Sheaves and Grooves

Over the past few decades, elevator system equipment has become more compact in the quest for decreased power consumption, reduced equipment costs and increased space utilization. The key to this downsizing is the drive sheave, which must be manufactured in smaller diameters to accommodate this trend. Technical Bulletin 10 shows how this downsizing has adversely affected wire rope and sheave life through changes to the sheaves, and addresses the superintendent who says "they don't make ropes like they used to," and "I've never EVER had to regroove a sheave."

Rope Performance

Groove Types

The U-groove Sheave

The U-groove sheave, found predominantly in older installations, is the sheave of choice for optimum rope life. Its large size (when compared with the drive sheave diameters in newer installations) in combination with its supportive grooves minimizes abrasion and fatigue.

Figure 1 illustrates the support given to the rope by the groove. Note the large groove area with which the rope comes into contact (A to B). The groove cradles the rope, resulting in low groove pressures that allow the wires and strands to move about freely while the rope is operating. Also paramount to the U-groove's success in achieving excellent rope life is the relative diameter of the sheave required to maintain traction. The larger D/d ratio makes bending easier, provides a large arc of contact between rope and sheave, reduces operating stresses, and generally optimizes rope life. Refer to Bethlehem Elevator Rope Technical Bulletin 9 on *Fatigue* for further information on D/d ratios.

Unfortunately, the U-grooved sheave with its large diameter also provides the least amount of traction. Hence, the U-grooved sheave, the favorite among wire rope manufacturers, has lost Close

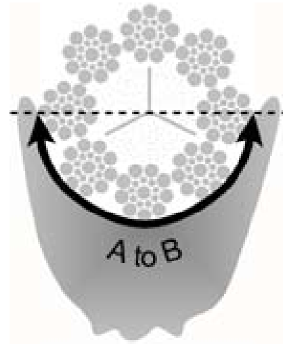

Figure 1
The U-grooved sheave provides full support to the rope with its large arc of contact.

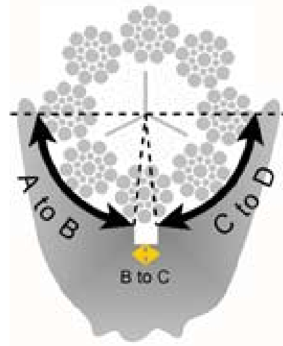

Figure 2
In the Undercut U-grooved sheave, note the decrease coming in contact with the sheave.

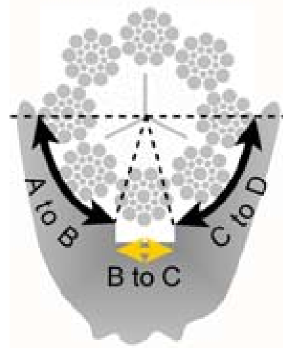

Figure 3
When the size of the undercut is increased, bearing pressure grows as the rope-to-sheave contact declines.

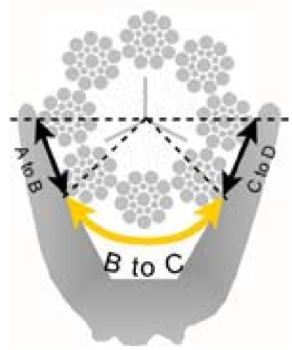

Figure 4
V-grooved sheaves provide the greatest amount of bearing pressures and rope wear.

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popularity in favor of other types of grooved sheaves that can increase traction and be downsized at the same time.

In general, the modern grooves—Undercut U and Progressive V—increase traction by increasing groove pressures. The beauty of these groove types is that the diameter of the sheave utilizing this modern groove design can be reduced. Why? With an increase in rope-to-sheave contact pressure, created by the gripping action (or rope pinching) of the groove, a large arc of contact is not needed to sustain traction.

The Undercut U-groove Sheave

With the reduction in sheave diameter comes a loss of contact area between rope and sheave. To compensate for this loss of contact, and traction, an undercut is placed in the groove (Figure 2). When compared with the U-groove in **Figure 1,** the surface area of the rope making contact with the Undercut U-groove decreases (A to B and C to D). Note the undercut where the rope no longer makes contact with the groove (B to C). Groove pressure is increased as the rope is "gripped" to provide the traction required for effective operation. These increased stresses lead to accelerated wear of the wires and sheave at the points of contact and increased wire fatigue breakage in these areas.

Note the size of undercut in Figure 3. Its larger size further reduces the area of contact between rope and groove. As undercuts become larger, groove pressures mount, traction increases, and unfortunately, rope and sheave wear and rope fatigue accelerates.

Quick Review

Wire ropes are harder then the sheaves on which they operate.

As the ropes operate, they decrease in diameter and machine themselves into the grooves, thus decreasing the diameter of the grooves. When the next set of ropes is installed, the new set of ropes with its new nominal + 2% -0% diameter, is forced to operate in grooves "machined" by the previous set of ropes. The second set of ropes will not perform as well as the first, and each subsequent set will perform more poorly than the last. It is not uncommon to hear that the first set of ropes lasted 18 years, while the last set had to be retired after only a few years. Refer to Bethlehem Elevator Rope Technical Bulletin 7, *Sheave Hardness* for further information.

The V- or Progressive V-groove Sheave

The V-groove is the ultimate groove for traction. The angle of the groove affects rope traction and performance. Generally, the angle of a V-groove is between 32° and 40°. This measurement is the included angle of both sides of the groove. Traction increases with the decreasing groove angle.

Note in **Figure 4** (A to B and C to D) how little of the rope makes contact with the surface of the sheave groove. This type of groove places the greatest amount of pressure on the ropes and sheave grooves, resulting in the greatest amount of traction, but also the greatest amount of rope abrasion. V-grooves increase the bearing pressure on the rope, resulting in shorter rope service life. Because of the increased groove pressures, it is imperative to use a rope that is designed to maintain its roundness.

Undercut U- and V-grooved sheaves adversely affect rope performance. But because these grooves increase traction and therefore do not require a large diameter sheave, these groove types are more attractive to elevator system designers.

Position of the Secondary Sheave

Compact elevator system designs have created some rather unique reeving configurations, the effects of which are covered in Bethlehem Elevator Rope Technical Bulletin 9, *Fatigue*. For the purpose of this bulletin, we will focus on one aspect of the new configurations—the position of the secondary sheave.

Figure 5
This sheave shows a number of defects that need to be corrected through either regrooving or sheave replacement: (a) the sheave alignment, of either this sheave or a secondary, needs to be assessed as the three of the four grooves (left to right) indicate ropes pulling to one side, as shown by the wearing of the groove. Unusual wear patterns and wire breaks along the wear plane will lead to premature rope retirement; (b) as a result of the improper sheave alignment, the first groove has developed a sharp edge on its right side where the rope has worn the groove; (c) likewise, the second groove also has a sharp edge, both of which will quickly abrade the rope; (d) differential groove depths, a result of improper tensioning, will further compromise the rope's service life.

The proximity of the secondary or deflection sheave to the drive sheave is critical for two reasons: (1) bending cycles, and (2) fleet angle.

Bending Cycles

Wire rope is actually a machine with a multitude of moving parts. For example, an 8x19 Seale has 152 moving parts (8 strands, 19 wires per strand) that must be work in conjunction with not only each other, but also with external forces, such as sheaves. The rope’s 152 wire and strand components continually adjust and readjust as the rope moves over a sheave and then straightens. When a wire rope operates over multiple sheaves, more work is required of the rope’s components as the wires and strands adjust to the additional bending cycles. For example, ropes installed on a 2:1 Double Wrap system have a greater number of bending cycles than ropes on a Single Wrap system. To achieve optimum rope life, it is advisable to have at least three to four rope lay lengths between sheaves to allow the wires and strands the necessary recovery distance between bends. Nevertheless, space is sometimes a luxury and the secondary sheave is placed immediately adjacent to the drive sheave. This inadequate spacing negatively impacts the rope’s performance and results in an acceleration of fatigue breaks.

Consider the Undercut U and V grooves. A traction groove is designed to pinch the rope, which in and of itself creates undue stress on the rope by hindering the 152 moving parts from operating freely. In combination with a crowded sheave design, the impact on rope life can be unfavorable. If a reverse bend is introduced into the system (Technical Bulletin 9), the effect on the ropes is devastating.

Fleet Angle

Also of concern in a close sheave configuration is the fleet angle. Generally speaking, the fleet angle is a measurement for describing the angle of the rope as it leaves one sheave and approaches another. The fleet angle has to remain relatively shallow for proper operation. If the rope approaches a sheave at too wide an angle, the rope will scrub against the flanges (sides) of the sheave grooves, causing wear along one plane of the rope and resulting in premature wear. If the secondary sheave moves closer to the drive sheave, the fleet angle becomes greater. If this increase is not taken into consideration during the design and installation process, or if the alignment of either one or both of the sheaves is incorrect, the fleet angle may be affected and rope and sheave life will suffer.

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sheave configurations further compromise rope performance as the diminished space allowance for sheaves results in excessive bending cycles, greater operating stresses and improper fleet angles.

Sheave Performance

All sheaves need to be inspected and gauged for wear when replacing rope. Generally speaking, all sheaves need to be regrooved at least once during their service lives, but the frequency of regrooving depends upon a number of factors, including groove type and number of cycles.

Grooves designed to increase traction, i.e. Undercut U- and V-grooves, wear more quickly and therefore require more maintenance. The gripping (pinching) action of these groove types causes the ropes to seat themselves into the groove at an accelerated pace. Obviously, the greater the pressure, the greater the frequency of regrooving. Therefore, V-grooved sheaves require more attention than Undercut U-grooved sheaves.

Traditional U-grooved sheaves do not require the same level of maintenance needed with the traction-grooved sheaves. However, they still need periodic regrooving, and it is important to recognize that age alone is an indication that rework may be necessary. If a U-grooved sheave has never been regrooved or replaced, it is definitely worth the time to inspect the grooves for size and groove depth (**reference Figure 5**).

Modern traction-grooved sheaves wear faster than U-grooved sheaves because of the higher groove pressures placed on the ropes.

Conclusion

In the good ol' days, servicing the large, expansive elevator systems with their U-grooved sheaves was relatively predictable. Initially, the systems were costly, but ropes and sheaves lasted "forever." Today, the downsizing trend in new construction and modernization is effectively holding down costs on the front end, but this push towards smaller systems is adversely affecting wire rope and sheave life, and can be costly on the back end if these changes go unrecognized.

Service superintendents must acknowledge (a) elevator systems are changing, and (b) existing equipment is aging, and remember that there is a direct relationship between sheave and rope. These new challenges to the service industry mean that close attention must be paid to the reeving configuration, size and groove type of the drive sheave, the age of the equipment, past maintenance records, and the effect all of this has on wire rope life. Especially when bidding for a new service contract, more consideration needs to be given to the condition of the sheaves. It could mean the difference between profit and loss.

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