Spooling 101:
Tips for Designing an Efficient Level Winding Operation

How linear actuators based on rolling ring technology reduce costs and provide simple operation as well as minimize maintenance, repairs and equipment downtime

By John Scavitto

The design of any level winding or spooling operation requires some method to properly guide payoff materials such as wire or cable onto take-up reels or spools. To create the reciprocating, back-and-forth motion that ensures smooth and even material take-up, most designs employ a linear actuator fitted with a guide for the material to be spooled.

Traditionally, reciprocating linear motion systems have often been based on ball screws, hydraulics or timing belts. All of these technologies have proven themselves over time. Their relative success means that designers of spooling processes often look no further in selecting linear actuators.

However, today's industrial designer must consider not only the reliability, robustness and initial cost of the equipment used in a particular process, but also the interaction of that equipment with human operators and plant processes as a whole. Particularly, they need to assess the degree of human intervention needed and the degree to which required modifications, adjustments and maintenance of a given piece of equipment impact the production operation.

The Basics of Linear Actuators for Spooling

In a typical spooling process, the material to be spooled is paid off from the production machinery and enters the take-up system which consists of a line tension control device, the linear actuator-based reciprocating motion assembly and the reel or spool powered by a drive motor. *Figure I* shows a basic spooling take-up system. Regardless of the nature of the material-from hair-thin optical fiber to heavy-gauge cable or chain-it passes through a material guide mounted on a linear actuator that traverses back and forth, thereby guiding the material evenly onto the spool for a level wind.

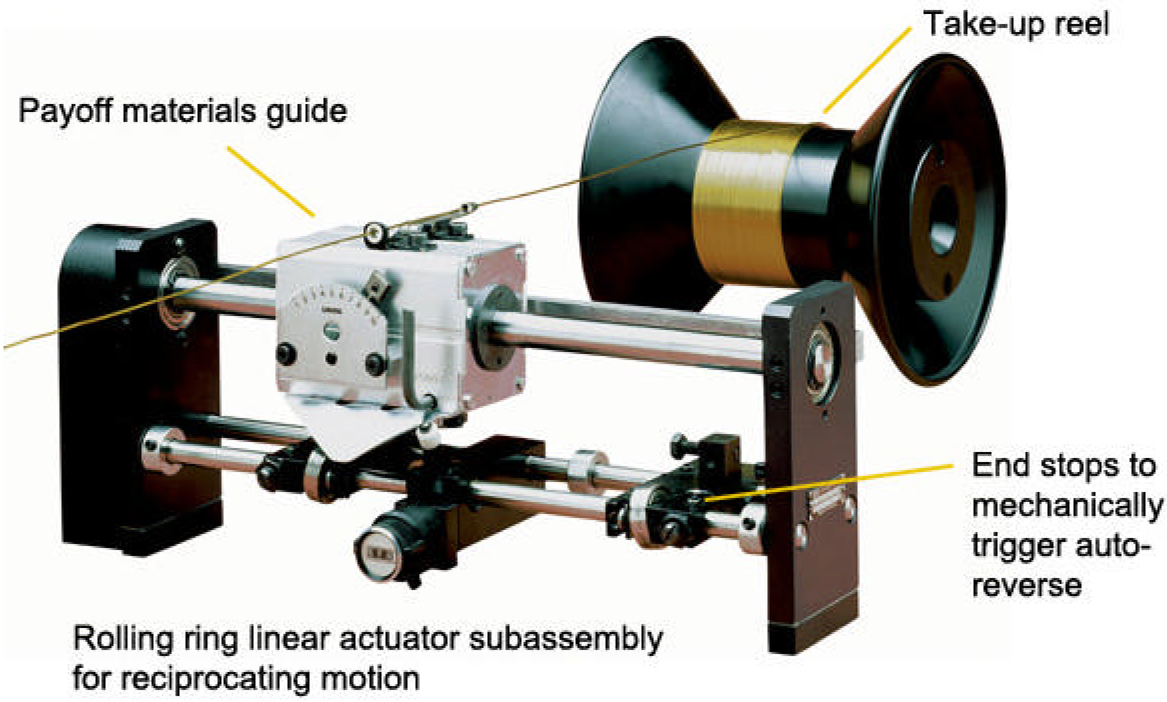

Fig. 1 —Schematic drawing of basic take-up system.

To ensure the desired take-up pattern, the correct speed relationship must be achieved between the linear actuator and the rotation of the take-up reel. Likewise, the pitch of the traversing mechanism must be carefully determined so that the material guide is always opposite a precise point on the take-up reel, regardless of how fast or slow the take-up spool shaft is turning.

In many spooling operations, the linear actuator must change speed in direct proportion to any change in rotational speed of the shaft on which the take-up spool is mounted. To ensure the traversing device remains synchronized with take- up reel rotation, intricate and often costly controls must be employed.

When designing an efficient reciprocating linear motion system for a spooling procedure, it helps to keep in mind that production machinery pays for itself only when it is running. An effective design should eliminate as many setup and maintenance operations as possible to help end users achieve peak production rates. If the user must frequently shut down a spooling system to change gear ratios, clean threads, fix jams or train operators to program PLCs, production rates will drop and throughput will suffer.

To meet production goals, users of spooling systems have come to expect the OEM design engineer to provide reciprocating motion systems that maximize cost-efficiency and overall system effectiveness. By employing a design for the reciprocating motion system that is as simple as possible, designers can spend less time at the "drawing board" and can create a design that enhances, rather than erodes, the client's ROL However, to achieve this it is necessary to pay more attention to the seemingly routine task of selecting a linear actuator.

How Traditional Systems Can Erode Profits

As stated earlier, the ability of traditional linear actuator systems to handle most production needs has helped keep them entrenched on the plant floor and in the minds of many OEM systems designers. But a broader view of such systems' impact on production work flow and costs can reveal several ways in which they may erode end user profitability.

Changeover Time and Effort: In any spooling system, the material to be spooled and the sizes and shapes of the take-up reels change from time to time. Any change will require some downtime so that the system can be setup for the new task. Traditional systems can complicate this task by requiring new setup parameters to be entered manually or via PLCs.

When the size of the material being spooled changes, many systems require a change in gear ratios. This usually requires a shutdown of the line. Systems that allow "on the fly" pitch changes can help reduce costly shutdowns.

Routine Maintenance: The extensive maintenance required by many traditional spooling systems has been an accepted part of manufacturing life for so long that it is difficult for many designers and users to recognize its true cost. For example, in harsh or dirty environments, ball screw systems require periodic cleaning of threads to avoid jams and clogs. Often, these systems require a bellows assembly to help minimize debris buildup. Other systems including timing belts and hydraulics usually require maintenance for servo or stepping motors, encoders, sensors and even PLCs. Despite the high cost of these maintenance duties, they can't be ignored, since the resulting breakdowns and failures are even more costly.

Lack of Free Movement Capability: For example, assume that a ribbon spooling operation experiences a break in the ribbon material during operation. The spooling system must be shut down while the end of the ribbon is fed back into the system. The material guide (mounted on the linear actuator) will probably have to be moved linearly to line it up with the precise point on the take-up reel where spooling will resume. With most linear actuator systems, this step requires the system to be restarted to "jog" the traversing mechanism to its home position. That start-and-stop operation, no matter how brief, can waste production time and eat into the user's profit margin. This procedure could be eliminated by using a linear actuator with a manual override free movement lever, permitting rapid, manual positioning of the material guide without requiring system startup.

Overly Complex Controls: An often under-recognized source of cost increase in designing spooling systems is the need for complicated control systems to manage the performance of the linear actuator. Complex control systems require expensive design and fabrication work. They also rely on costly electronic sensors, encoders and controllers that can complicate setup and maintenance tasks. The spooling system's ongoing costs are increased by the need for extensive operator training as well as by breakdowns and failures due to operator error.

Backlash: Traditional reciprocating linear motion systems are prone to backlash at the reversal points, often causing bunching and tangling, leading to system shutdown or even costly failures. Actuators with preloaded nuts can help eliminate this problem, however, they are more expensive than actuators without preloaded nuts and may require additional maintenance. Also, actuators with preloaded nuts often have a shorter life expectancy than other models.

Selecting the Optimum Linear Actuator for Spooling Operations

In selecting a reciprocating linear motion system, the most important criteria for both OEM system designers and their clients are as follows:

- Providing reliable performance while limiting initial costs
- Enabling simple, straightforward operation
- Minimizing ongoing maintenance, repair costs
- Minimizing downtime for maintenance, repair, changeovers

In addition, system designers should look for an approach that reduces design time and is flexible enough to be readily adapted to multiple types of spooling operations in order to avoid a "reinventing of the wheel" for every new project.

A technology particularly successful in designing for spooling and winding applications is rolling ring technology. Linear actuators using the rolling ring principle permit automatically reversible reciprocating motion without clutches, cams, gears, etc., thereby facilitating low-cost, low-maintenance reciprocating motion in payoff and take-up operations.

The Advantages of Rolling Ring Actuators

Linear actuators based on rolling ring technology use simple, straightforward mechanical principles for both movement and reversal of direction. *Figure 2* shows a rolling ring actuator, with a schematic of its operation.

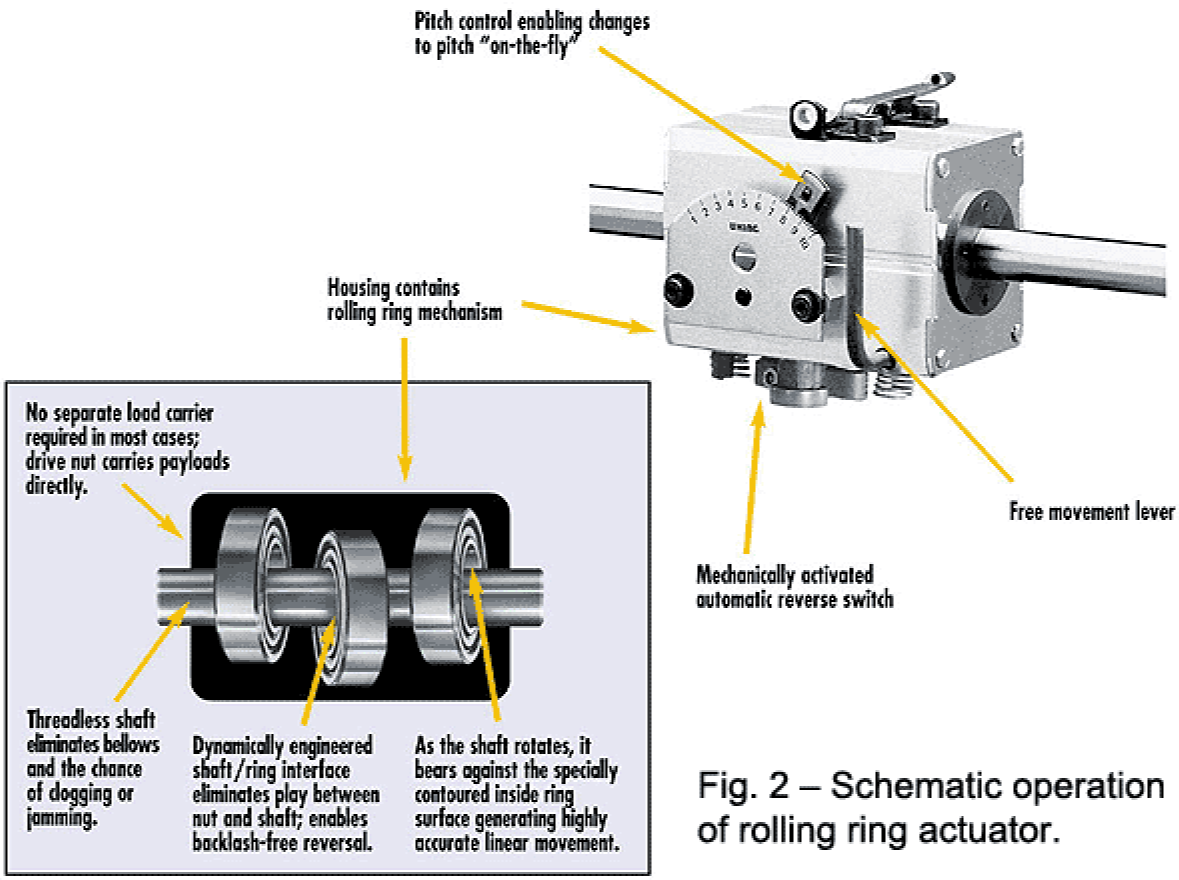

Fig. 2 – Schematic operation of rolling ring actuator.

Rolling ring linear actuators convert the unidirectional rotary motion of a smooth, motor-driven threadless shaft into linear output. This is accomplished by using three or four rolling bearings with specially contoured inner surfaces. The device moves in a linear direction as the contoured surfaces bear against the rotating smooth shaft.

The operator-adjustable angle at which the rings contact the drive shaft determines pitch, or the linear output for each rotation of the shaft. A simple mechanical reversing mechanism typically located on the bottom of the linear actuator "flips" the rolling rings to a mirror image orientation, which causes the actuator to reverse direction.

When evaluated against the criteria above for selecting an optimum linear actuator system, the advantages of rolling ring technology become apparent:

Reliable Performance While Limiting Costs: Clutches, cams and gears are often needed for reciprocating linear motion when ball screws and other devices are adapted for spooling systems. The mechanical simplicity of the rolling ring approach is in sharp contrast to the complexity of such methods.

In a rolling ring linear actuator system, the shaft rotates in one direction at a constant motor speed. For some rolling ring linear actuator models, pitch is infinitely adjustable on-the-fly without stopping the system. There is no reprogramming and no additional input to motor controls required. These devices afford a much simpler and less costly level of control. Similarly, reversal of traverse direction is done via simple mechanical means while the system continues to run by automatically "flipping" the orientation of the roller bearings inside the housing. The need for an expensive multi-direction, multi-speed motor—one that may have to be direct-braked—is eliminated.

Rolling ring actuators designed for spooling operations can have various material guides that attach directly to the actuator housing. In essence, the material guide is the payload. With traditional technology, often the payload may not be directly attached to the linear actuator "nut." A separate load carrier must be fabricated or purchased, which is costly and increases the overall size of the machine.

Simple, Straightforward Operation: Traditional technologies rely on complex electronics to control speed and reversal. In contrast, changing the pitch of rolling ring linear actuators is done via a pitch control lever typically located on the linear actuator housing. Moving the lever changes the angle of the roller bearings inside the housing. Reversal points are easily set with end stops that mechanically flip the rolling ring configuration, causing the linear actuator to change direction.

By eliminating the complex controls of traditional systems, operator training time is reduced, errors in system setup are eliminated and shutdowns due to control system problems are virtually nonexistent. The design complexity and high cost of control systems for traditional technologies are avoided.

Perhaps even more noteworthy is the fact that rolling ring actuator assemblies do not require the synchronization of a separate drive motor with the take-up motor. At a constant line speed, the take-up naturally slows down as the reel fills up. In rolling ring systems, the actuator is driven directly by the take-up motor. The result is that both the actuator and the rotational speed of the take-up are integrally linked without the time and expense of buying and synchronizing a separate motor.

Minimized Ongoing Maintenance and Repair Costs: One of the main differences between rolling ring technology and traditional methods is reduction of ongoing costs. Procedures like screw thread cleaning, purchasing or building of bellows assemblies, maintaining and training of operators for servo or stepping motors all add cost to any level winding operation.

Rolling ring actuators use a smooth, threadless drive shaft, which is virtually maintenance free and will not clog or jam in harsh environments. In most cases, the only regular maintenance required is periodic, light lubrication of the drive shaft.

Minimized Equipment Downtime: The fact that rolling ring actuators have been designed specifically to support reciprocating motion helps reduce, and in many cases, eliminate equipment downtime for repair, maintenance and changeovers.

Many models of rolling ring actuators allow the adjustment of pitch on the fly while the shaft is rotating. In traditional systems, pitch adjustment typically requires system shutdown. Also, the smooth direction reversal characteristic of rolling ring systems eliminates backlash, and with it the equipment downtime that results from bunching and tangling.

Most rolling ring actuators allow disengagement of the actuator assembly from the drive shaft via a lever for free and precise assembly movement. This eliminates the starting and stopping to realign the actuator after material breaks. It also saves time when changing reels, spools or rolls.

Finally, the fact that rolling ring technology is designed specifically for reciprocating motion systems, lifts a big load from the OEM designer. Instead of spending unnecessary time and money on a complex design using traditional technology, the designer can optimize other aspects of the system design.

Spooling system design needn't be complicated. However, by looking past traditional methods to technologies specifically designed for reciprocating linear motion, OEM systems designers can minimize their clients' initial costs for design, fabrication and installation as well as ongoing costs of maintenance, repairs and shutdowns. By thinking "outside the box" the designer can significantly boost the client's profitability.

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