Traction in Elevators

by Snehal Toralkar

"Seven people had escaped with minor injuries on a Sunday evening when the elevator carrying them came down crashing from the third floor." There was no doubt that the elevator was overloaded, and this was established as the obvious cause of the incident. Yet a deeper investigation appeared to reveal that the overloading was just a trigger, with the root cause of loss of traction probably being an angle of contact less than 120° (Figure 1) on account of a design flaw that overlooked this key aspect of traction elevators. A discussion with the lift supplier revealed that it had established the layout based on thumb rules rather than any detailed calculation. This appears to be a trend with many suppliers.

The situation is further complicated as the Indian standards appear to be silent on this crucial aspect, giving no direction to designers. In comparison, EN 81 mentions all the minute design details required for traction, yet does not prescribe a minimum angle. ASME A17.1 mentions that sufficient traction shall be provided between the rope and groove to safely stop and hold the car with rated load in the down direction.

In most mechanical systems, considerable emphasis is placed on reducing friction between parts; the reverse is the case in elevators. A lot more importance is given to utilizing friction for traction-driven machines. In layman's terms, traction is the gripping force along the surface. In technical terms, traction is the frictional force.

Starting with the elevator basics, the elevator system first consists of the car, which carries the passengers to the destination floor. The counterweight is placed either at the side or rear with respect to the car position in the hoistway shaft. This balance is provided to conserve energy. These components are held by steel ropes looped around the sheave. The sheave is a pulley with grooves around its circumference. The sheave is driven by the motor. The sheave grips the hoist ropes so that when it rotates, the ropes move, too. This gripping is due to traction.

Traction Calculation

Consider a rope passing over a driving sheave (Figure 2). Let T_1 be the tension in the car side, and T_2 in

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Figure 1: This article explores the fundamentals of traction.

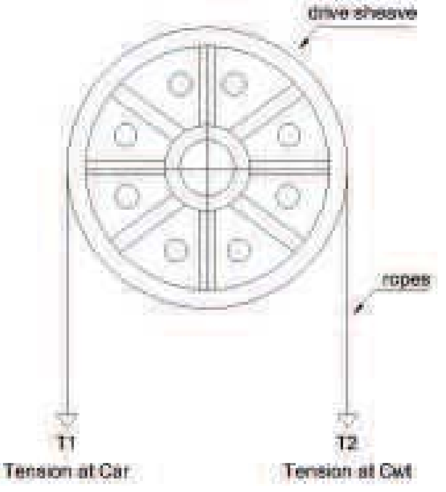

Figure 2: Traction calculation

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the counterweight side. The required traction for any elevator system is expressed as T_1/T_2. T_1 is the addition of all weights (i.e., 125% of rated load, car weight, ropes and traveling-cable weight), whereas T_2 is the counterweight.

The maximum available traction that can be developed is a function of the actual coefficient of friction between the rope and groove, the shape of groove and angle of contact.

Maximum available traction = $e^{f\Theta}$

where e = the base of natural logarithm

f = coefficient of friction

Θ = angle of contact

Hence the condition so that the elevator does not lose traction is given by:

$$T_1/T_2 \times C < e^{f\Theta}$$

where C is constant, considering acceleration and deceleration, and is given by:

$C = (gn + a)/(gn - a)$, where gn = acceleration due to gravity and a = rated speed of the elevator.

Obviously, from the above expressions, we can conclude that the maximum traction can be achieved when the value of $f\Theta$ is increased.

Factors Affecting Traction

Angle of Wrap

"Angle of wrap" or "angle of contact" is the angle that the rope makes with the circumference of the sheave. The maximum angle for single-wrap traction (SWT) that can be achieved is 180° (Figure 3). However, the problem occurs when there is a diverter pulley. In this case, the angle decreases, but with suitable arrangements like adjusting the height and length between the sheave centers, maximum angle can be achieved.

The other option by which to achieve the maximum angle is double-wrap traction (DWT) (Figure 4). In DWT, traction is considerably increased, as in this case, angle becomes (S1 + S2). But this system has some disadvantages. The design of the machine is complicated. The height is greater, and the width of the sheave rim is larger, as the number of grooves is doubled. The rope bends number is greater, resulting in additional rope wear. This also results in an overall cost increase of the equipment.

Sheave Diameter

The ratio of rope diameter to sheave diameter also plays an important role in traction. Per Indian standards, sheave diameter should be equal to 40 times the rope diameter. The larger the sheave diameter, the more the contact area between the rope and sheave is achieved. The sheave diameter should also be large enough to account for the bending stresses exerted by the ropes. However, cost is also to be considered while setting the final diameter. It will also result in a larger machine assembly, which will create problems during installation.

Type of Groove

The other important factor that affects traction is the shape of the groove. Commonly used groove shapes are U-groove, U-groove with undercut and V-groove.

U-Groove

The U-groove is the sheave of choice for optimum life (Figure 5). Its large size, in combination with its supportive grooves, minimizes abrasion and fatigue. Note the large groove area with which the rope comes in contact. The groove cradles the rope, resulting in low groove pressures, allowing the wires and strands to move about freely while the rope is operating. Unfortunately, however, the U-grooved sheave provides the least amount of traction.

U-Groove with Undercut

When compared to the U-groove, the surface area of the rope making contact with the undercut U-groove decreases. Note the undercut where

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Figure 3: SWT (angle of contact: 180°)

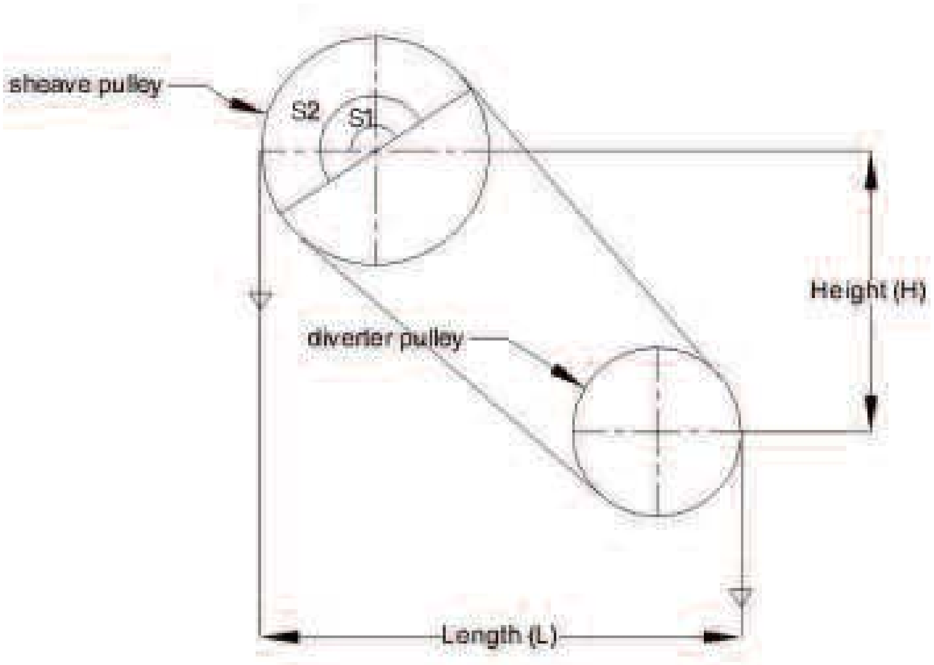

Figure 4: Double-wrap traction

the rope no longer makes contact with the groove (Figure 6). Thus, groove-bearing pressure is increased upon which the higher available traction is based. The available traction can be increased by increasing the angle of undercut in the sheave groove. However, it has limitations, since the larger the undercut, the less support it receives from the groove and therefore the less load we can put on the ropes without causing rapid sheave wear and rapid rope failure. The undercut angle is therefore kept between 90° and 106°.

V-Groove

The V-groove is the most widely used type of groove (Figure 7). These provide the greatest amount of bearing pressures, hence maximum traction. The angle of the groove is kept between 32° and 40°. Traction increases with decreasing angle of the groove, but it also leads to shorter rope life.

Conclusion

While the magnitude of the groove pressure distributions associated with each groove varies, it is to be noted that in no case does the "actual" rope-to-groove coefficient of friction change. However, the "apparent" coefficient is a direct function of the groove pressures and actual coefficient of friction, and it does change as the groove shape changes. For the latter case, elastomer-lined drive-sheave grooves are used. These have a higher coefficient of friction and afford a very efficient method of increasing available traction. It is also to be noted that specific pressure of the ropes does not exceed the pressure value with the car loaded with its rated load:

Specific pressure of ropes

$$P \le \frac{12.5 + 4\,v_c}{1 + v_c}$$

Finally, summing up the proof concludes the following:

1) Available traction can be increased by increasing the arc of contact that the rope subtends with the sheave.
2) Available traction can be increased by changing the shape of the groove.
3) Available traction can be increased by increasing the actual coefficient of friction of the material.

Note that all the above parameters are dependent on one another. Compromising on any of the above factors should not change the final traction value. With this background, elevator system designers need to be very careful in estimating traction and establishing their designs.

References

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[3] *Bethlehem Elevator Rope* Technical Bulletin 10

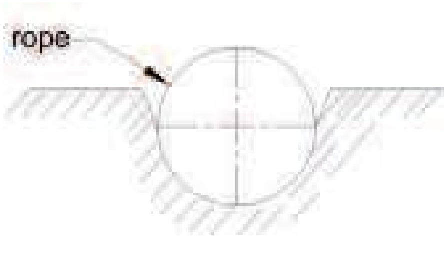

Figure 5: This illustrates the support given to the rope by the groove.

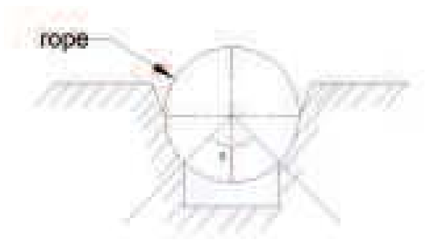

Figure 6: The U-groove with undercut has its undercut at the bottom.

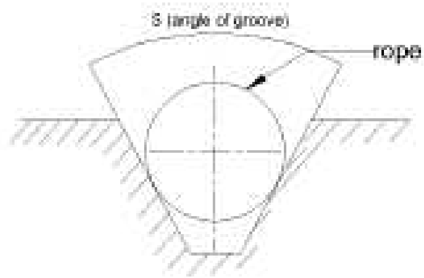

Figure 7: V-grooves provide maximum traction.