LINEAR MOTORS & LINEAR ACTUATORS FOR ADVANCED AUTOMATION

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Fig. 1—Linear servo motor manufacturers have created three basic types. Flat bed motors, top, may be designed for virtually unlimited drive force and travel distance. U-channel motors, center, use air-core Forcers for exceptional speed and responsiveness. Tubular motors, bottom, are rugged, simple, easily integrated into automation applications, and are available as fast-response linear actuators.

Fig. 3—Linear motor positioning stage provides a rugged, cost-competitive drop-in upgrade for ball screw and servo-pneumatic positioning mechanisms.

FIG. 2—Tubular linear motors replace external position encoder with integral Hall sensor, bringing distinctive cost, performance and application benefits.
Fig. 5 — Brake maintains actuator position in vertical applications

DYNAMIC SUPERIORITY

Dynamic Stiffness
Superior Settling
Short Distance Moves

ADVANCED APPLICATIONS

Fast Repetitive Positioning

Fig. 6 — Tubular linear motor lends itself to use with multiple Forcers to (A) double productivity or (B) multiply drive force.

Two Motors-In-One
Challenge Servo Pneumatics
Introducing Micro Actuator & Micro Motor
100+ Million Operations

MATCHED PAIR

Fig. 7 — Micro actuator is only 28 mm wide. It provides the 10 million operating cycles, long stroke, superior bandwidth and powerful drive needed by the next wave of innovative automation

CONCLUSION

END

FIG. 8 — Matching linear motor or actuator to a high performance digital drive provides a wide range of operating modes.
Linear Positioning Technology For Tomorrow’s Automation...Today

Introduction
Moore’s Law, famous for predicting long-term gains in semiconductor chip density, has long endured, thanks in large part to ongoing advances in linear motor performance and dependability.

Driven by semiconductor industry requirements, linear motor manufacturers have steadily increased precision, reduced prices, developed multiple motor types, and simplified integration into automation equipment. Modern linear motors provide 20g peak acceleration and 10-meters/second velocity, deliver unmatched dynamic agility, minimize maintenance, and multiply uptime. They have moved beyond specialized semiconductor industry usage to provide advanced performance in hosts of applications. In fact, with ten times the speed and ten times the operating life of ballscrews, linear direct drive technology is often the only solution for modern productivity-enhancing automation. No longer do linear motors depend upon early adopters for market expansion!

THREE LINEAR MOTOR TYPES
Different manufacturing groups have specialized in one or another of three basic linear motor configurations: Flat bed, U-Channel, and Tubular motors. Each motor has its intrinsic benefits and limitations. Drawbacks specific to one motor type can often be sidestepped by using either of the two alternatives.

Flat Bed Motor
Flat bed motors (Fig.1, top), while offering unlimited travel and highest drive force, exert considerable and undesirable magnetic attraction between the load carrying forcer and the motor’s permanent magnet track. This attraction force requires bearings that support the extra load.

U-Channel Motor
The U-Channel motor, Fig.1 center, with its ironless core, has low inertia hence maximum agility. However, the Forcer’s load carrying magnetic coils travel deep within the U-Channel frame, restricting heat removal.

Fig. 1—Linear servo motor manufacturers have created three basic types. Flat bed motors, top, may be designed for virtually unlimited drive force and travel distance. U-channel motors, center, use air-core Forcers for exceptional speed and responsiveness. Tubular motors, bottom, are rugged, simple, easily integrated into automation applications, and are available as fast-response linear actuators.
Tubular Linear Motor
Tubular linear motors, Fig. 1 bottom, are rugged, thermally efficient and the simplest to install—they provide drop in replacements for ballscrew and pneumatic positioners. The tubular motor's permanent magnets are encased in a stainless steel tube (Thrust Rod), which is supported at both ends. Without additional Trust Rod support, load travel is limited to 2-3 meters depending on Thrust Rod diameter.

TUBULAR MOTOR DISTINCTIONS
Copley Controls specializes in the manufacture and application of tubular linear motors. Of all three motor types, tubular motors are best equipped for mainstream industrial usage. This article explains why. It will discuss tubular motors design, installation ease, flexibility and performance. It will also discuss direct drive linear actuators, in which the Thrust Rod, rather than the Forcer, is the moving component.

Integral Position Sensor
Tubular linear motors have gained profound benefits from a fundamental engineering innovation. Copley Controls has developed a novel and patented magnetic circuit that enables Hall effect sensors to achieve almost tenfold improvement in resolution and repeatability. Thanks to this critical magnetic circuit invention, Copley’s linear motors replace the traditional external linear encoder with integral Hall sensors. Offering repeatability from 8 to 20 microns (depending on model), the Hall sensors deliver sine and cosine position signals that can be read by standard drives. See Fig. 2.

Wide Range Of Benefits
Eliminating the external encoder brings a cascade of very significant benefits on many fronts. For instance, linear encoders can cost almost as much as the linear motor itself, so an immediate benefit of encoder elimination is a major cost reduction. Dispensing with the external encoder also simplifies linear motor integration into automation systems: there’s no finicky encoder to support and align. Other benefits, as this article will explain, cover ruggedness, dependability, and freedom from an encoder’s need for protected environments.
Drop-In Upgrade
Consisting of two basic parts, linear motors may be configured as complete positioning stages, to provide drop-in upgrades for ballscrew mechanisms Fig.3. With roughly ten times the speed and a tenfold increase in dependable operating life, the linear stage offers a dramatic productivity gain over the ballscrew mechanism.

Linear Actuator
Tubular linear motors, more than the two alternative motor configurations, may be transformed into powerful and very versatile direct drive linear actuators, Fig.4. In an actuator incarnation, the Forcer remains stationary (bolted to machine frame), while the load positioning Thrust Rod travels on low friction lubrication free bearings mounted within the Forcer. Not only does the linear actuator provide major performance advantages over ballscrews and belt drives, it also creates a potent alternative to programmable servo-pneumatic positioning systems.

MECHANICAL BENEFITS
Consisting of just two parts, direct drive linear motors and actuators are inherently simple which leads to superior dynamic agility. But there’s appreciably more to these benefits than meets they eye. The following section provides deeper insights into motor and actuator mechanical parameters. Subsequent sections discuss singular but less-than-obvious dynamic benefits.

Motor Integration Ease
Tubular linear motors are built with a large air gap between Forcer and Thrust Rod. This clearance, besides preventing wear, simplifies motor integration into industrial equipment. Replacing the traditional linear encoder with integral position sensor brings further installation ease by eliminating alignment hassles. Motor loads mount directly to Forcer T-slots without added brackets.

Unmatched Motor Uptime
The linear motor load-carrying forcer travels on long life single rail bearings. In contrast, ballscrew rotary-to-linear conversion mechanisms involve additional sources of wear that degrade performance and shorten life.

Actuator Dependability
The linear actuator Thrust Rod glides on long life lubrication free bearings mounted in the Forcer. This intrinsic simplicity enables the actuator to deliver 10 million dependable operating cycles. Actuator bearings are self-aligning, which adds to installation ease. The actuator drive force is applied directly to the Thrust Rod, ensuring unmatched acceleration and responsiveness.
Meets IP67
With traditional external encoder replaced by a solid state sensor integrated into the Forcer, direct drive motors and actuators become very simple two-component devices. Forcer and Thrust Rod are both inherently very robust components, which enables motor and actuator to conform to international IP67 washdown ratings.

Abrasion Free And Foodsafe
Conventional positioning mechanisms involve fast-spinning lead screws and gear train, which can produce oil spray and abraded particles. This potential for contamination can prevent their use in food preparation and other critical applications. The linear actuator runs on lubrication free slide bearing and qualifies for foodsafe and other contamination-sensitive uses. In some applications, the linear motor may also be operated with lubrication free bearing, to meet the needs of clean-room and other critical environments.

A striking packaging application that highlights the numerous benefits of direct drive technology is a commercial tortilla stacker that handles 20,000 tortillas an hour. The system uses 12 linear actuators that receive tortillas fed by conveyor from the oven. The actuators are incrementally lowered by one tortilla thickness for each incoming tortilla. When an actuator accumulates a stack of eight tortillas, its stack is swept onto a different conveyor for delivery to the packaging station.

The transition to fast response direct drive actuators from a servopneumatics system doubled tortilla throughput. It permitted on-the-fly changes to stack heights: 6, 8, 10, or 12 tortillas. The actuator’s mechanical simplicity also removed maintenance, hence uptime, as a productivity issue.

Strong And Silent
Absence of grinding gears and whirring lead screw gives linear motors and actuators an increasingly vital qualification: low noise operation. OSHA is following close on the heels of European industrial codes, which place increasingly stringent rules on workplace noise. Quiet operation is already critical in laboratory and hospital environments; this concern will become increasing widespread as OSHA extends its ruling to other production environments.

OSHA in Church? One Copley customer—a church organ builder—prizes linear actuators for their silence in controlling organ loudness or “expression” during church services.

Natural Cooling
The Forcer of tubular motors and actuators is surrounded on all sides with free air and is inherently self cooling. The Forcer is also equipped with cooling fins that further facilitate heat removal. Rarely do either motor or actuator applications require additional cooling.

Brake Permits Vertical Operation
Vertical operation is not a barrier in linear actuator applications. Copley Controls offers an electromechanical brake that holds load position when drive power is removed, Fig.5. The brake also protects against damage in event of power failure and shutdown.
DYNAMIC SUPERIORITY

Dynamic Stiffness
Dynamic performance of conventional positioning mechanisms is limited by leads screws, gear trains, belt drives, and flexible couplings, which produce hysteresis, backlash and wear. Similarly, pneumatic actuators suffer from piston mass and piston-cylinder friction, as well as air compressibility, which produce servo control complexity. Linear motors and actuator shed the mass and inertia of the conventional positioners, and freed from these fundamental limitations, provide unequalled dynamic stiffness.

Superior Settling
Direct creation of drive force enables linear motor and actuator to achieve closed loop bandwidths unavailable with alternative positioning mechanisms. Absence of cascaded mechanical linkages obviates positioning uncertainty and mechanical resonances. Motor and actuator are able to take full advantage of modern controller performance. The controller is tuned for high loop gain operation, achieving wide bandwidth control, fast settling, and rapid recovery from transient disturbances.

Short Distance Moves
Linear motors and actuators excel in making millimeters distance moves that operate in the static friction zone. Their low mass and minimal static friction minimize the drive force necessary to start travel, and simplify the control system’s task in preventing overshoot when stopping. These attributes enable direct drive motors and actuators to scan microscope slides, for instance, and chart the X-Y locations of artifacts only millimeters apart.

ADVANCED APPLICATIONS

The following applications exploit the tubular motor/actuator’s singular bandwidth advantage to provide productivity not otherwise possible. Multiple actuators operating on a single Thrust Rod introduce striking benefits too.

Fast Repetitive Positioning
Applications that demand rapid repetitive motion can exploit the linear actuator’s high bandwidth to achieve twice the throughput available with ballscrews or belt drives. Machines that slice rolls of material to length (paper, plastics, even diapers) maximize throughput by operating without stopping the material flow. To cut on the fly, such machines accelerate the cutting blade to synchronism with material flow, travel at material speed to the cutting location, and then initiate the cut. After cutting, the blade is returned at high speed to its starting point, to wait the next round-trip cutting cycle.
Throughput, in such applications, is directly related to the blade’s forward/reverse excursion time.

**Two Motors-In-One**

Tubular linear motors lend themselves to productivity doubling applications with two independent Forcers operating on a single Thrust Rod, Fig 6. Each Forcer has its own servo drive, and can travel fully independent of the other. One Forcer can then load, for example, while the other unloads. The technique can double throughput by lifting items two at a time from a fast traveling conveyor and place them with precision on a second conveyor. Try this with a ballscrew positioner!

Similarly, multiple Forcers operating on a single Thrust Rod can double; triple or even quadruple drive force. The Forcers can be operated by a single controller.

**Challenge Servo Pneumatics**

Simple “bang-bang” pneumatic cylinders provide fast back-and-forth operation, but only for fixed—hard-wired—travel distances. Modern short-run automation demands variable load positioning. Closing a servo loop around an air filled cylinder and its high friction piston is difficult, tends to be cumbersome and costly, and can’t come close to direct-drive agility and precision. Today’s linear motors and actuators are cost-competitive, quiet, provide unmatched bandwidth, and don’t need a supply of compressed air.

**Introducing Micro Actuator & Micro Motor**

Copley has recently introduced a Micro actuator and Micro motor measuring just 28 cm wide that bring automation to a new level of intricacy, Fig.7. Both provide travel and drive force far surpassing piezo electric or voice coil positioners. An assembly deploying ten independently controlled actuators occupies less than 12 inches. Micro actuators and motors will power productivity-enhancing mechanisms in rehabilitation medicine, assembly, packaging, printing and many more uses.

**100+ Million Operations**

John Odenthal, a pioneering Chicago system integrator, observes a clear trend to boost productivity by applying decreasingly costly computer power to coordinate increasingly sophisticated electromechanical systems. His own organization is working on a distributed control solution for printing high definition images on plastic bottles carried by a fast conveyor. Historically, the client had to stock a whole range of pre-printed adhesive backed labels. Now, label cost and changeover time are eliminated as the machine simply prints the next preprogrammed image.

Odenthal’s clients demand automation systems with wide bandwidth and microns precision, and capable of 10 million operational cycles. Performance of a typical multi-actuator assembly is characterized by 30 million cycles per year, with 200+ programmed corrections per cycle, while exhibiting life expectations of 2 or more years.

**MATCHED PAIR**

A linear motor or actuator, matched with an advanced servo drive, makes a powerful plug-and-play positioning sub system, Fig 8. DSP-based, today’s drives permit multi-axis and stand-alone operation.
and provide a wide range of application versatility. Operating modes include point-to-point moves, indexing, contouring, velocity and torque control. The drives are available with CANopen, EtherCat, DevNet and MACRO network interfaces.

Copley speeds the system designer’s task with highly intuitive software tools. A Java-based drive configuration environment provides auto tuning and makes system setup and commissioning fast and simple. The software also includes powerful oscilloscope, function generator, and diagnostic tools.

CONCLUSION

Linear motors and actuators are now cost competitive with ballscrews and belt drives and offer distinctly superior agility and bandwidth. They provide cost competitive drop-in ballscrew replacements for bandwidth upgrade, or to exploit direct drive simplicity and MTBF advantage. New micro motors and actuators models will spark creative automation of tasks not previously feasible. Direct linear drives will increasingly replace servo-controlled pneumatic cylinders, contributing reliability and controllability, free from the cost, noise, and upkeep of air compressors.

END