Temposonics®

Magnetostrictive, Absolute, Non-contact Linear-Position Sensors

MTS® SENSORS

Replacing Linear Encoders with Magnetostrictive Technology

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White Paper

Model RP Profile-style position sensor

Model RH Rod-style position sensor

Designing with Magnetostrictive Sensors opens many options. This article explores how Design Engineers are increasingly finding that magnetostrictive linear position sensors can replace their encoders in applications while improving productivity and cost of ownership.

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HOW ARE LINEAR ENCODERS CURRENTLY USED?

A linear encoder is a critical part of a motion control system, providing continuous, linear position feedback to drive the motor position. Linear encoders improve the positioning accuracy of an electro-mechanical actuator by providing direct position feedback at the load to compensate for backlash or other sources of error. Linear encoders are also used as the primary feedback device for linear motors that directly convert electrical energy into linear motion.

CHANGING MARKET DEMANDS

Productivity improvements, frequent product changes, and sophisticated machining tasks are constant challenges in linear actuator applications. Traditionally, optical or magnetic linear encoders have been used to provide the required position feedback. However, design engineers are increasingly finding that magnetostrictive linear position sensors can replace their encoders in applications while improving productivity and cost of ownership. Designed for precise and robust position measurement, magnetostrictive sensors can be installed in electrical linear motors, as well as electro-mechanical actuators, pneumatic, hydraulic, spindle or power-grip belt drives, or wherever high-accuracy, dynamic positioning tasks must be performed. A wide variety of applications include assembly lines, material handling, component feed equipment, quick positioning systems, quick-change systems for work-piece holders, packaging applications and machine tools.

Many designers continue to specify linear encoders for applications that would work well with magnetostrictive sensors simply because they've always used linear encoders—they are familiar with the technology. However, it is easy to utilize magnetostrictive sensors as encoders because they offer the performance and reliability needed for dynamic closed loop control. Continuous, precise, position feedback permits velocity and position-controlled movements at a very high or very low speed.

KEY FEATURES OF MAGNETOSTRICTIVE POSITION SENSORS

Magnetostriction offers several benefits over other technologies to provide reliable and accurate positioning. One of the key benefits that magnetostrictive sensors offer over incremental linear encoders is inherent absolute positioning. A linear encoder is basically a ruler (scale) that is marked with increments that a reading head counts as it travels over the marks. Each mark encodes a specific distance such that the encoder can determine how far it has moved from a reference point. There are limitations to that approach, however, because there is a maximum and minimum speed the reading head can travel before losing track of the marks it has scanned. Dropping below the minimum speed will create a cogging effect, due to the "in between marks" time that do not produce feedback for the amplifier and forces the amplifier to speed up until the next signal is received. The result is an uncontrolled jerky movement not acceptable in most of the low speed applications. In addition, contamination or disturbances can interfere with the encoder's ability to read the marks.

Magnetostrictive position sensors, on the other hand, do not have a maximum or minimum speed limitation because they are absolute position devices; they continue sampling absolute position at a fixed rate and resolution regardless of the application velocity.

Another benefit of absolute position sensors is that they eliminate the need for moving to a reference mark or home position after a power reset. At any point in time, the absolute position sensor can report where it is without requiring a movement. Many applications are now moving beyond incremental encoders and are advancing to absolute position feedback for improve safety and productivity.

The main reason many applications have used encoders in the past is that they used electro-mechanical actuators along with drives that required incremental signals such as quadrature or sinusoidal. Magnetostrictive sensors have historically been used inside hydraulic cylinders employed in harsh environments, whereas linear encoders were externally mounted on machine tools. Today, however, magnetostrictive sensors are available with many options for mounting on machine tools (as shown below) and offer many interfaces, such as an absolute SSI interface, which supports the trend towards absolute linear encoders. So, in many applications where an encoder was previously used, magnetostrictive sensors are now an option along with the benefits they provide.

Performance was also previously a factor in some cases. Optical linear encoders have a range of performance that at the upper end could achieve resolutions and accuracy that magnetostrictive sensors could not meet in the past. However, advancements in magnetostrictive technology over the years have now increased the overlap in performance so they now fit into applications that could previously only use linear encoders. Magnetostrictive sensors provide precise, dynamic measurement of absolute position and velocities and are capable of measuring signals in the sub-millisecond range. They can reach sub-micron resolutions which permits displacements at very low speeds of only 0.5 mm/s; measurement cycle times down to 100 microseconds to track fast motion; a linearity of <± 0.01% and typical repeatability of 2.5 microns. Real-time linearity correction is available to get measurement accuracy down to 20 microns or better.

Another advantage of magnetostrictive technology is that it is not sensitive to contamination in harsh environments. An optical encoder's reading head, a piece of glass and a laser that's counting the marks, can be contaminated by dust or oil, causing loss of the optical signal which means the reader is unable to count the marks. Also, glass is a fragile material not suitable for an environment where mechanical vibrations can occur. The magnetostrictive sensor's parts are enclosed within the sensor, and the magnet provides non-wear technology that ensures robustness of the sensor for the life of the equipment. Some magnetostrictive sensors are designed with double-shielding to eliminate electrical interference which ensures a high signal-to-noise ratio and allows them to be used even in applications where other sensors can't be utilized.

A disadvantage of the optical encoder is its use of a moving cable. In the encoder, the electronics are embedded inside the reading head that is moving back and forth, requiring an attached cable that can create design challenges. With magnetostrictive technology, the only moving part is a passive position magnet. There are no electronics or cables attached to the position magnet, only the moving machine part. This makes the magnetostrictive position sensors a more rugged and reliable technology. In addition, the position magnet does not need to be physically tethered to the sensor, but could, for example, be attached to a moving carriage that comes in and out of range of the sensor. Multiple positions can even be reported from a single sensor using some interfaces such as Profibus, EtherCAT, and POWERLINK.

Linear motors are used for a wide range of applications because they offer a multitude of advantages based on their functional principle. Linear motors have efficient energy conversion compared with traditional mechanical components used for converting the rotary motion of an electric motor into linear motion (gear head, belts and pulley efficiency is in 90% range or lower) resulting in energy savings and less maintenance costs. As a linear drive converts electrical energy directly into mechanical energy, translation by means of a mechanical device is unnecessary. A magnetic field of traveling waves generates the force at the moving part. This is ideal for high-end applications in the electronics, automotive, printing or robotics industries, or in the general mechanical engineering fields of machine tools, cutting machines, handling and assembly or packaging machines. Due to high dynamics, positioning accuracy, durability and reduced maintenance requirements, the linear drive improves the quality and the efficiency of the production, but requires a suitable linear position feedback device. Despite the presence of a strong magnetic field that drives the linear motor, numerous applications have been implemented with magnetostrictive sensors providing feedback without issue.

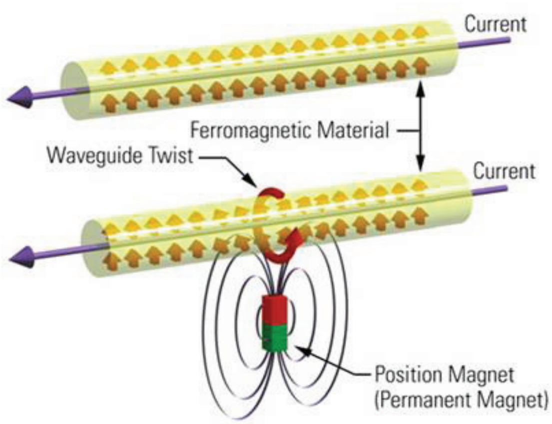
There are multiple technologies to provide continuous position feedback, so the choice comes down to the specific application implementation.

What are the interface requirements? What is the environment like? Is there a risk of contamination, shock, or vibration? There are still applications that are best suited for linear encoders because of specific requirements, but today's magnetostrictive technology is increasingly meeting the needs of a wide range of applications and provides significant productivity and cost of ownership benefits.

HOW MAGNETOSTRICTION WORKS

Magnetostriction is a term that describes the tendency of some materials to change shape, constrict or elongate in the presence of a magnetic field. Normally, a material's magnetic domains are randomly oriented. If a magnetic field is applied, those domains will align, causing a change in shape or lengthening.

A magnetostrictive position sensor takes advantage of this effect by inducing a mechanical wave or strain pulse (as shown below) in a specially-designed magnetostrictive wire called a waveguide. The time of flight of this pulse is measured and can be equated to distance because the speed of traverse is very constant and repeatable. The pulse is created by momentarily causing the interaction of two magnetic fields.



One magnetic field originates from a permanent magnet, which passes along the outside of the sensor tube. The other electromagnetic field, encompassing the entire length of the waveguide, is created when a current interrogation pulse is applied to the waveguide.

At the interaction point between these two magnetic fields a torsional strain pulse is produced, that travels at the speed of sound in the specialized waveguide alloy (about 3.55 microseconds per centimeter of travel) along the waveguide path until the pulse's arrival is detected at the head or mode converter end of the sensor.

The position of the magnet is determined precisely by measuring the elapsed time between the creation of the current pulse and the arrival of the strain pulse. That information is converted either to a duty cycle derived analog signal or is read as a serial or bus signal by the user's controller. As a result, accurate non-contacting position sensing is achieved with absolutely no wear to any of the sensing elements. The strain pulse is small, on the order of 20 to 30 microstrain, resulting in virtually no fatigue of the waveguide.

ABOUT MTS SENSORS:

MTS Sensors, a division of MTS Systems Corp., is the global leader in the development and production of magnetostrictive linear-position and liquid-level sensors.

MTS Sensors Division is continually developing new ways to apply Temposonics® magnetostrictive sensing technology to solve critical applications in a variety of markets worldwide. With facilities in the U.S., Germany, Japan, and China, MTS Sensors Division is an ISO 9001 certified supplier committed to providing customers with innovative sensing products that deliver reliable position sensing solutions.

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