Fact Sheet
Steel Rope Inspection

14.09.2009

SHEAVES AND DRUMS

In the course of normal operations, wire rope comes into contact with sheaves, drums, rollers and scrub boards—all of which must be maintained in first class condition.

What causes a groove and wire rope to wear? Basically, the answer derives from the fact that a wire rope, when loaded, stretches much like a coil spring. When the rope is bent over a sheave, this load-induced stretch causes the rope to rub against the groove. As a result, both the groove and the rope are subject to wear. Additional rubbing, within the rope, is encountered as the rope adjusts, by movement of the wires and strands, as it is bent around the sheave or drum. The smaller the ratio of sheave diameter to rope diameter (D/d), the greater will be the adjusting movement, and the more rapid will be the resulting wear.

The amount of wear, and the speed at which it takes effect on both the wire rope and grooves of the sheaves and drum, are also determined by the sheave material, and the radial pressure between rope and groove. Simply stated, excessive wear can be caused either by sheave or drum material that is too soft, or a diameter (tread diameter) that is too small.

To determine the unit radial pressure between rope and groove, use the following formula:

$$p = \frac{2T}{Dd}$$

where p = Unit radial pressure in pounds per square inch
T = Load on the rope in pounds
D = Tread diameter of the sheave or drum in inches
d = Nominal diameter of the rope in inches

Table 8 gives examples of allowable unit radial bearing pressures of ropes on various materials commonly used in sheaves and drums. The values given are typical for the materials listed; they are not precise values since these materials are made to a wide range of specifications.

In the foregoing equation, if the calculated value of "p" exceeds the allowable radial pressure for the sheave or drum material, the groove will wear quite rapidly. Wear will manifest itself in the form of either an undersize or corrugated groove—either of which will contribute to accelerated wear in the rope.

Values for the allowable unit radial pressures given in Table 8 are intended solely as a user's guide. And use of these figures does not guarantee prevention of any trouble. Further, the values should not be taken as restrictive with regard to other or new materials. There are, for example, certain elastomers in current use that are apparently providing excellent service, but since there is insufficient data to support specific recommendations, such products are not mentioned.

BENDING WIRE ROPE OVER SHEAVES AND DRUMS

Sheaves, drums and rollers must be of a correct design if optimum service is to be obtained from both the equipment and the wire rope. Because there are many different types of equipment and many different operating conditions, it is difficult to identify the one specific size of sheave or drum most economical for every application.

The rule to follow is this: the most economical design is the one that most closely accommodates the limiting factors imposed by the operating conditions and the manufacturer's recommendations.

All wire ropes operating over sheaves and drums are subjected to cyclic bending stresses, hence the rope wires will eventually fatigue. The magnitude of these stresses depends—all other factors being constant—upon the ratio of the diameter of the sheave or drum to the diameter of the rope. Frequently, fatigue from cyclic, high-magnitude bending stress is the principal reason for shortened rope service.

To illustrate, in order to bend around a sheave, the rope's strands and wires must move relative to one another. This movement compensates for the difference in diameter between the underside and the top side of the rope, the distance being greater along the top side than it is on the underside next to the groove. Proper rope action (and service) is adversely affected if shifting the wires cannot compensate for this situation. Also, there can be additional motion retardation because of excessive pressure caused by a sheave whose groove diameter is too small, or by a lack of lubrication. Changing the bending direction from one sheave to another should be scrupulously avoided as this reverse bending still further accelerates wire fatigue.

The relationship between sheave diameter and rope diameter is a critical factor that is used to establish the rope's fatigue resistance or relative service life. It is expressed in the tread D/d ratio mentioned earlier in which D is the tread diameter of the sheave and d is the diameter of the rope. Table 9 lists "suggested" and "minimum" values for this ratio for various rope constructions. Tables 10 and 11 show the effect of rope constructions and D/d ratios on service life.

TABLE 10
RELATIVE BENDING LIFE FACTORS

Rope Construction	Factor	Rope Construction	Factor
6 x 7	.57	6 x 31 WS	1.09
18 x 7	.67	6 x 36 WS	1.31
6 x 19 S	.80	8 x 25 FW	1.39
6 x 30 Style G	.80	6 x 41 SFW	1.39
6 x 25 Style B	.80	6 x 43 FWS	1.54
6 x 21 FW	.92	6 x 49 SWS	1.54
6 x 25 FW	1.00	6 x 42 Tiller	2.00

If a change in construction is being considered as a means of obtaining longer service on a rope influenced principally by bending stresses, the table of factors may be useful. For example: a change from a 6 x 25 FW with a factor of 1.00 to a 6 x 36 WS with a factor of 1.31 would mean the service life could be expected to increase 1.31 times or 31%.

It must be pointed out however that these factors apply only for bending stresses. Other factors which may contribute to rope deterioration have not been considered.

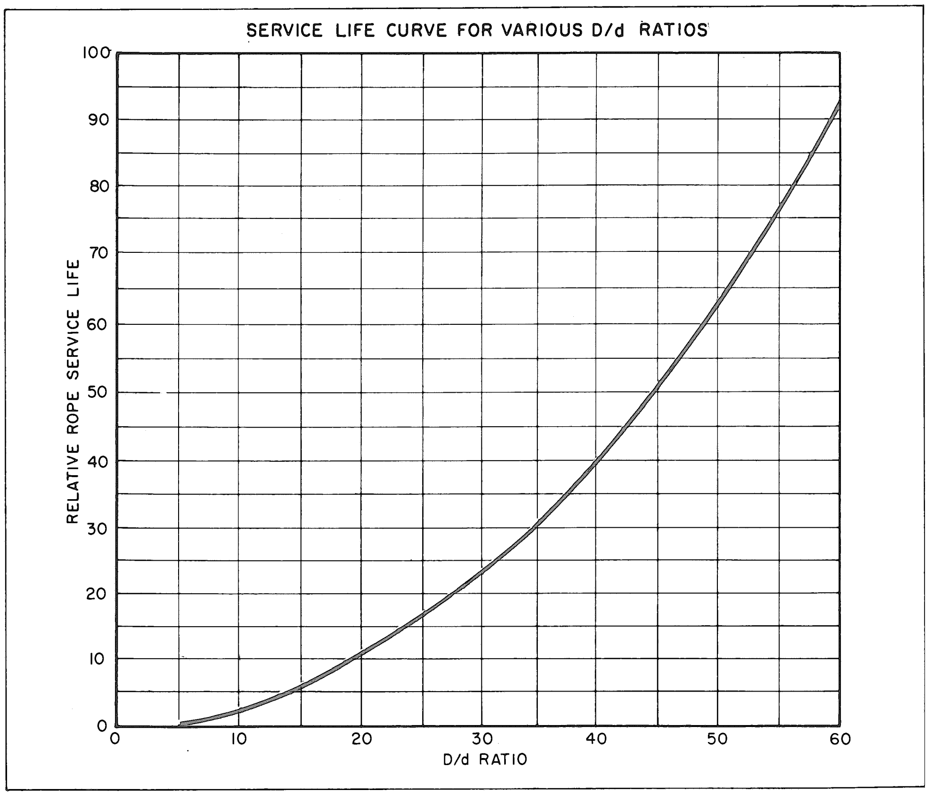

Figure 28. This *service life curve* only takes into account bending and tensile stresses. Its applicability can be illustrated by the following example: A rope working with a D/d ratio of 26 has a relative service life of 17. If the same rope works over a sheave that increases its D/d ratio to 35, the relative service life increases to 32. In short, this rope used on a larger sheave, increases its service life from 17 to 32—or 88%.

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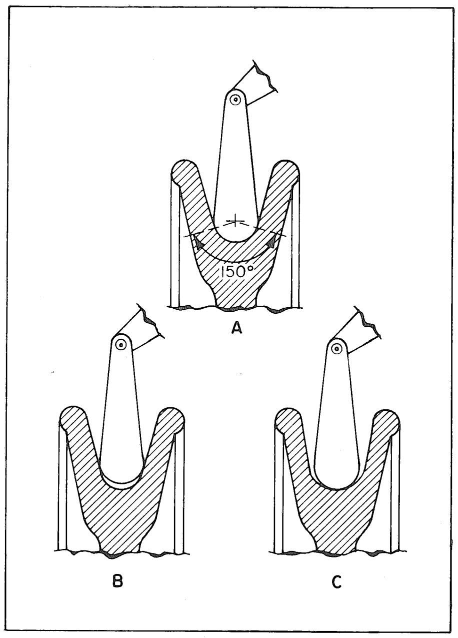

Figure 29. Cross-sections illustrating 3 sheave-groove conditions revealed by the metric arrangement of wires in the strand. tight; and C is too loose.

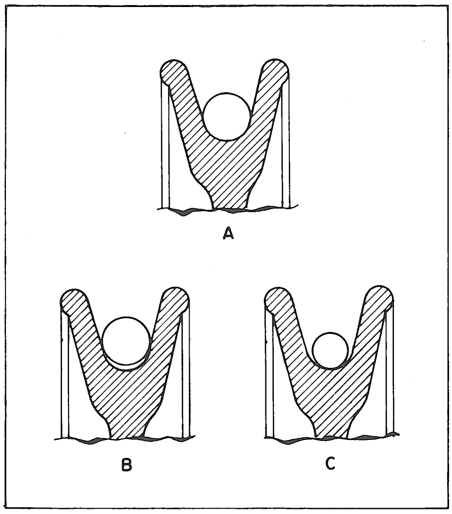

Figure 30. These sheave-groove cross-sections represent 3 wire rope seating conditions: A, a new rope in a new groove; B, a new rope in a worn groove; and C, a worn rope in a worn groove. (See also Figs. 29 and 31.)

INSPECTION OF SHEAVES AND DRUMS

Under normal conditions, machines receive periodic inspections, and their over-all condition is recorded. Such inspections usually include the drum, sheaves, and any other parts that may come into contact with the wire rope and subject it to wear. As an additional precaution, rope-related working parts, particularly in the areas described below, should be re-inspected prior to the installation of a new wire rope.

The very first item to be checked when examining sheaves, rollers and drums, is the condition of the grooves (Figs. 29, 30, and 31). To check the size, contour and amount of wear, a *groove gage* is used. As shown in Figure 29, the gage should contact the groove for about 150° of arc.

Two types of groove gages are in general use and it is important to note which of these is being used. The two differ by their respective percentage *over nominal.*

For new or re-machined grooves, the groove gage is nominal plus the full oversize percentage. The gage carried by most wire rope representatives today is used for worn grooves and is made nominal plus ½ the oversize percentage.

This latter gage is intended to act as a sort of "no-go" gage. Any sheave with a groove smaller than this *must* be re-grooved or, in all likelihood, the existing rope will be damaged.

When the sheave is re-grooved it should be machined to the dimensions for "new and machined" grooves given in Table 11. This table lists the requirements for new or re-machined grooves, giving the groove gage diameter in terms of the nominal wire rope diameter plus a percentage thereof. Similarly, the size of the "no-go" gage is given, against which worn grooves are judged. Experience has clearly demonstrated that the service life of the wire rope will be materially increased by strict adherence to these standards.

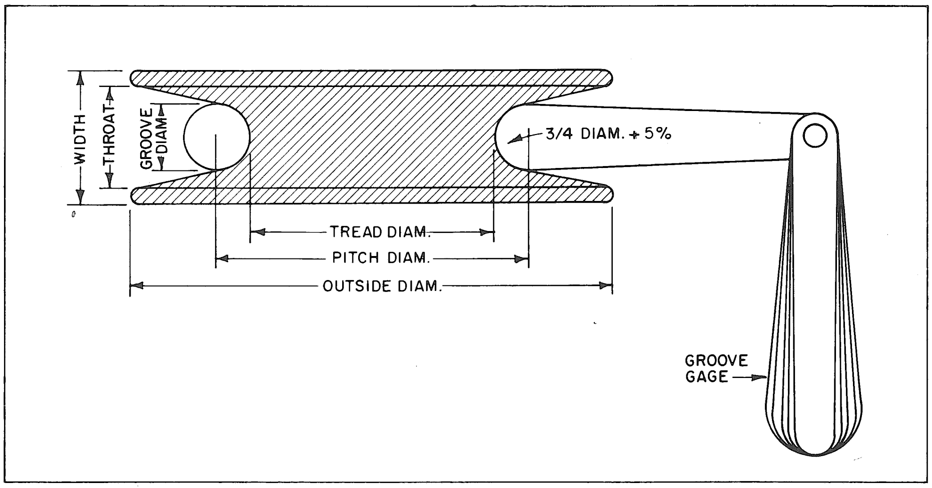

Figure 31. Illustrating the various dimensions of a sheave, and the use of a groove gage.

If the fleet angle (Fig. 34) is large, it may be necessary to accept a smaller arc of contact at the throat; 130° for example instead of 150°. This is done to avoid scrubbing the rope on the flange of the sheave.

As previously noted, the groove size is evaluated on the basis of how the gage leaf fits the groove. Daylight under the gage is not tolerable when using the worn groove gage. If a full over-size gage is used, some daylight may be acceptable, but this really must be judged by relating the measurement to the *actual* size of the rope.

For new rope, extra caution should be observed as to its fit in the groove. Characteristically, ropes become smaller in diameter immediately after being placed in service. As a result, they would operate satisfactorily in a "worn" groove; one that was gaged OK by the "worn" groove gage. Nonetheless, in some cases, a rope may not "pull down," and if this happens, abnormal wear may occur.

It is important to remember that a tight groove not only pinches and damages the rope but that the pinching prevents the necessary adjustment of the wires and strands. On the other hand, a groove that is too large will not provide sufficient support; in this case, the rope will flatten and thereby restrict the free sliding action of the wires and strands.

The size of the groove is not the only critical item to be examined closely. The *condition* of the groove is also an important factor of concern. Is it smooth or imprinted? If the groove is imprinted then it must be re-machined or, if it is imprinted too deeply, it means that sheave, roller or drum must be replaced. If replacement is indicated, a larger sheave or drum should be installed if possible, or a harder material should be specified for the replacement.

Groove examination should also concern itself with *how the groove is wearing*. If it is worn off-center, thereby forcing the rope to undercut or to rub against the flange, it then becomes necessary to correct the alignment of the reeving system, and to specify a harder material.

When checking the grooves, the bearings of the sheaves and rollers should also be examined. They should turn easily. If not, each bearing must be properly lubricated. "Wobble" in the sheave—from broken or worn bearings—is not acceptable. Bad bearings will set up vibrations in the wire rope that can cause rapid deterioration unless the condition is remedied. Bad bearings also increase the force on the rope that is needed to move a given load, since friction forces will be greatly increased.

Sheaves with broken flanges may allow the rope to jump from the sheave and become fouled in the machinery. When this happens, the rope is cut, curled, and the crowns of the wires in the strands are burred. There is ample evidence to support the rule that sheaves with broken flanges must be replaced immediately.

A sheave or drum with a flat spot can induce a "whip" into the line. This whip, or wave, travels until it is stopped by the end terminal, at which point the rope may bend severely. This condition helps to accelerate the fatigue breakage of wires. Sometimes the reeving is such that the whip or wave is arrested by a sheave, or the drum itself. In these circumstances, the whipping will cause wire breaks along the crowns of the strands. Obviously, sheaves or drums that excite vibrations of this sort, must be repaired or replaced.

In addition to the items listed above, inspection should also focus on any and all conditions that could cause wear and eventual damage to the wire rope.

For example, plain-face (smooth) drums can develop grooves or rope impressions that will prevent the rope from winding properly. Imprinting is greatest at the pickup point when the machine is accelerating. If this happens, the surface should be repaired by machining or replaced. The winding should be checked to make sure that the rope is winding "thread wound" (Fig. 27).

Excessive wear in grooved drums should be checked for variations either in the depth or pitch of the grooves. This condition is particularly critical when double drums are used because a differential force will be set up that can break the drum and shear the shaft.

No matter what type of drum is in use, excessive drum wear will usually result in rapid rope deterioration. This condition will accelerate rapidly when winding in multiple layers.

STRENGTH LOSS OF WIRE ROPE OVER STATIONARY SHEAVES OR PINS

Rope breaking strength is determined in a standard test wherein fittings are attached to the ends of the rope and the rope is pulled in a straight line.

If, however, the rope passes over a curved surface (such as a sheave or pin) its strength "is decreased." The amount of such reduction will depend on the severity of the bend as expressed by the D/d ratio. For example, a rope bent around a pin of its own diameter will have only 50% of the strength attributed to it in the standard test. This is called "50% efficiency" (Fig. 33). Even at D/d ratios of 40, there may be a loss of up to 5%. At smaller D/d ratios, the loss in strength increases quite rapidly.

The angle of bend need not be 180°, 90°, or even 45°; relatively small bends can cause considerable loss.

All discussion of strength pre-supposes a gradually applied load not in excess of 1"/minute.

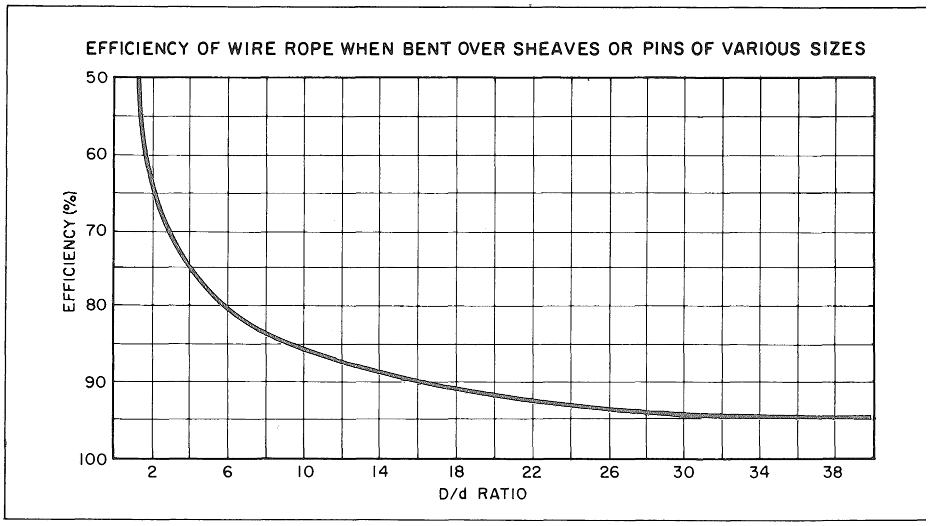

Figure 33. Derived from standard test data, this curve relates rope strength efficiency to various D/d ratios. The curve is based on static loads only and applies to 6 x 19 and 6 x 17 class ropes.

FLEET ANGLE

The achievement of even winding on a smooth faced drum is closely related to the magnitude of the D/d ratio, the speed of rotation, load on the rope, and the fleet angle. Of all these factors, the one that exerts perhaps the greatest influence on winding characteristics, is the fleet angle.

The schematic drawing (Fig. 34) shows an installation where the wire rope runs from a fixed sheave, over a floating sheave, and then on to the surface of a smooth drum. The fleet angle (Fig. 34) may be defined as the included angle between two lines; one line drawn through the middle of the fixed sheave and the drum—and perpendicular to the axis of the drum and a second line drawn from the flange of the drum to the base of the groove in the sheave. (The drum flange represents the farthest position to which the rope can travel across the drum.) There are left and right fleet angles, measured to the left or right of the center line of the sheave, respectively.

It is necessary to restrict the fleet angle on installations where wire rope passes over the lead or fixed sheave and onto a drum. For optimum efficiency and service characteristics, the angle here should not exceed 1½° for a smooth drum, nor 2° for a grooved drum. Fleet angles larger than these suggested limits can cause such problems as bad winding on smooth drums, and the rope rubbing against the flanges of the sheave grooves. Larger angles also create situations where there is excessive crushing and abrasion of the rope on the drum. Conversely, small fleet angles—less than ½°—should also be avoided since too small an angle will cause the rope to pile up.

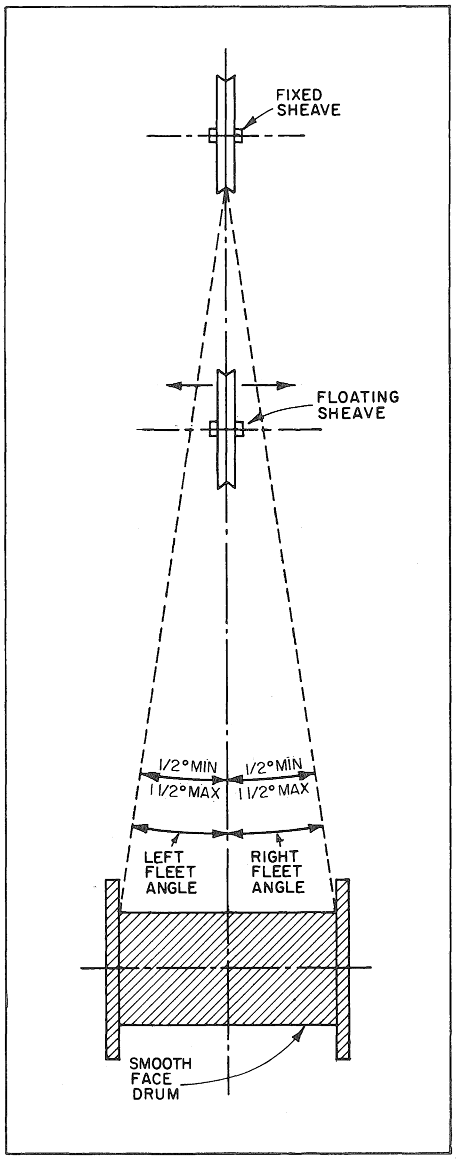

Figure 34. This illustration of wire rope running from a fixed sheave, over a floating sheave, and then on to a smooth drum, graphically defines the *fleet angle*.