these are inexpensive, their performance is unpredictable.

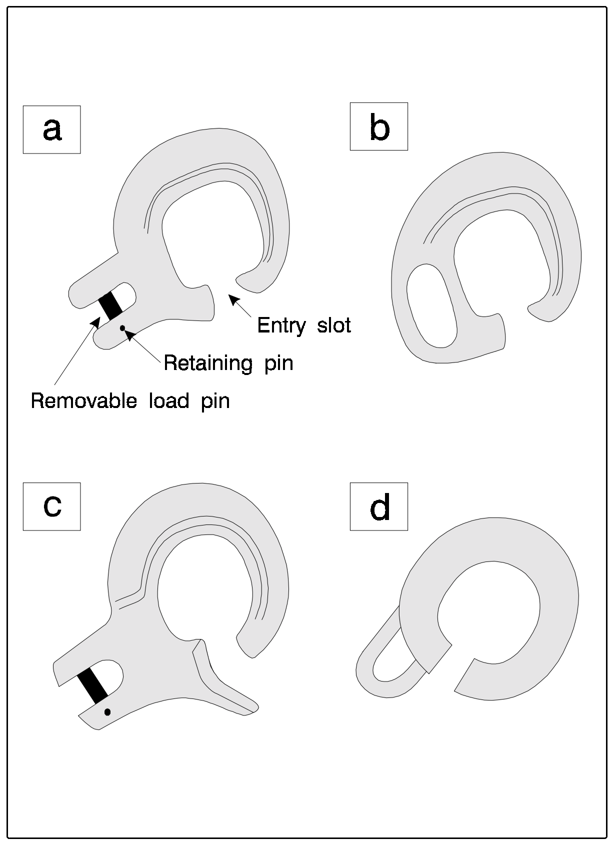

Figure 4. Slotted hooks.

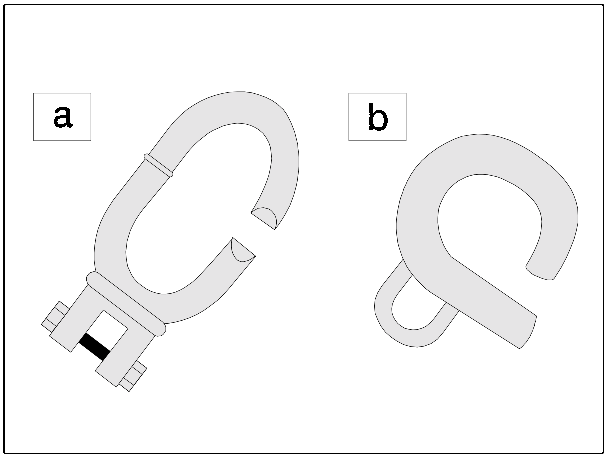

Figure 5. Homemade hooks.

Sliding Rings

Chain chokers with sliding rings are a simple and dependable choking system (Figure 6a). Sliding rings come in various shapes (round, oblong, pear-shaped) and because most have larger dimensions than the chain, they cannot be inserted through its terminal link; thus, they must be attached to the chain using a slightly larger terminal link (as in Figure 6a). Connector links are another means of attachment.

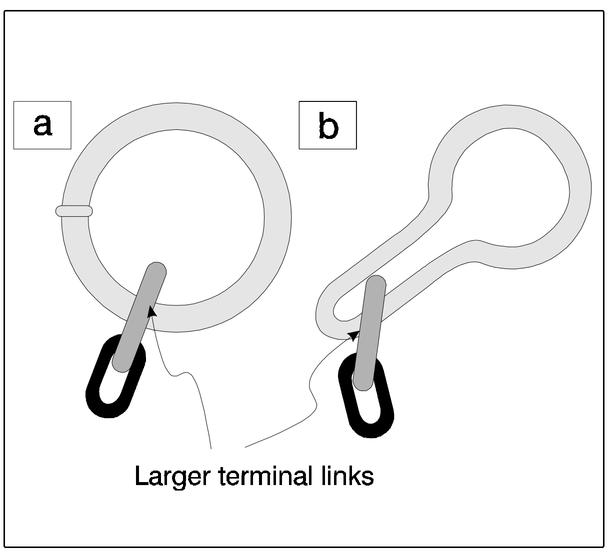

Figure 6. A round sliding ring (left) and a pear-shaped slider.

Round sliding rings are more prone to elongation (Figure 7) than either oblong or pear-shaped sliders, whose form lets them withstand greater loads than a round ring of the same dimensions. Pear-shaped sliders (Figure 6b) can serve another purpose. The chain can slide freely through the wide portion of the ring to choke a log, or the ring can be inverted and its narrow portion used to create a locking slot for load binding.

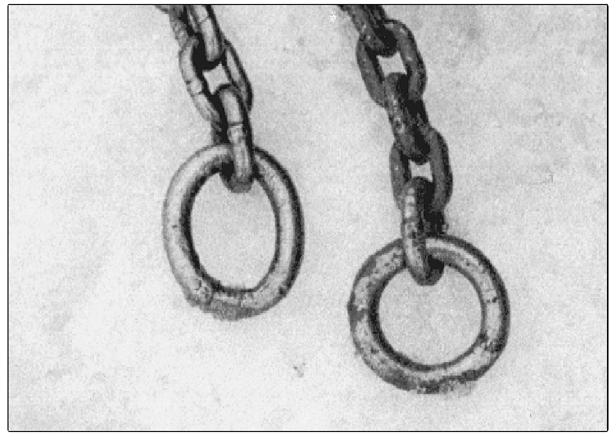

Figure 7. Deformed (left) and normal (right) sliding rings.

Free-end Attachments

To improve the efficiency of chain chokers, most manufacturers attach a pull-through needle on the chain's free end (Figure 8a). This allows operators to insert the chain's free end more easily under logs partially buried in earth or snow and facilitates feeding the free end through a keyhole slider on a mainline. The needle should be at least 20 cm long and 7 to 10 mm in diameter, with a slight bend at the center. Heat treatment is unnecessary since the needle won't support heavy loads and may require occasional reshaping.

Some manufacturers fit a cross "T" rod (approximately 12 cm long) at the chain's free end as a retaining device to prevent the chain from detaching completely from a keyhole slider. This configuration is best suited for applications in which stems are winched row by row (e.g., plantation row thinning); in this case, the chokers need not be completely removed from the keyhole sliders on the mainline. Figures 8b and 8c show welded and twisted end attachments. Removing the T-retainer from a keyhole slider and reinserting it can be awkward.

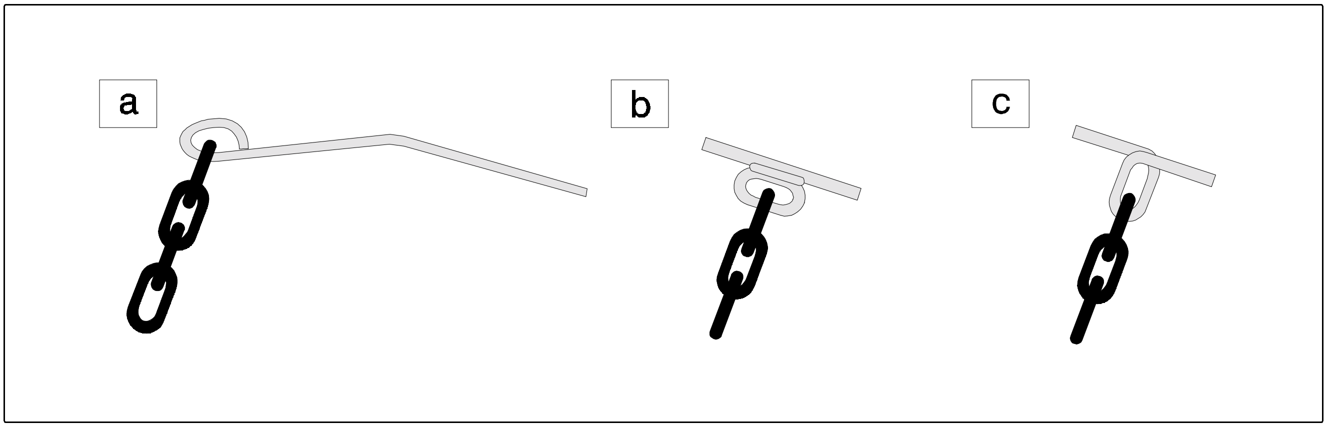

Figure 8. A pull-through needle (a) and two cross "T" retainers (b, c) for the chain's free end.

Mainline Attachments

The most common attachment for connecting chain chokers to a winch's mainline cable is a keyhole slider (sliding shoe), which comprises a sliding saddle, a connecting nut and bolt (or alloy rivet), and a keyhole plate (Figure 9). The saddle portion, forged or cast from alloy steel, has a large bearing surface that slides freely along the mainline, but will abrade over time. One European version uses a small sheave (pulley) that travels freely along the mainline to replace the sliding saddle, minimizing friction and abrasion (Figure 10). The keyhole plate is available in 45°, 90° or flat configurations. Depending on the diameter of the log being choked, excess chain can be adjusted by setting it in the keyhole slot. This adjustment ensures that the log is partially off the ground during skidding, thus minimizing drag.

On eastern U.S. skidder operations that use chain chokers, a common mainline attachment system (Figure 11) comprises a cast alloy sliding ring ("log slider") on the mainline connected to a forged alloy "grab link" by means of a Hammerlok™ connector. The grab link resembles a pear-shaped slider, but is much larger. To attach a chain to the mainline, the worker slips it into the slotted portion of the grab link.

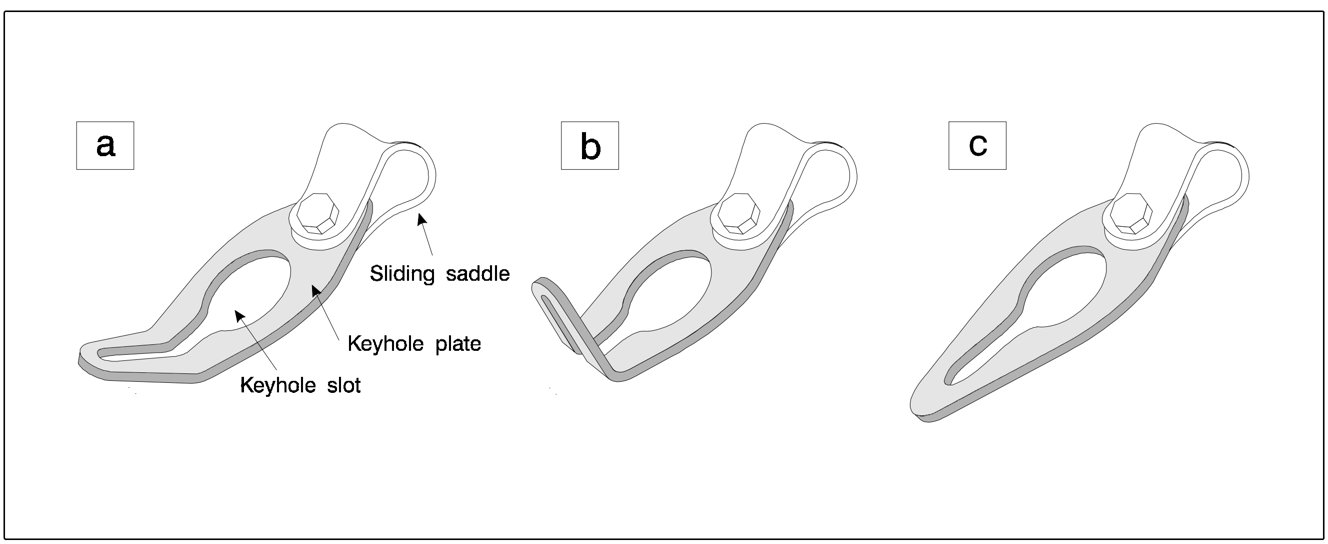

Figure 9. Keyhole sliders with (a) 45°, (b) 90° and (c) flat keyhole plates.

At the base of the slot, a built-up area provides additional support and reduces wear on the chain links. The sliding rings nest together as they accumulate along the mainline during winching.

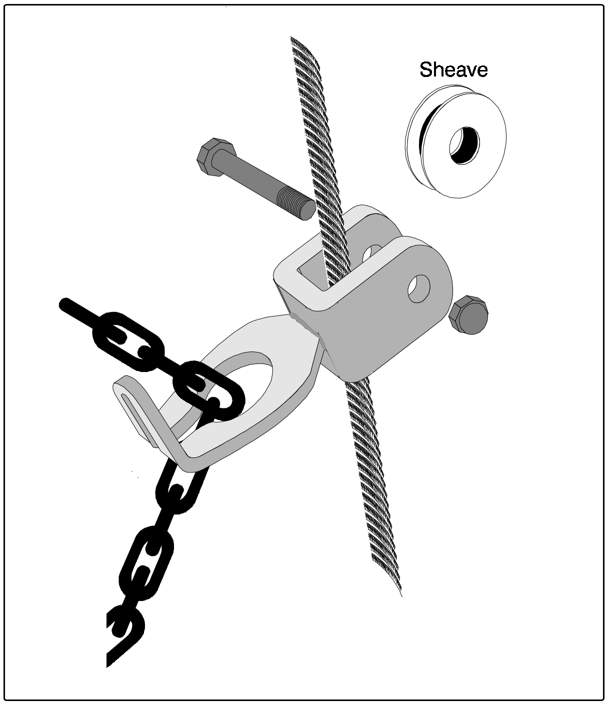

Figure 10. Replacing the sliding saddle with a pulley reduces abrasion.

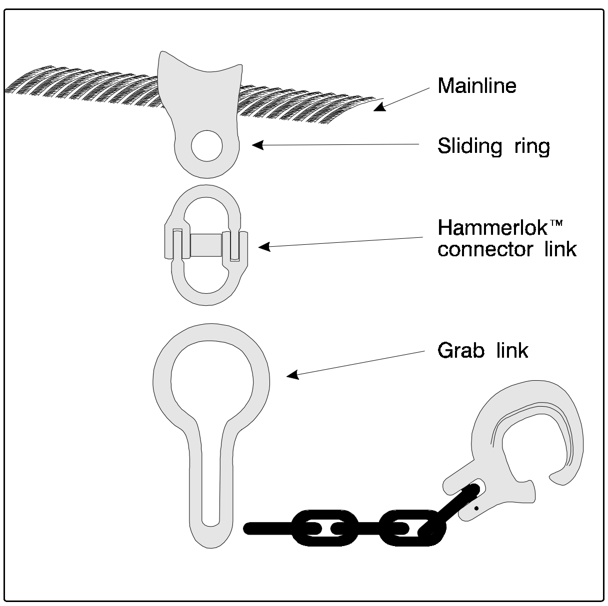

Figure 11. A skidder-based mainline attachment.

Mainline End Hooks

Most mainline end hooks (Figure 12) are produced from drop-forged or manually shaped heated carbon or alloy steel rod. Their primary purpose is to provide an additional choker attachment point. The hook is also effective for quickly freeing individual chokers that remain stuck between logs while unchoking at the landing. The mainline cable feeds through the eye of the end hook and is secured in place with cable clips or a crimped sleeve. During winching, keyhole sliders accumulate against the leading cable clip, not the end hook. End hooks produced from heated rod are typically 12 to 15 mm in diameter and occasionally deform slightly, letting the choker chain slip out of the slot. The drop-forged version is more reliable.

Figure 12. Chain choker (left) attached to mainline end hook (right).

The end hook should not be looped back to the mainline to choke a log or bundle of logs because the hook will create a concentrated area of wear on the mainline cable's strands. If such looping ("bunch slinging") is necessary (e.g., when winching pre-bunched stems with a skidding pan), attach the end hook to a short (<30 cm) length of chain attached to a saddle slider on the mainline rather than to the mainline itself (Figure 13).

Table 2 lists some characteristics of the various chain choker components, with some specifications presented as ranges due to their wide variation.

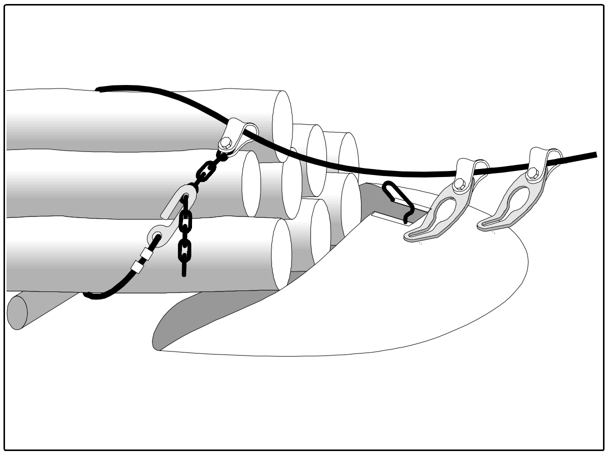

Figure 13. When slinging a load (e.g., for use with a skidding pan), hook the end hook onto a short length of chain attached to a saddle slider on the mainline.

Combination Wire and Chain Chokers

FERIC investigated the feasibility of a combination wire rope and chain choker system (Figure 14) as an alternative for tractor-mounted winches. The goals were to address some concerns that operators had with using chain chokers instead of wire rope chokers and to develop a system that combined the benefits of wire rope and chain. The results were three choker configurations, comprising a 10-mm-diameter wire rope choker (in 1.0-, 1.25- and 1.8-m lengths) fitted with a sliding bell and an end ferrule. Each of the three lengths was attached to various lengths (90, 60 and 45 cm) of 8-mm chain with a pull-through needle. (In this case, the needle facilitates insertion of the chain into the keyhole slider.) Each combination was approximately 2.0 m long. The inherent advantages of the wire rope and bell (e.g., ease of connection, ease of insertion under logs, etc.) combined with those of the chain provided a flexible, effective connection to the keyhole slider. The combination chokers were sent to four contractors for evaluation in the field.

Table 2. Chain choker components[a]

	Slotted hook	Sliding ring	Pear-shaped slider	Keyhole slider	Mainline end hook
Sizes	will accept chain with 6, 7, 8 or 10 mm rod diam	10 to 15 mm rod diam, minimum inside ring diam approx 50 mm	7 to 10 mm and greater rod diam	35-mm opening for chain up to 8-mm diam, 40-mm opening for chain up to 11-mm diam	Will accept mainline cable diam up to 13 mm
Weight (kg)	0.2 - 0.7	0.2 - 0.3 (approx)	0.15 - 0.25	0.4 - 1.2	0.6 (approx)
Working load (tonnes)	1.8 - 5.7	n/a	n/a	4.1 - 6.8	n/a
Breaking strength (tonnes)	up to 7.2	4.0 to 7.5	4.0 - 6.0	up to 7.5	approx 6.0
Cost	$7.50-$17.00	n/a	n/a	up to $38.00	approx $25.00
Manufacturers	Pewag, Igland Wallingford, Norse	Farmi, Skid'n'Winch, Norse	Igland, Norse	Pewag, Farmi, Skid'n'Winch	drop-forged: Igland, Norse heat-formed rod: Farmi, Fransgard

[a] n/a = Information not available.

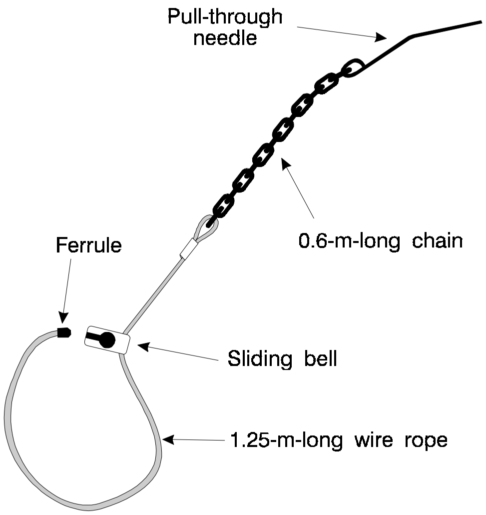

Figure 14. FERIC's combination wire rope and chain choker.

For most situations, the 1.25-m wire rope attached to the 60-cm-long chain was the most practical length. Some operators felt that this system was best suited to thinning applications in which tree diameters were uniform, thus minimizing the need to choose one wire length over another. One concern during field evaluations was that there was insufficient adjustability between the log and the keyhole slider. Excessive wire rope lengths caused choked stems to trail behind the winched-in load, which could cause the trailing butt to hang on an obstacle. Another concern was that the eye connection between the wire rope and the chain link, an abrupt bend, might wear prematurely.

The estimated cost of each prototype choker ranged between $15 and $20, considerably less than that of carbon-steel or alloy chokers. No further testing of this choking system has been conducted by FERIC.

Discussion

Many of the opinions expressed by small-scale contractors using chain chokers centered upon the usefulness of the sliding component, in particular the slotted hook or sliding ring.

The slotted hook was considered more durable and efficient than the sliding ring, allowing operators to attach and detach it from the chain quickly and easily, particularly when a twitch of logs became jammed together at the landing. In this situation, the slotted hook can be easily detached and the bound portion of chain can be loosened using the mainline's end hook. The same situation is awkward with a sliding ring component, as the ring must be slid back along the chain length in order to detach it. Ring sliders were considered more reliable than slotted hooks in securing a log, but one contractor noted that it takes three times longer to unchoke a sliding ring than a slotted hook from its chain.

A potential problem with any chain choker, including FERIC's combination wire and chain device, is that the chain might detach from the mainline's keyhole slider. This could occur during skidding when releasing the mainline to avoid bogging down in a soft area. Altering the direction of line pull to winch in the load might also cause a chain to detach.

Synthetic-fiber mainlines are currently being tested by FERIC as an alternative to traditional steel mainlines, and have resulted in a significant reduction in "haul out" weight. This weight reduction could potentially negate the greater weight of chain chokers (compared with wire rope), making them a more attractive option for long-distance winching. Synthetic-fiber chokers are now being used in some Nordic countries, and could further reduce the haul-out weight, but there is some concern over their ability to withstand abrasion.

Conclusions

Interest in tractor-mounted forestry attachments and their potential uses continues to expand. The many models of tractor-mounted winches currently on the market demonstrate the increased demand and potential new applications (e.g., selective harvesting, thinning). The demand for chain chokers will continue to rise as a result of this increased activity.

The popularity of alloy steels for manufacturing chain chokers is also increasing. North American and European distributors now offer lightweight alloy chains of Grade 80 and 100 with high tensile strength and wear resistance that provide better properties than carbon-steel chains. Alloys with high strength to weight ratios should be considered by small-scale contractors even if the costs are slightly higher than those of carbon steel chain. Their longer working life will compensate for this initial investment.

Chain chokers can be assembled by the manufacturer or the various components can be purchased separately and assembled by the user. Selecting appropriate chains and components is important. Each item must be compatible in its dimensions, working load and breaking strength to avoid damage to equipment and for safety reasons. For further information, contact the author or the winch distributors listed in the supplement to McCallum (1993).

Acknowledgments

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Disclaimer

This report is published solely to disseminate information to FERIC's members. It is not intended as an endorsement or approval by FERIC of any product or service to the exclusion of others that may be suitable.

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Appendix

Sample Chain Ratings from one Manufacturer

Steel grade and type[a]	Stock size mm (in.)[b]	Weight (kg/m)	Working load kg (lb.)	Proof test kg (lb.)	Min. breaking strength kg (lb.)
Grade 40	7.1 (1/4)	1.07	1 181 (2 600)	1 954 (4 300)	3 522 (7 750)
(C1018)	8.5 (5/16)	1.52	1 772 (3 900)	2 909 (6 400)	5 272 (11 600)
low to med. carbon	10.0 (3/8)	2.15	2 454 (5 400)	4 045 (8 900)	7 363 (16 200)
Grade 70	7.1 (1/4)	1.10	1 431 (3 150)	2 863 (6 300)	5 727 (12 600)
(e.g., C10B22)	8.5 (5/16)	1.47	2 136 (4 700)	4 272 (9 400)	8 545 (18 800)
med. to high carbon	10.0 (3/8)	2.10	3 000 (6 600)	6 000 (13 200)	12 000 (26 400)
Grade 80	7.1 (1/4)	1.07	1 863 (4 100)	4 250 (9 350)	6 545 (14 400)
(8620) HA 800	8.5 (5/16)	1.35	2 050 (4 500)[c]	4 715 (10 350)[c]	n/a n/a
alloy	10.0 (3/8)	2.10	3 318 (7 300)	8 318 (18 300)	12 818 (28 200)

[a] AISI/SAE number in brackets.

[b] Conversions are approximate; the manufacturer's Imperial units are provided to give exact measurements.

[c] Approximate.