Designing flexibility into a winding system using rolling ring linear motion

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Part of any winding system includes a traversing unit (linear drive) to move the wire, or other material being spooled, back and forth across the spool.

There are many technologies used to drive traversing units including screws, pneumatics, hydraulics and belts. This paper focuses on the rolling ring traverse which has been in use for over sixty years. In many winding applications, rolling ring traverses are desirable because they offer time and money saving advantages over other types of traverse systems.

Many winding systems are dedicated to spooling a single type of wire, fiber or other material. Designing a basic winding system to spool one type of material – having only one diameter or thickness – is straightforward once fundamental parameters are known such as material diameter, line tension and take-up spool size.

In these types of winding systems, the material being spooled is wrapped across the spool core in evenly placed lines. When material of only one diameter is being spooled, the linear pitch of the traversing unit does not need to be adjustable. For each shaft revolution, the traverse will move a distance equal to the diameter of the wire, fiber or other material being spooled.

What if a single winding system will be used to spool materials of different diameters or widths? This means the linear pitch of the traversing unit must be adjustable. The winding system must then be "flexible." That is, capable of winding different materials having various diameters or thicknesses. A flexible winding system meets the vast majority of spooling application needs by enabling a single winding system to accommodate materials of varying diameters.

Overview of design goals

To assure that a single winding system offers flexible capabilities to handle the majority of different materials, the system must be designed around application requirements beginning with the largest size material to be spooled **(Figure 1)**. Similarly, a flexible winding system must be developed based on the widest spool which will be used – measured from flange-to-flange. Basing the design of a winding system on these parameters optimizes the winding system so that: **A)** it will accommodate the broadest range of materials; and **B)** the traversing unit's pitch and thrust capabilities are not exceeded.

As stated above, in a flexible winding system, each different material being spooled has different pitch requirements. If the material being spooled is being fed from a process, such as an extruding machine, then as more material is spooled onto the take-up spool, the drive motor reduces in speed. The pitch of the traverse, however, must remain constant regardless of the take-up motor speed. As the drive motor turning the take-up spool slows down, the traverse will also slow down but must still move the same distance on the shaft to assure the material is placed properly on the reel.

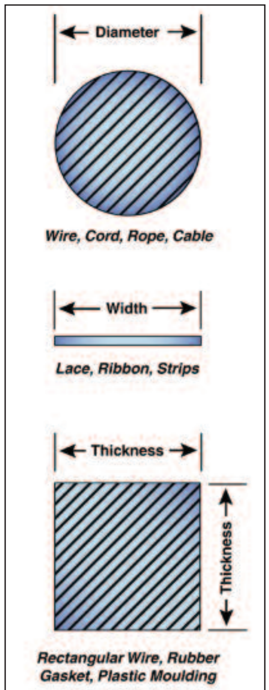


***Figure 1:** Use the thickest or widest material to determine the maximum linear pitch of the traversing unit.*

A winding system designed to handle a variety of materials and spool sizes must, therefore, provide a method of assuring the relationship between traverse linear pitch and take-up spool rotation. With rolling ring traverse drives this may be accomplished using a simple, mechanical pulley system. In order to synchronize traverse pitch with spool rotation, screw based winding systems, and other types, must often incorporate costly external controls. These controls may include electronics, multi-speed bi-directional motors, valves and solenoids, gear head assemblies, sensors, clutches, encoders and more. The costs of training personnel to operate and maintain these systems also adds to project budgets and can often be avoided by using a rolling ring traverse drive.

Thickness of material and linear pitch

In any winding system, the traverse drive moving the material guide back and forth must travel a specific linear distance per one revolution of the shaft. This is the linear pitch of the traversing system. The correct linear pitch assures that material is laid onto the spool in evenly spaced rows.

If the material being spooled is fed at a uniform speed, then thicker material will fill across the spool core in a shorter period of time than thinner material. The traversing unit guiding the thick material onto the spool must move a longer linear distance per shaft revolution **(Figure 2)** than it will when guiding thin material. The linear pitch of the traverse guiding the thick material is therefore larger than that of the traverse guiding the thin material.

Suppose a wire manufacturer needs to wind 1" diameter cable and 1/8" diameter wire on the same winding system. Regardless of the take-up spool rotational speed, the traverse must move 1" per reel revolution for the thick material, but

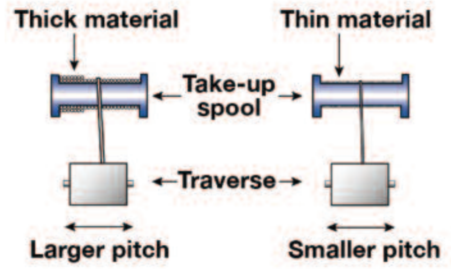


Figure 2: *The traverse moves a longer linear distance per shaft revolution when spooling thick materials than it does when spooling thin materials.*

only 1/8" per reel revolution for the thin material. Another way of saying this is that the linear pitch of the traverse must be adjustable from 1 inch down to 1/8 inch.

Unlike screw-based systems, the pitch on a rolling ring traverse drive is manually adjustable **(Figure 3)** on-the-fly. Whereas some winding systems require programming and gearing changes to adjust pitch, these options take time and can be costly to implement and maintain. To support profitable production objectives, it is necessary to select a traverse unit which minimizes set-up, operating and maintenance requirements without sacrificing required functionality or efficiency. A cost-effective alternative is to use a rolling ring traverse drive which includes an adjustable pitch control.

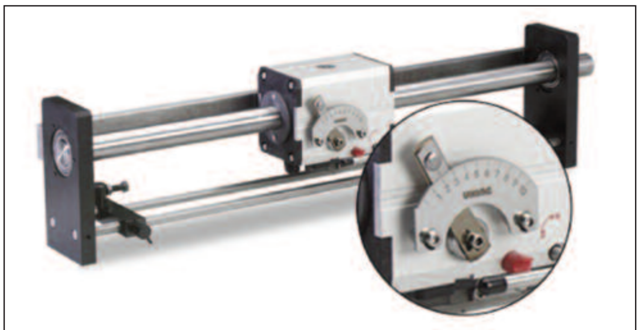


Figure 3: *Uhing traverse drive. Inset shows close up of pitch adjustment lever. A Uhing rolling ring traverse has a 10:1 pitch turndown range.*

Optimizing the system for thrust capacity

In Diagram A below, assuming distance B remains the same, angle M will be largest when the traverse is at its maximum stroke – at the spool flange. To move the wire or other material to this point the traverse must have a certain amount of axial thrust capacity. As distance B decreases, angle M increases and the thrust requirement becomes greater. Similarly, as spool width increases, so does the thrust requirement of the traverse

It is, therefore, necessary to select a traverse with enough thrust to accommodate the widest spool being used relative to the B distance. The innate line tension of the material being spooled must also be considered and factored in when selecting a traverse that has enough thrust capacity to meet application needs. The maximum amount of thrust that will

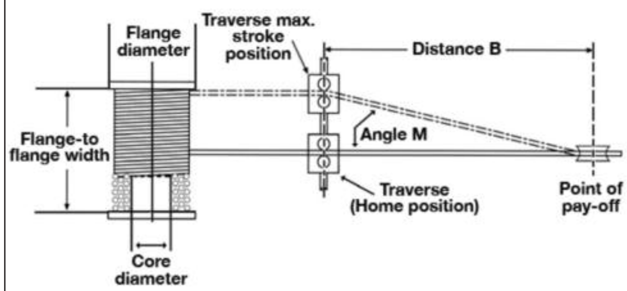


Diagram A: *Distance B and the spool width combine to determine the amount of axial thrust required by the traverse. The traverse needs thrust to move the wire back and forth as it is spooled onto the take-up reel.*

be required of the traverse can be calculated by the formula:

F = (C) (F1) / (1.6) (the square root of {C2/4 + B2})

F is the line tension created by the angle M

C is the traverse width

F1 is the innate tension in the material being spooled

B is the linear distance from the point of pay off to the material guide mounted on the linear actuator

1.6 is the constant value for conversion

(F and F1 are expressed in Newtons. C and B are expressed in inches or millimeters)

Rolling ring traverse drives generate thrust through the friction created between the shaft and the bearing. This will be discussed later in this paper.

Synchronizing traverse linear motion with take up take-up spool rotation

When the winding operation begins, the core of the take-up reel is empty. If the material being spooled is coming from a process, like an extruding machine, it is likely that the take-up spool drive motor is electronically linked to the line feed speed.

When the spool core is empty, the take-up spool drive motor will be rotating the spool at a faster rate than when the spool is near full. As more material is wrapped around the spool core, the material must cover an ever-increasing circumference, and the take-up spool rotational speed will start to decrease. If the traverse shaft is being driven by a belt and pulley linkage to the take up spool shaft as in Figure 4, the traverse will automatically being to slow down as the spool speed.

Regardless of the take-up spool rotational speed, the traverse linear pitch must remain the same. The material must be guided across the spool core at a steady rate per shaft revolution. So there must be a means of synchronizing the rotation of the take up reel with the reciprocating linear motion of the traverse. With rolling ring traverse drives, this is achieved with the mechanical linkage shown in Figure 4. A

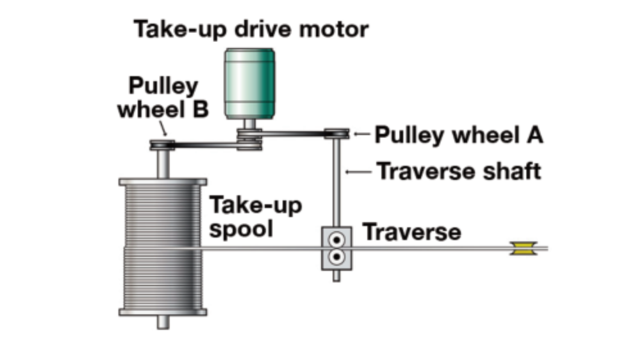


Figure 4: *This diagram shows the typical manner in which a rolling ring traverse is driven. Establishing the correct gear ratio between pulley wheels A and B set the traverse pitch range and permit the traverse winding assembly to handle materials of varying diameters.*

mechanical, closed-loop condition exists. Elimination of the need for programming through this mechanical linkage is one of the main advantages of using rolling ring motion in a winding system.

To establish the desired linear pitch range for the traverse, it is necessary to select the correct size ratio between the pulley wheels in Figure 4. For example, suppose the wire being spooled ranges from 1 inch in diameter down to 0.1 inch, and the traverse has a linear pitch of 1/2 inch. Wheel A in Figure 4 must then be half the size of wheel B in order to move the traverse 1 inch per shaft revolution. The traverse must be adjustable so that the pitch can be turned down from 1 inch to 0.1 inch. A rolling ring traverse offers this capability.

The pulley wheel ratio between take-up spool shaft and the traverse drive shaft may be calculated using this formula:

$i = (0.95)\ (hmax/dmax)$

i is the ratio value being calculated

hmax is the maximum pitch setting of the linear actuator

dmax is the maximum diameter measured in step number 1 above

0.95 is the constant value for conversion

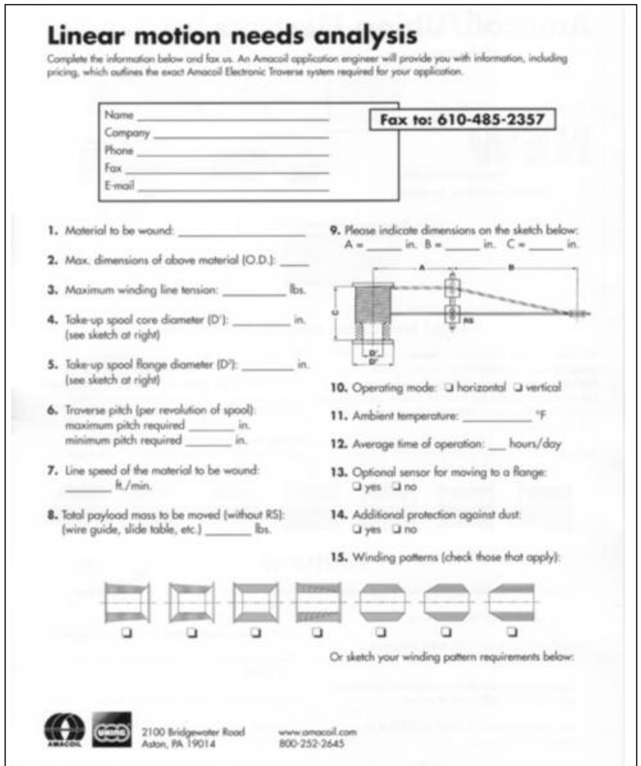
(hmax and dmax are expressed in inches or millimeters)

The pulley wheels must be selected to create the optimum ratio, i. In the calculation above, if i is less than 1, the traverse shaft must turn faster. Therefore the pulley wheel on the traverse shaft must be smaller than the wheel on the take-up spool shaft. If i is greater than 1, the traverse shaft must turn slower and so a larger pulley wheel would be used.

With a rolling ring traverse drive, once the correct gear ratio is established, the reciprocating linear motion of the traverse will remain synchronized with the rotational motion of the take-up spool regardless of drive motor speed. The traverse will always travel the same linear distance per shaft revolution. Therefore the material being spooled will always be guided across the spool at the correct rate.

Calculations for winding system efficiency

In the form shown in Figure 5, the criteria for an efficient winding system is organized into a useful questionnaire. When preparing to design a winding system, completing this form puts information at your fingertips which you'll need when you begin designing a traverse winding system. The form is also online at http://www.amacoil.com/request-quote-form1.html and the calculation formulas are at http://www.amacoil.com/rg-technical.html



Linear motion needs analysis

Complete the information below and fax us. An Amacoil application engineer will provide you with information, including pricing, which outlines the exact Amacoil Electronic Traverse system required for your application.

Name ______
Company ______
Phone ______
Fax ______
E-mail ______

Fax to: 610-485-2357

1. Material to be wound: ______
2. Max. dimensions of above material (O.D.): ____
3. Maximum winding line tension: ______ lbs.
4. Take-up spool core diameter (D'): ______ in. (see sketch at right)
5. Take-up spool flange diameter (D'): ______ in. (see sketch at right)
6. Traverse pitch (per revolution of spool): maximum pitch required ______ in. minimum pitch required ______ in.
7. Line speed of the material to be wound: ______ ft./min.
8. Total payload mass to be moved (without RS): (wire guide, slide table, etc.) ______ lbs.
9. Please indicate dimensions on the sketch below: A = ____ in. B = ____ in. C = ____ in.
10. Operating mode: ❑ horizontal ❑ vertical
11. Ambient temperature: ______ °F
12. Average time of operation: ___ hours/day
13. Optional sensor for moving to a flange: ❑ yes ❑ no
14. Additional protection against dust: ❑ yes ❑ no
15. Winding patterns (check those that apply):

❑ ❑ ❑ ❑ ❑ ❑ ❑

Or sketch your winding pattern requirements below:

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800-252-2645

Figure 5: *Winding application requirements form*

Rolling ring traverse motion

Rolling ring traverse drives with adjustable linear pitch have long been used for spooling and winding because the rolling ring operating principle enables efficient, automatically reversing, reciprocating motion without using clutches, cams, gears or other external controls. This minimizes system design costs and simplifies operation and maintenance.

Reversal in a rolling ring traverse is practically instantaneous – about 2 to 70 milliseconds (depending on drive size) – and is achieved through purely mechanical means without resorting to complex, electronic control systems. What's more, the speed and direction of travel of rolling ring drives may be mechanically controlled to meet special winding requirements.

For example, a winding operation may require ramping down the traverse speed at the reversal points. This may be desirable to create a smoother reversal. The need for a smoother, more gentle reversal may arise when spooling delicate materials that could break or distort if the reversal is too sudden.

With some winding systems, meeting winding application requirements for ramping up or down during the reversal process can involve designing-in clutches, cams and complex control systems. However, the performance characteristics of rolling ring bearings make rolling ring linear drives uniquely adaptable to special linear motion requirements using relatively inexpensive, mechanical modifications to the auto-reverse mechanism.

Machined inner race is the key

At first glance, a standard ball bearing and a rolling ring bearing look the same. Examining the inner race of the rolling ring bearing, however, shows that the surface has been machined **(Figure 6)**. Machining a standard bearing to make a rolling ring bearing is a precise, proprietary procedure. Once machined, the bearing has a contoured, central "ridge" running around the entire inner race surface. It is the presence of this central ridge that gives rolling ring bearings their unique performance characteristics.

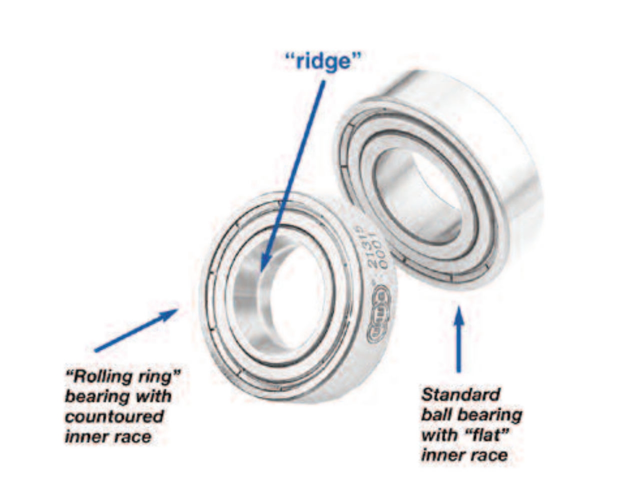

Figure 6: *The "rolling ring" bearing shown is custom engineered in Germany by Joachim Uhing KG & Co., and used in Uhing rolling ring linear drives. The central ridge of the rolling ring bearing gives the bearing performance characteristics which, in many cases, permit automatically reversing reciprocating motion and adjustable pitch control without complex controls, clutches, cams or gears.*

When mounted on a shaft, a rolling ring bearing contacts the shaft on a single point on the apex of the central ridge. This permits the rolling ring bearing to be pivoted left or right on the shaft, and still maintain point contact with the shaft. If the inner race was flat, as in a standard ball bearing, it would be virtually impossible to pivot the bearing **(Figure 7)**.

Pivoting a rolling ring bearing on a rotating shaft so it is at an angle relative to the shaft generates force against the bearing's central ridge. This causes the bearing to roll along the length of the shaft. The rotary input provided by the motor-driven shaft is thereby converted to linear output.

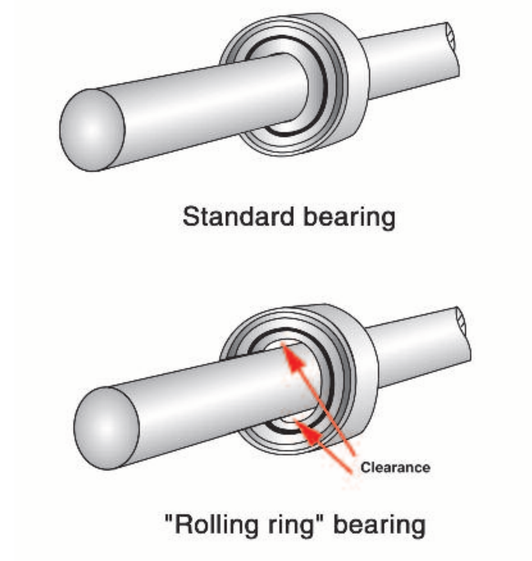

Figure 7: *A standard ball bearing on a smooth shaft will not pivot whereas the central ridge on a rolling ring bearing provides a natural pivoting point. Pivoting the bearing enables control over linear pitch and traversing direction.*

The housing, or nut, enclosing the rolling ring bearings can support light loads such as a guide roller to hold the wire or other metrical being spooled. As the rolling ring assembly moves it carries with it the load-bearing housing. The linear direction in which the traverse moves is determined by the adjustable angle at which the bearings contact the shaft.

In a rolling ring linear drive, such as the one shown in Figure 8, an assembly of rolling ring bearings is positioned within the drive housing. To reverse the traversing direction of the rolling ring drive, the entire rolling ring bearing assembly must be pivoted to its opposite position on the shaft **(Figure 9)**. The bearings' central ridge provides the pivotal point on which the rolling ring bearing assembly may be pivoted.

The process of pivoting the ring assembly is purely

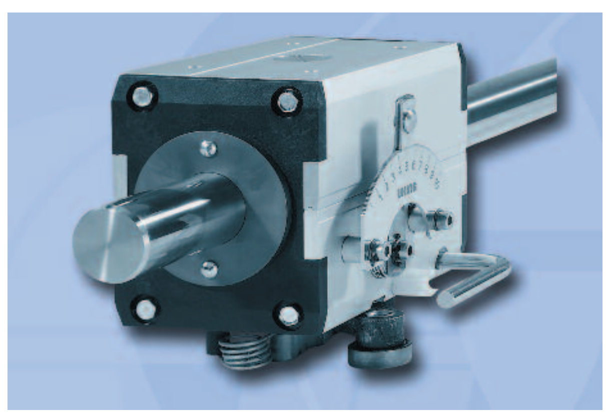

Figure 8: *Uhing Model RG rolling ring traverse drive. The rolling ring assembly is inside the housing.*

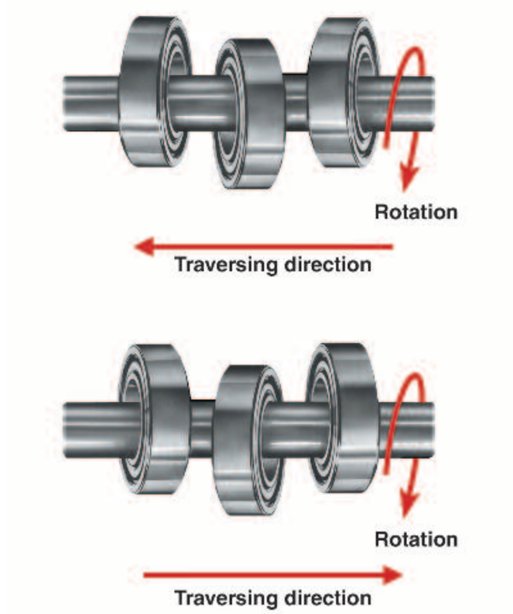

***Figure 9:** The traversing direction of a rolling ring linear drive is determined by the angle of the rolling ring bearing assembly relative to the shaft. This is true regardless of the rotational direction of the motor. Pivoting the ring assembly is mechanically controlled by the reversal mechanism located on the linear drive.*

mechanical and automatic controlled by the spring-actuated reversal mechanism on the bottom of the rolling ring traverse linear drive **(Figure 10)**. When the linear drive reaches the end of its stroke, an end stop pushes the reversal mechanism. The reversal lever flips which changes the angle of the rolling ring bearing assembly on the shaft. When the rolling ring bearing assembly is pivoted so that the rings assume the exact opposite angle on the shaft, immediate, automatic reversal results.

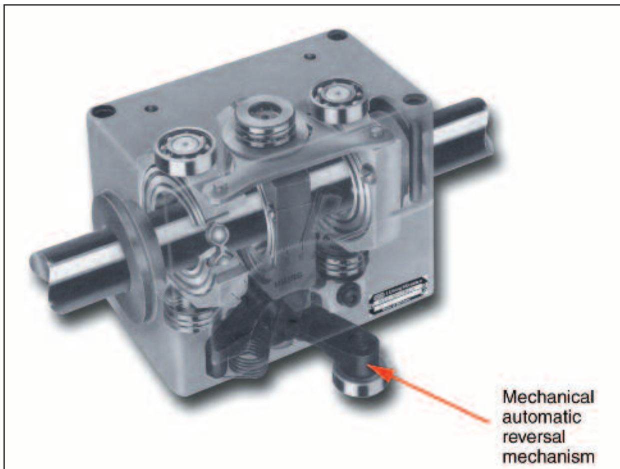

***Figure 10:** The end stops on the rolling ring traverse assembly frame turn the reversal mechanism which pivots the rolling ring assembly situated inside the housing. When the ring assembly is pivoted to its mirror position on the drive shaft, the linear drive traversing direction is reversed.*

Controlling linear speed independently of the drive motor

The angle of the rolling ring bearings on the shaft determines the traversing direction of the linear drive. This angle also determines the traversing unit's linear pitch – the linear distance traveled per one shaft revolution. Changing the pitch setting effectively changes the traverse linear speed relative to each revolution of the linear drive shaft – even if the drive motor speed remains unchanged.

If the rolling ring bearing angle is slowly changed as the traverse moves, the traverse speed will increase or decrease. It is important to note that this is achieved without making any adjustments to the drive motor speed or any other controls. This means a rolling ring linear motion system will have variable speed without clutches, cams, gears and so forth. Whereas changing pitch in other types of reciprocating motion systems can require changes to gearing or even require a completely different traverse.

The most common rolling ring linear drive set-up is for automatic, instantaneous reversal **(Figure 11)**. In such a system, the rolling ring linear drive traverses in one direction until it contacts an end stop. The end stop flips the reversal mechanism, which pivots the ring assembly inside the housing to its mirror position on the shaft causing reversal of the traverse.

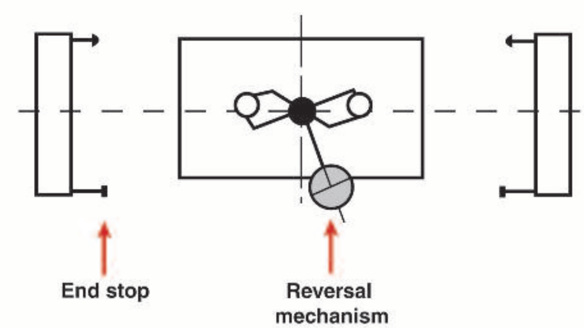

***Figure 11:** End stops and reversal mechanism configured for routine automatic reversal.*

While this method of reversal is typical for winding applications, correctly exploiting the rolling ring bearing performance characteristics permits the use of a rolling ring linear drive to meet a variety of other linear speed requirements in other reciprocating linear motion applications. Rolling ring traverse drives readily enable these processes through purely mechanical means.

A rolling ring linear drive is typically supplied within a production framework **(Figure 12)**. The assembly is installed at the appropriate location in the manufacturing line. Adjustable end stops are used to set stroke length. Various hardware fixtures may be attached to the reversal mechanism on the bottom of the traverse in order to meet requirements for ramping up or down and other changes to linear speed.

Figures 13 and 14 are line illustrations of the bottom of a

Figure 12: *Rolling ring linear traverse drive assembly ready for installation into a production line.*

rolling ring traverse. In Figure 13, the K-lever makes contact with a stop and partially rotates the reversal mechanism. As the reversal mechanism is turned, so is the rolling ring bearing assembly which reduces the traverse's linear pitch (speed). As the traverse continues to move at a reduced speed, it contacts the main end stop. This flips the reversal mechanism and the traverse reverses direction at normal speed.

Figure 14 illustrates the H-lever which pivots the rolling ring assembly like the K-lever to cause ramp-down of linear speed. After the reversal mechanism has been tripped, the other end of the H-lever catches and prevents the rolling rings from flipping all the way over on the shaft. The result is a gradual increase in linear speed until the H-stop clears. At that point, the rolling rings are allowed to flip completely and the traverse resumes its normal speed.

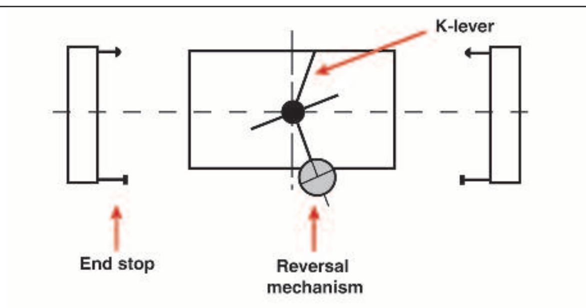

Figure 13: *Screws called K-stops are positioned to contact the K-lever in such a way that the rolling ring assembly is partially pivoted just before the reversal point, thereby reducing linear speed of the drive before reversal takes place. This cushions the intensity of the reversal motion.*

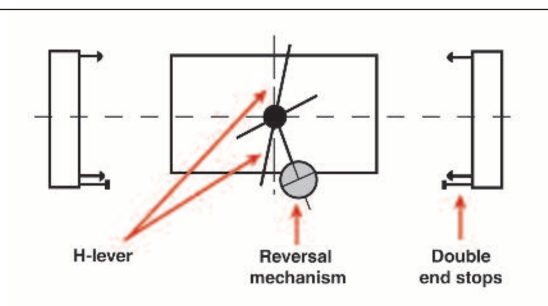

Figure 14: *The H-lever contacts the first stop and begins to ramp down the linear drive speed. When the reversal mechanism is flipped, the other end of the H-lever catches on the second stop which holds the ring assembly at an acute angle. When the drive starts back in the opposite direction, the H-lever gradually permits the rolling ring assembly to assume its full pitch position and the drive's linear speed ramps-up.*

With mechanical manipulation of the rolling ring bearing assembly a rolling ring traverse drive can be used to meet many different linear motion needs including dwell.

For best results, ask the experts

In some cases, such as in precision winding systems, even rolling ring drive systems require additional controls to meet highly accurate winding application requirements. Rolling ring drive systems may also be PLC-controlled if the take-up pattern required is unusually intricate. A PLC-controlled rolling ring drive set-up is illustrated in Figure 15.

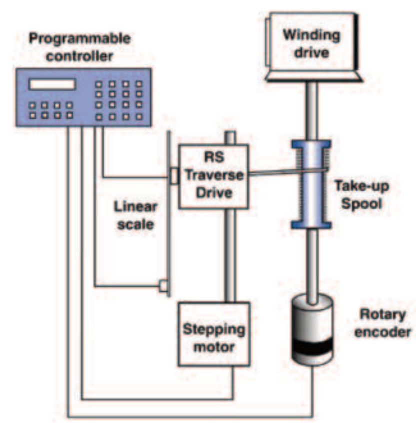

Figure 15: *Custom winding set-up using a rolling ring linear drive controlled by a PLC.*

Special applications like these require the attention of rolling ring engineering experts. If you use a rolling ring linear drive, or are considering doing so, consulting with a rolling ring linear motion engineering firm can help you make sure your production process receives the full benefits this technology has to offer. An experienced rolling ring applications engineer can guide you in designing, fabricating and installing the appropriate system for your application requirements. This is your best bet for ensuring the rolling ring system you design enhances your production process and reduces maintenance and operating costs.

Note: Amacoil, Inc., is the exclusive North American value-added distributor of Uhing brand rolling ring traverse drives used for reciprocating and positioning linear motion. Amacoil provides complete rolling ring linear drive service including engineering and technical support, rolling ring system design including assembly fabrication, installation, parts and repairs. For additional information please contact Amacoil, Inc., 2100 Bridgewater Road, Aston, PA. Tel: 1-800-252-2645.
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