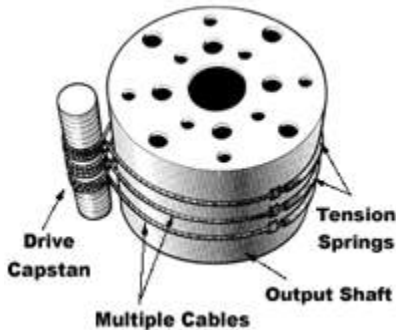


The Roto-Lok[®] Rotary Drive

An Elegantly Simple, Yet Powerful Technology



The Roto-Lok[®] Rotary Drive is an elegantly simple technology that utilizes the averaging effect of many cables—each sharing the load—wrapped around a drive capstan and an output shaft. It was originally invented as an inexpensive way to rotate large observatory telescopes accurately and smoothly.

The driven capstan, and output drum are connected by multiple precision cables, each with a tension spring at one end. The cables are wound in a figure eight pattern around the shaft and capstan. The drive carries torque through the friction of the cables on the drum and capstan, and also through cable tension, as the cable ends are anchored to the drum. The springs accommodate wear and keep the cables at a proper design tension. As the spring provides tension throughout the length of the cable, the Roto-Lok[®] drive is constantly preloaded in both directions; even at rest. This assures that there is absolutely no backlash. Unlike gears that wear and degrade performance, the springs on the Roto-Lok[®] drive keep the cables at proper tension indefinitely; thus, the performance remains in "like new" condition throughout many millions of cycles. The Roto-Lok[®] drive is virtually maintenance free.

Traditionally, precision gears have been used to position such loads. However, even the best gears suffer from high friction, drive irregularities, backlash, and wear. They also require costly sealed housings to support the gears and their lubricants. Both the housing and lubricant add weight, and the lubricant may limit the gearbox's operating temperature.

Roto-Lok[®] Rotary Drive capstans and output shafts typically have smooth cylindrical shapes that are relatively easy to produce. Either may be grooved to improve cable tracking, and include mounting, weight-reduction, and other necessary features. The arrangement of the Roto-Lok[®] drive places the capstan and output drum close together, minimizing the unsupported free span of cable, and maximizing the drive's coupling stiffness. The many cables serve to average the rotation rate so that imperfections, dirt or other slight irregularities on a single cable or drum do not have a significant effect. This results in superb drive smoothness with no cogging or drive rate irregularity.

In many applications the Roto-Lok® drive provides a great improvement over gears, belts and pulleys, chains and sprockets and other currently available alternative technologies. It provides both cost and performance advantages in all types of industrial, commercial, aerospace, military, medical and research applications.

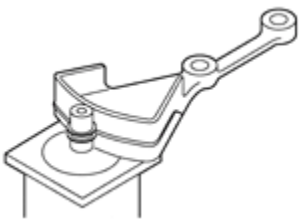
Roto-Lok® drives provide useable ratios from 1:1 to 40:1 or higher. Because of their extremely high efficiency (in excess of 99%), they can also be back driven to provide a speed increase rather than speed reduction.

Among the many advantages and benefits of the Roto-Lok® drive:

- Backlash free & high stiffness. The load bearing elements (cables) are statically tensioned to increase the no-load stiffness of the drive. In a gear drive, such tensioning would create friction and shorten the useful zero-backlash life of the gears.
- Multiple spring-loaded cables carry the load and provide superb smoothness by averaging the work done by each individual cable. This virtually eliminates "cogging" found in traditional gear drives. Near-perfect smoothness can be attained with a properly designed drive because of the averaging effect of the many cables.
- The cable wear from sliding or stretching is minimal. The cable simply picks up or lays down on the capstan and drum
- High efficiency, comparable to the loss created by the use of a high quality bearing. Because the drive is stiff and efficient, smaller motors, wiring and power supplies can be used.
- Can be back driven to amplify angle sensitivity

Application of the Roto-Lok® rotary drive typically provides the following benefits:

- Reduces motor power proportional to drive ratio
- Lubrication required only in bearings
 - Either the drum or the capstan can be fixed. Fixing the drum often results in no relative motion between the motor, capstan, and payload. This can greatly improve the packaging of some systems.
 - Conformable form factor. The Roto-Lok® Drum can be integral to the mechanical structure, and can be shaped as an arc segment, or a complete circle.
 - Conformable shapes often reduce weight when compared to other types of drives
- Backlash free & high stiffness
- Shock resistant



What Can't the Roto-Lok® Technology Do?

As with all technologies, the Roto-Lok® rotary drive is not perfect. It has its own unique set of limitations, including the following:

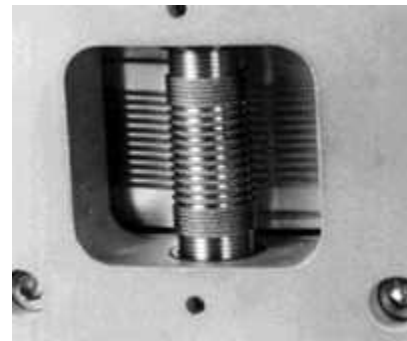
- Continuous rotation is not possible. Both ends of the cable must be fixed to the drum.
- For the best positional repeatability over time, the position instrument must be on the output shaft. At a micro-level, the cables can “creep” around the capstan. In many systems, this condition is reduced or eliminated by increasing the number of cable wraps around the capstan.
- Similar to “friction” drives, the drive ratio is not absolute. Small variations in the output shaft, capstan, and cable diameters as well as variations caused by thermal expansion/contraction can affect the drive ratio.
- For a given drum diameter, the required drum height will increase as the range of motion increases.
- At ranges of 360 degrees or greater drive ratios become limited by the cable layout on the drum.
- Torsional stiffness and drive performance is a function of many factors.
- The capstan diameter is a function of the bend radius of the cable, which increases as the cable diameter increases. Therefore, drive ratios greater than 20:1 usually require drums with diameters of several feet.
- Drive performance is less predictable near the ends of the cables.
- The extremely high drive efficiency means that the drive can be backdriven by an imbalanced payload if power is removed from the motors. In most applications, Sagebrush Technology strongly recommends balancing the payload inertia about the Roto-Lok® drive axis. In some applications where the payload cannot be adequately balanced, brakes may be required.

The Importance of Stiffness, Torque Capacity, and Backlash

The three primary performance attributes of the Roto-Lok® Rotary Drive are its extremely high torsional stiffness, its high torque capacity, and its total freedom from backlash.

Why is Torsional Stiffness so Important?

To achieve extremely accurate rotary positioning, the coupling between a motor and the load must be so stiff that a miniscule position change of the motor armature produces a corresponding change in the position of the payload. If the drive transmission is not stiff enough this miniscule motion is lost in torsional windup and the payload does not move. Sagebrush has delivered hardware with one microradian (57 millionths of one degree) positioning capability and believes that it can achieve a 10 times better resolution if or when required.



Why is Torque Capacity Important?

The high torque capacity of the Roto-Lok® drive is a major feature. It permits driving loads with torques up to one million foot pounds or more. Doubling the diameter of a Roto-Lok® drive allows for designing to an increase in torque capacity by a factor of eight.

There is no practical limit to the size loads that can be positioned with the Roto-Lok® drive. Sagebrush has designed drives from 3 oz-in of output torque to more than one million foot pounds.

Why is Freedom from Backlash Important?

The drive's freedom from backlash makes it the preferred technology in applications where precision positioning is required. Backlash prevents sustained smooth operation. It limits the ability to reverse the direction of devices that are required to operate with high accuracy. In applications where precise positioning is critical it provides a positional error the size of the amount of backlash. Perhaps most importantly, in many current systems it greatly simplifies servo design, enabling the designer to obtain the desired degree of control. Finally, it gives the drive longer life as it reduces stresses.

The Roto-Lok® Drive Works in Harsh Environments

The Roto-Lok® Rotary Drive works equally well underwater, or in dusty or oily environments. It is essentially immune to thermal changes and shock or vibration. It uses no greases or oils except in the bearings that hold the components. It can be used in clean rooms, food or pharmaceutical processing or medical environments. It is in use worldwide in the manufacture of computer chips.

Roto-Lok® Drives Can Have a Large Thru Hole

Other important features of the Roto-Lok® drive include a large diameter thru-hole (for optical beams or cables), extremely long life, exceptionally low noise, and almost non-existent maintenance cost. In many cases the drive components can be fitted directly to the device that needs rotation which further reduces the cost and complexity.



Elegant Simplicity Provides Advantages

The basic idea of the Roto-Lok® drive is the essence of simplicity. But what this simplicity delivers to Sagebrush's customers is unparalleled performance and cost benefits that go right to their bottom line. For some customers the Roto-Lok® drive solution allows them to proceed with a project that otherwise might not be possible to complete-at any cost. For other customers, Roto-Lok® drive technology is providing a major advantage in their quest for superior quality and cost effectiveness.