THE ADVANTAGES OF MAGNETIC ENCODER TECHNOLOGY IN HARSH OPERATING ENVIRONMENTS

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TIMKEN

Abstract

In industrial automation and motion control applications, maximizing performance is strongly influenced by selecting the proper encoder technology. This paper outlines the differences between optical encoders, resolvers and magnetic encoders. It illustrates why magnetic encoders are preferable in many applications. It also provides an overview of how Timken encoders employ patented Hall effect technology to help optimize accuracy and reliability, and illustrates real-world examples of how magnetic encoder technology has been successful in specific applications.

Introduction

The rapid spread of automation into a broadened range of industries has increased the need for robust servo systems that can manage an entirely new set of application challenges. For example, automation is now widely used in packaging, paper handling, power generation and other operating environments that are dirty, hot, humid and subject to high levels of vibration.

Optical encoders designed for use in cleaner automation environments have been employed in these rugged applications with some success, but more reliable feedback operation has been available only through traditional, high-cost devices such as resolvers or sealed optical encoders.

Recently, advancements in magnetic sensor technology have made magnetic encoders a more viable option for machinery operating in higher shock, vibration and contamination environments.

Optical, Resolver and Magnetic Technologies

Optical Encoder Technology

Optical encoders use line-of-sight sensing to create signals. This is done with a light source that splits into two 90-degree out-of-phase beams that pass through transparent, evenly-spaced windows in a rotating optical disc. The light is then read by a receiver and converted into digital square wave quadrature output signals. Good signals are dependent on a clear, consistent line of sight. Any material contamination that impedes the light source will cause signal disruption and encoder failure. Servo systems located in dirty and dusty environments where particles can penetrate into the optical path are especially prone to this type of failure. In addition, failure is possible when servo systems are subject to fluctuating humidity and temperature, which cause condensation to form on the rotating disc.

Maintaining a correct air gap between the pulse disc and optical sensor of an optical encoder is critical for reliable operation. The air gap for a typical optical encoder is often less than 0.25 mm (0.010"). This small distance is needed to maintain light signal integrity and accuracy. As a result, optical encoders are vulnerable to shock and vibration, which may damage the rotating optical disc or sensor.

Traditional solutions include sealed, ruggedized packaging for optical encoders. Many optical encoder manufacturers have gone to great lengths to develop well-sealed products that are resistant to vibration, shock and temperature. Unfortunately, this additional protection has resulted in bulkier, higher-cost products.

Resolver Technology

Resolvers present robust alternative to optical encoder technology. Typical brushless resolvers are constructed of two static windings that are mechanically off-set by 90° and a rotary or reference winding that is fed with a sinusoidal current supplied by a rotary transformer. As rotation occurs, the induced currents in each of the static windings are measured and their relative signal intensities provide position. The materials of construction and the method of signal production create the robustness of this device. While resolvers are nearly immune to the environmental hazards found in industrial environments, their control systems are usually far more costly than that of an optical or magnetic encoder. They require a resolver to digital (R to D) converter integrated circuit that is located in a remote area, thus requiring cabling to carry low level signals. The cabling can add to the complexity of installation, operation and maintenance.

Magnetic Encoder Technology

Advancements in magnetic encoding technology have enabled the development of compact, low-cost encoders that are more tolerant of dirty and harsh operating environments where optical encoders could skip pulses. At Timken, engineers have patented new magnetic encoder designs that use Hall effect technology to obtain high resolution from a durable magnetic target disc.

Magnetic sensing does not need a clean transparent gap. Only some distance between the magnetic target and sensor is needed to operate properly. As long as this gap is not filled with a ferrous material, magnetic pulses will be sensed by MPS technology. Dirt, dust, oil, condensation and other contaminants do not affect the reliability of a magnetic encoder.

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Magnetic encoders are also inherently shock and vibration resistant. The gap between the sensor and the target magnet is large when compared to an optical encoder and can be as large as 4 mm (0.157") without affecting signal accuracy. These encoders can operate with end play and run out tolerances as high as 2.5 mm (0.98") total, reducing the potential for target disc and sensor impact damage.

Magnetic sensing technology prevents the need to ruggedize the magnetic encoder packages. Large gap requirements, immunity to light impeding contaminants, and basic materials of construction that are rated to 135° C (275° F) allow the use of a modular packaged encoder to be used without additional cost. Digital quadrature output signals are the same as in an optical encoder, so the additional control costs typically encountered when using resolvers are avoided.

Hall Effect Technology in Timken® Magnetic Encoders

Timken offers magnetic encoder technology in two commercial forms – as a complete-package encoder design (Fig. 1) and as a single-sensor chip Timken MPS linear encoder ASIC (Figs. 1 and 2) that is easily integrated into existing customer designs. Both options use Hall effect technology.

The Timken M15 modular magnetic encoder is a high-resolution speed and position feedback sensor used in electrical motors and other mechanical devices where shaft position or speed feedback is required.

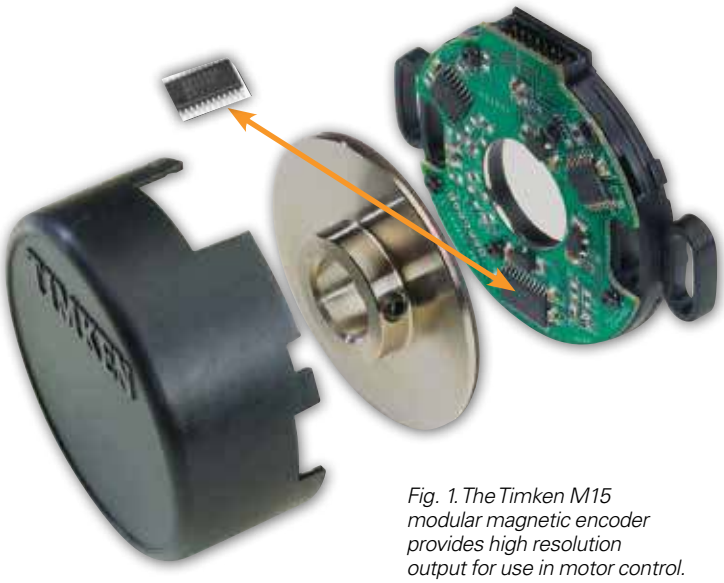


Fig. 1. The Timken M15 modular magnetic encoder provides high resolution output for use in motor control.

The M15 encoder has mounting and connection features that lend themselves to common formats used in automation, specifically on both brushless and brush-type servomotors and smart stepper motors. It can be easily applied to existing motor designs where optical encoders are currently used, allowing for both mechanical and electronic signal interchangeability. Additional common features with optical encoders include commutation, index pulse, open collector or line driver outputs.

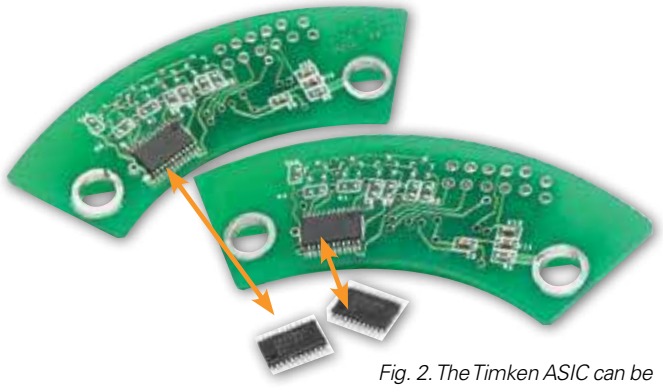


Fig. 2. The Timken ASIC can be used in a variety of applications.

The M15's commutation signals are produced from three small independent Hall effect sensors placed on the encoder PCB to detect a second magnetic track on the target magnet. The commutation track is independent of the MPS160 sensor magnet track and is inboard of the MPS160 track. The three Hall effect sensors used for commutation are digital sensors that turn high when over north pole and low when over a south pole. The number of pole pairs on the magnet commutation track and the position of the three digital Hall effect sensors combine to produce three commutations signals – U, V, W – that are phased by 120 electrical degrees.

Magnetic Encoder Technology in Real-World Applications

Customers in a variety of industries have achieved optimum application performance using Timken magnetic encoder technology in both the M15 encoder's packaged format and in the MPS Encoder ASIC's single chip format. This technology has been successfully used in such applications as automotive steering systems, stepper motor drives, mining trucks, measurement systems, medical devices, lighting systems and transmission sensors for off-road equipment. The following case studies are examples of successful magnetic encoder technology use in two of these applications.

Stepper Motor Drives

The Timken M15 encoder has been applied successfully in stepper motor drives that help control motion in automated lighting products for indoor and outdoor stage productions. In these applications, stepper motor drives control the motion of stage light systems as they move horizontally, tilt and rotate.

In one case, the M15 encoder replaced a similarly-size optical encoder with superior results. The M15's package design enabled the customer to integrate the unit into existing beta units for testing. The M15 encoders were mounted securely within the customer's stepper motors. Both lab testing and field results confirmed that the units were less vulnerable to debris, condensation, inclement weather and extreme temperatures than their optical encoder counterparts. The M15 encoder is now used in production units.

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Schneider MDrive® Actuators

In a different industry, another customer improved the precision and reliability of its motion control systems using the MPS Encoder ASIC linear encoder ASIC.

Schneider Electric Motion USA (previously IMS Motion Control Systems), a global producer of all-in-one motion systems used in robotics, pharmaceutical processing and the manufacture of medical, biomedical, electronic and semiconductor products, replaced optical encoders with the MPS Encoder ASIC in its Schneider MDrive® actuators (Fig. 3). The actuators help automated equipment move with high accuracy and repeatability.

The MPS Encoder ASIC provides feedback about the position and speed of the shaft as it moves. The advantage is that it allows for an off-axis design and can be installed in compact areas.

Previously, Schneider's stepper motors used a remote drive with external optical encoders, and the drive was connected to the motor with a cable. This presented issues with noise and debris contamination. Both challenges were overcome with the MPS Encoder ASIC, because the compact sensor could be placed directly into the embedded motor electronics.

Schneider also selected the MPS Encoder ASIC because its programmability offers easier product customization. The company quickly programs the sensors for the appropriate number of pulses per revolution needed for the application, installs the encoders in the MDrive® units and then sends them out for installation into automation equipment.

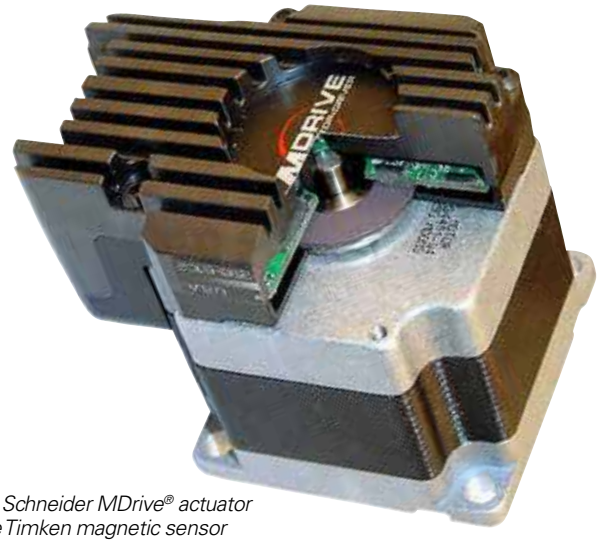


Fig. 3. The Schneider MDrive® actuator utilizes the Timken magnetic sensor technology to improve accuracy and repeatability in automated equipment.

Encoder Technology Comparison

	On Axis Magnetic Encoder	Resolver	Optical Encoder	Timken Off-Axis Magnetic Encoder
Absolute or Incremental	Absolute and Incremental	Absolute	Absolute and Incremental	Absolute and Incremental
Absolute Resolution	8-12 bits	16 bits	15 bits typ	13 or 16 bits
Incremental Resolution	1024 lines	N/A	10,000 lines typ/250k possible	25,000 lines
Typical Accuracy (arc minutes)	30 to 50	3 to 50	.15 to 6	4 to 20
Gap/Alignment Requirements	Sensitive	Sensitive	Highly Sensitive	Least Sensitive
Handles Contamination Well	Y	Y	N	Y
Handles Shock/vibration Well	Y	Y	N	Y
Typical Maximum Temperature	125 °C (257 °F)	150° C (302° F) (125 for R/D converter)	85° C or 100° C (185° F or 212° F)	135 °C (275° F)
Simple Architecture	Y	N	Y	Y
Redundant System	Y	N	Y	Y
Required Space	Very Small	Large	Medium	Very Small
Cost	Less	Higher	Less	Less

Table 1. Comparing the operating parameters of various encoder types can help engineers select the appropriate encoder technology for their specific applications.

Encoder Selection

Several factors, such as environmental challenges, package size, resolution and cost, should be taken into consideration when selecting the most reliable encoder type for a specific application. Table 1 provides a comparison of various position feedback sensor types and their operating parameters.

Conclusion

Magnetic encoders offer several advantages over traditional optical encoder designs, including greater durability, reliability and compact packaging. They are highly-suitable for applications that are subject to challenging environments where dirt, humidity, high temperature and high levels of vibration are present. Magnetic encoders, which use Hall effect technology, have operated successfully in such applications, including stepper motor drives used in automated stage lighting products and the Schneider MDrive® actuator, which is used in a wide variety of industrial automation systems. This new generation of off-axis magnetic sensor technology has been successfully used in such applications as automotive steering systems, stepper motor drives, mining trucks, measurement systems, medical devices, lighting systems and transmission sensors for off-road equipment.

When selecting the proper encoder technology for an application, engineers should consider environmental, packaging, resolution and cost requirements. In cases where performance requirements can't be compromised and the operating environment could be challenging, magnetic encoder technology can meet the customer's needs at a relatively low cost.

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