Temposonics®

Magnetostrictive, Absolute, Non-contact
Linear-Position Sensors

MTS® SENSORS

Implementing Position Sensors for Hazardous Areas & Safety

White Paper

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By:
Robert Luong, Technical Marketing Manager, MTS Sensors (Germany)

A significant proportion of industrial equipment will be deployed in what are described as hazardous areas, or possibly applications that require a functional safety assessment. Hazardous areas include locations where there is the risk of exposure to flammable or even explosive substances. In such circumstances, ensuring ongoing operation can prove to be challenging. It is therefore critical that the component parts which make up such items of equipment are suitably constructed to function in these uncompromising environments. Functional safety applications are ones in which safe operation must be ensured due to the risk of equipment damage or personal injury. Linear position sensors are widely used in all manner of industrial systems, and in many cases the potential for hazardous events occurring needs to be taken into account - otherwise the consequences could be very serious, with expensive equipment being severely damaged, or even lives being put in danger.

In hazardous areas the presence of flammable gas, vapor, liquid, or dust, can bring major risk to the activity of an electrical device, as there is the prospect that the device could ignite the flammable substance. For equipment incorporating position sensing technology, the constituent sensor device (or devices) should have appropriate features to address these issues. The following white paper looks, in detail, at the different steps that need to be taken during the sensor selection process to ensure that the correct device is eventually chosen.

Before making an in-depth study, it must be made clear that hazardous area rated devices are designed to operate in a potentially explosive environment while functional safety products are designed for applications where there is risk to equipment or people. These two parameters are not necessarily interrelated. An application might require either functional safety or hazardous area ratings without necessarily requiring the other.

DEFINING HAZARDOUS AREAS

There are a multitude of different examples of hazardous areas. Among the most commonplace of these are oil exploration rigs, gas utility plants, chemical/pharmaceutical fabrication facilities, sewage treatment sites and large scale dry cleaning operations, as well as places where industrial chemicals are processed/produced, powders (such as magnesium and aluminum) are stored, or chemically-active products (such as fertilizers) are manufactured.

INDUSTRY STANDARDS

For any electrical device that will be situated in potentially flammable or explosive surroundings, compliance with stringent industry standards is mandated. The most prominent of these standards are the International Electrotechnical Commission's IECEx, the European Union's ATEX (as described in directives 99/92/EC and 94/9/EC) and the National Electrical Code (NEC) used in the United States. For devices being used anywhere in North America, testing should be carried out by a nationally-recognized testing laboratory (NRTL) and labeling prerequisites should be abided by. Ratings are categorized by both class and division in order to denote the type of hazard. This can go from the unlikely presence of an explosive substance right up to a continuous presence. Different protection methodologies are employed to attain the necessary approval rating. These are dependent on the type, condition and nature of the environment involved.

IEC 61508 FUNCTIONAL SAFETY

The concept of functional safety is that having detected a potentially hazardous situation, measures can be taken to avert a hazardous event actually occurring, or to ensure that if it does occur its effect is mitigated to an acceptable degree - so that the welfare of operatives are not put at risk and damage is not done to valuable pieces of equipment.

The IEC 61508 provides a standard to assess that a safety function performs to the required level, including failure modes. Adherence to the IEC 61508 standard makes it is possible to lower the risk of failure that a particular hazard will have associated with it via safety functions which enable its detection. In addition, it allows an assessment of the probability of failure to perform the required function. Through this, risk analysis can be undertaken. Devices are categorized in accordance with a specific Safety Integrity Level (SIL), which relates to the probability of failure occurring. A SIL 1 rated device has a probability of failure between 0.01 and 0.1 for low demand operation - which translates into a probability of failure lower than 0.00001 per hour for high demand operation. Likewise, a SIL 2 rated device has a failure probability between 0.001 and 0.01 for low demand operation, equating a probability of failure that is within the confines of 0.000001 per hour for high demand operation. Failures are classified as either safe or dangerous and they can either be detected or undetected. The safe failure fraction defines the ratio of failures that are either safe or detectable over the total number of failures. From this it is possible to determine the likelihood of dangerous undetectable failures. Even in the best case scenario failure of equipment/instrumentation will lead to operational downtime. This will reduce productivity and result in repair costs and expense on replacing component parts being accrued.

Through functional safety it is possible to quantify the probability of a hazardous event taking place and what the consequences would be. When developing industrial systems that will be situated in hazardous areas, engineers therefore need to include functional safety aspects into their thought process. This cannot be left until that last minute, it should be a key consideration throughout the development cycle.

KEY PROTECTION METHODS

There are a wide array of different methods that can be employed to mitigate the impact of hazardous environments. Shielding can be put in place to offer basic protection. How the system design is manifested can take into account keeping delicate components away for places where the conditions are most severe. Inclusion of redundancy into the system also has great value, so that if a failure happens there is provision for the required function to continue via a back-up. When there is a constant threat from explosive substances, housing of electronic/electrical equipment inside an explosion-proof enclosure may be deemed necessary. Through this it will be possible to contain an internal explosion so that the external environment is not affected.

POSITION SENSING IN HAZARDOUS AREAS

Sensing equipment is deployed in many applications so that positioning feedback can be delivered. Often this has to be done in hazardous scenarios. Examples include the gas/steam turbines found inside power generation plants, oil/gas drilling apparatus, steel/wood presses, the equipment in fuel servicing depots and oil drilling rigs, but the list goes way beyond this. A variety of different sensing mechanisms are used to accomplish position measurement in such settings. Among these are:

1. Potentiometers - These act as voltage dividers with position measurement being established via a voltage signal which is proportional to the point in which a wiper resides on a linear transducer element. This method has been very popular in the past, but it does have shortfalls and these are now becoming more apparent in modern day implementations. The most notable of these is that potentiometers are prone to mechanical wear and tear. This is due to the contact between the transducer and the wiper.

2. Encoders - These employ a reader head to scan a marked scale and thereby indicate incremental changes in position. Long term operation of this kind of mechanism is subject to failure because of the presence of vibrational movement and high temperatures. Furthermore, oil, grease and other substances often found in heavy industrial environments mean that they will require cleaning and maintenance work on a regular basis (all of which adds to the running costs).

3. Linear variable differential transformer (LVDT) devices - LVDTs rely on the movement of a ferromagnetic core that varies the magnetic coupling between primary and secondary coils. Thanks to their high temperature rating, these devices have seen fairly widespread deployment in hazardous areas. However, they exhibit an intrinsically poor linearity. Also they need to be recalibrated periodically.

4. Magnetostrictive linear sensor devices - Using the principles of magnetostriction, where a magnetic field can alter the physical properties of a ferromagnetic material, magnetostrictive sensors have shown themselves to be highly effective at delivering accurate position measurement in hazardous applications. Since these devices give an absolute position figure, rather than a relative one, they eliminate the need for recalibration work. In addition, as they dispense with the need for reader heads, the time allocated and costs relating to cleaning and maintenance work can be taken out of the equation. It is also worth mentioning that they have much stronger resilience to shock and vibration, as well as far greater immunity the electromagnetic interference immunity (EMI) than other measurement options. Finally (and most importantly, in this context) it is relatively straightforward to integrate functional safety mechanisms into these devices.

PRINCIPLES OF MAGNETOSTRICTION & MAGNETOSTRICTIVE SENSING

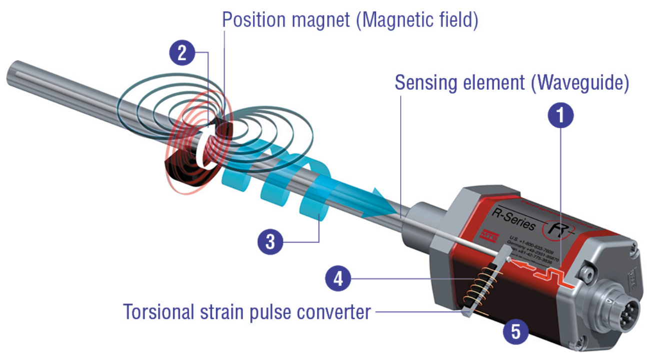
When a ferromagnetic material is placed within a magnetic field, microscopic changes to its structure are brought about. As a result of this its dimensions will be altered - this is known as magnetostriction. The magnitude of the dimensional change correlates directly with the strength of the magnetic field applied. This phenomenon furnishes a highly effective non-contact sensing method. As there are no moving parts involved, magnetostrictive sensors offer heightened reliability and prolonged operational lifespan.

UTILIZING ADVANCED MAGNETOSTRICTIVE TECHNOLOGY

To enable exact position measurement in even the most difficult of industrial settings, MTS Sensors' developed its proprietary Temposonics® magnetostrictive sensing technology. Temposonics sets new performance benchmarks that rival sensor devices cannot match. The position sensing system comprises the following components parts.

1. A ferromagnetic waveguide
2. A mobile position-determining permanent magnet which traverses along the waveguide
3. A strain pulse converter, along with its supporting electronics

Exact position measurement using this technique is derived through the momentary interaction between two magnetic fields. One of these fields emanates from the mobile magnet (which is rigidly connected to the object from which positioning data is required). This is a longitudinal field. The second field is radial. This is generated by current pulse that is applied to the waveguide and runs parallel to the direction over which the mobile magnet moves. When the pulse comes into close proximity with the mobile magnet, the interaction of their respective magnetic fields instigates magnetostriction. The waveguide is elastically distorted and an ultrasonic torsion wave is subsequently generated. This wave travels back down the waveguide and is converted into an electrical signal when it reaches the end of the waveguide. Since the wave maintains a constant speed while traveling along the waveguide, the precise position of the mobile magnet can be calculated - using the principles of time-of-flight.



Measurement Cycle	
1	Current pulse generates magnetic field
2	Interaction with position magnet field generates torsional strain pulse
3	Torsional strain pulse propagates
4	Strain pulse detected by converter
5	Time-of-flight converted into distance

Figure 2: Temposonics Magnetostrictive Technology

Based on its Temposonics technology, MTS Sensors has introduced a portfolio of products to respond to growing demands for hazardous areas and safety. Devices can be specified that are both flame- and explosion-proof, with ATEX, IECEx Zone 0/1 NEC 500 and NEC 505 Zone 0/1 compliance are available. Safety applications can be addressed either by redundancy, or by a specific functional safety assessment such as SIL2 under the IEC 61508 standard.

One method to address safety requirements is to provide a redundant measuring system within the sensor as a backup. The RT4 sensor is highly suited to placement in safety applications with two key features that improve reliability. The first of these is built-in redundancy, in which two independent sensing elements are contained within the rod with signals going to two separate sets of electronics. The benefit of redundancy is that the second measuring system can continue to report measurements if the first channel should fail. The second feature of the RT4 the detached electronics, which permits the sensitive semiconductor components required for signal conditioning and signal processing purposes to be kept away from the most extreme conditions (at distances of up to 600mm from the sensor rod) - thereby safeguarding them from possible damage. In addition, an IP68 rated housing protects completely against ingress of water or dust. The RT4's 24/25/26-bit synchronous serial interface (SSI) output ensures elevated signal integrity levels are upheld.

Figure 3: RT4 with Detached Electronics & Built-In Redundancy

CONCLUSION

The increasing need for functional safety to be address in hazardous applications is bringing about a steady migration away from traditional LVDT position sensing and towards a more sophisticated approach based on magnetostriction. As well as disadvantages in terms of performance and operational longevity, LVDT and the other position sensors mentioned are not able to offer the same degree of functional safety that magnetostrictive sensors can. To sum up, appropriate sensor selection is critical to position sensing system deployment. There are many different factors that must be given serious contemplation if a suitable device is to be specified. It is clearly worthwhile engaging with a sensor manufacturer that offers a comprehensive sensor portfolio capable of meeting a broad spectrum of different requirements and has a strong understanding of functional safety issues. This needs to be backed up by a high level technical support and extensive application knowledge.

ABOUT MTS SENSORS

MTS Sensors is a division of MTS Systems Corporation (NASDAQ: MTSC) and is recognized worldwide as a leader in the design and manufacture of high precision, robust position sensing solutions for industrial, mobile hydraulic and liquid level sensing applications. Among the key sectors it serves are industrial machines, power generation, construction/agricultural vehicles, textiles, paper production, steel plants and saw mills. Sensors from MTS are often implemented in safety-critical applications, including hazardous areas. MTS Sensors has manufacturing facilities in the United States, Germany and Japan. Customers are supported by an extensive global partner network including cylinder manufacturers. Through its research, development and production of leading-edge sensing technologies, MTS Sensors provides its customers with a comprehensive and constantly expanding product portfolio and is continually working with them to improve performance and reduce downtime in their operations.

For more information on MTS Sensors, please visit www.mtssensors.com or contact a local MTS representative.

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LEGAL NOTICES

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LOCATIONS

USA
MTS Systems Corporation
Sensors Division
3001 Sheldon Drive
Cary, N.C. 27513, USA
Tel. +1-919-677-0100
Fax +1-919-677-0200
info.us@mtssensors.com
www.mtssensors.com

GERMANY
MTS Sensor Technologie
GmbH & Co. KG
Auf dem Schüffel 9
58513 Lüdenscheid, Germany
Tel. +49-23 51-95 87 0
Fax +49-23 51-5 64 91
info.de@mtssensors.com
www.mtssensors.com

JAPAN
MTS Sensors Technology Corp.
737 Aihara-machi,
Machida-shi,
Tokyo 194-0211, Japan
Tel. +81-42-775-3838
Fax +81-42-775-5512
info.jp@mtssensors.com
www.mtssensors.com