NON-CONTACT DISPLACEMENT MEASUREMENT USING INDUCTIVE (EDDY CURRENT) SENSORS

Precision Non-Contact Measurement

Precision measurement has long been a part of manufacturing and process control. Dimensional measurement of parts, monitoring of production equipment and final inspection of assembled systems require process engineers and plant managers to collect and analyze endless amounts of data to ensure that their production lines are operating at peak efficiency and that disruptions in the process flow are minimized. Measurement devices can take many forms, from simple gage blocks and go/no-go fixtures to high-resolution, nanometer-accurate measurement systems. Choosing and deploying the correct measurement technique for a given point in the process is as critical as the measurement itself.

MTI Instruments Inc., a leader in providing precision, non-contact measurement systems, offers several different technologies based on the required measurement parameters. Non-contact measurement systems provide several advantages over contact methods. They can be used on extremely small or fragile parts where contacting the target can cause damage. They have higher accuracy and precision than traditional contact devices and can be used in closed-loop, highly dynamic environments to provide real-time process information and control without operator intervention.

Selecting the Proper Measurement Technique

Choosing the correct measurement technology requires defining the parameters under which the sensor must operate. The ability of each sensor technology to satisfy the measurement parameters is then analyzed to determine which one is most appropriate. It is important to note that non-contact, displacement measurement sensors measure the gap between the probe face and a target. By monitoring changes in this gap, the absolute target location or target motion through a range can be determined. Advanced calculations can then be made to determine such things as vibration amplitude and phase, the thickness and shape of a piece, or the run-out of a rotating shaft.

Each non-contact measurement technology has its own unique advantages and disadvantages. Selecting the proper technology often involves a compromise between sensor performance and the environment in which it must operate. A brief summary of four different non-contact technologies is shown below.

MEASUREMENT TECHNOLOGY	ADVANTAGES	DISADVANTAGES	RELATIVE COST
Fiber Optic	– High Accuracy and Resolution – High Frequency Response – Small Sensor Size	– Small Sensor-to-Target Stand-off – Small Measurement Range – Affected by Target Reflectivity	High
Laser Triangulation	– Large Measurement Range – Large Sensor-to-Target Stand-off – Not Affected by Temperature Changes	– Large Sensor Head – Operates in Clean Environment – Affected By Changes in Target Surface	Moderate
Capacitance	– High Accuracy and Resolution – High Frequency Response – Probe Geometry Easily Customized	– Small Sensor-to-Target Stand-off – Operates in Clean Environment – For Conductive or Semi-Conductive Targets	Moderate
Eddy Current	– Operates in Any Environment – Large Measurement Range – High Frequency Response	– Conductive Target Only – Lower Relative Accuracy and Resolution – Affected by Temperature Changes	Low

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While the cost of applying measurement systems is always an important concern, it should not carry undue influence when evaluating each measurement technology. One must also consider the impact of installing the incorrectly applied solution. The money saved by choosing a given technology can be quickly overshadowed by the cost of inaccurate or insufficient measurement.

For detailed information about other non-contact measurement technologies from MTI Instruments, go to our website at www.mtiinstruments.com and visit the MTI University.

Principles of Operation

In its simplest form, an Eddy Current sensor consists of a precision wire coil around a ferrite core. When an AC current flows through the coil, a magnetic field is formed about the coil. When the coil and its magnetic field are placed in proximity to a conductive target, electric currents are established in the target. These currents, traveling in closed loops in the opposite direction of current in the coil, are called Eddy Currents. The Eddy Currents in return generate their own magnetic field. As the distance between the coil and the target (air gap) changes, the Eddy Current magnetic field changes the overall electrical impedance of the sensor coil. The change in coil impedance causes a change in the voltage across the coil that can be converted to a change in output by the probe drive electronics.

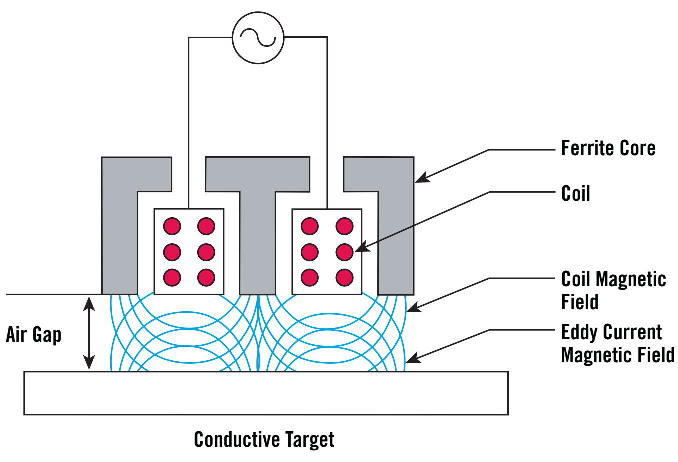


Figure 1

Starting with the probe face offset from the target approximately 10% of total range, the absolute value of the analog voltage output of the drive electronics increases as the air gap increases. Typically, drive electronics have an output -2 to -14 VDC, which can be offset to positive values using signal processing. By utilizing the linear portion of the output,

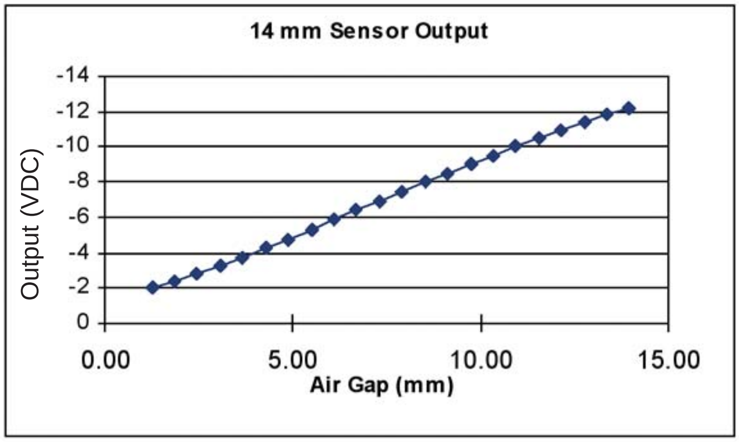


Figure 2

changes in air gap can be quickly determined. Figure 2 shows the typical output of a 14 mm range Eddy Current probe. Drive electronics are calibrated at the factory to achieve maximum linearity of the signal over a specified range. Non-linearity is typically specified as a percent of full range. For example, a 14 mm range probe with a specified non-linearity of ±1% FS will have a maximum signal output error of ±0.14 mm. Higher linearity can be achieved using signal processing techniques such as look-up tables. By creating a multi-point table of air gap vs. output voltage, signals received can be compared to the look-up table and a more exact air gap determined by performing a linear interpolation using the two closest points in the table. To extend the usable range beyond the factory calibrated range, more advanced data correction algorithms may be used, such as curve fitting with fifth order polynomials.

Parameters Affecting Measurement with Eddy Current Sensors

The application requirements determine the type of technology to be used for a specific measurement. Once the type of sensor is chosen, specific attention is required for those parameters that may influence the accuracy and reliability of the measurement.

Environment

One of the major advantages of using Eddy Current sensors is they are not affected by non-conductive materials in the sensor-to-target gap. This allows their use in dirty environments (dirt, water, oil, machine fluids), where other displacement sensor technologies fail. The presence of conductive materials near the sensor face can, however, distort the magnet field generated by the coil and Eddy Currents. To minimize the effect of nearby conductive materials, a shielded sensor tip should be used.

In addition, large temperature changes in the measurement area will induce errors. The impedance of the coil and target changes as temperature changes. The temperature-induced error can be overcome by applying compensation during signal processing. Special care should also be taken in probe mounting fixtures to limit the thermal expansion and contraction of all components in the measurement system.

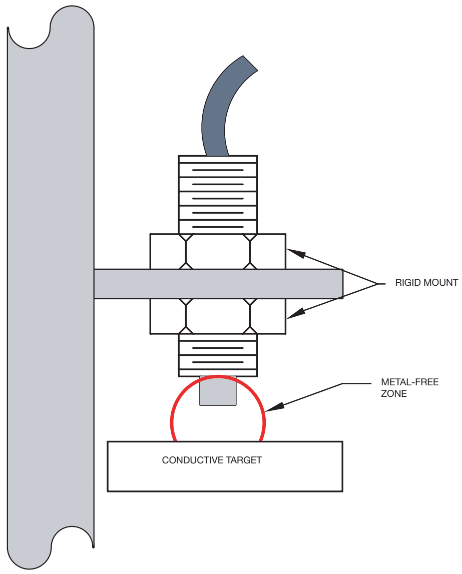
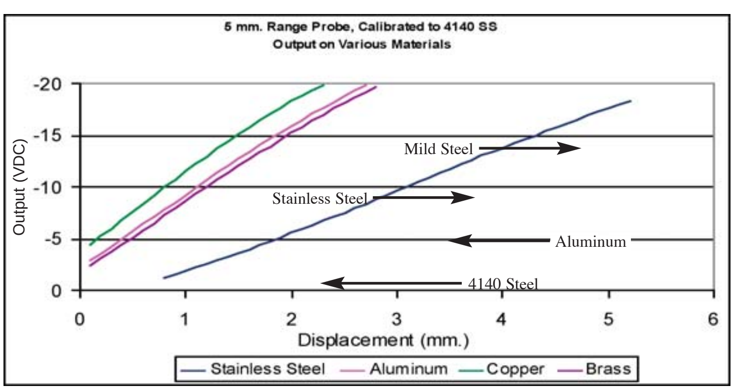


Figure 3

Target Material

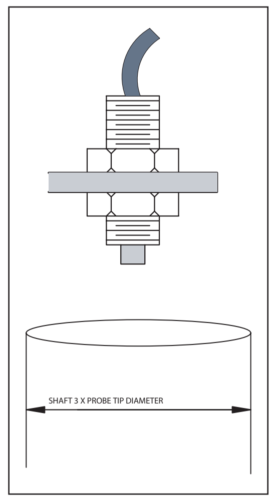
Use of Eddy Current displacement sensors requires that the target be electrically conductive. The magnitude of the coil impedance change is directly influenced by the resistivity and magnetic permeability of the target material. Ideally, the target is a non-ferrous, low-resistance material such as copper, aluminum or brass; however, ferrous material targets can be used. Systems are calibrated at the factory in accordance to API 670, which specifies 4140 steel for the target material. For maximum range and accuracy, target materials



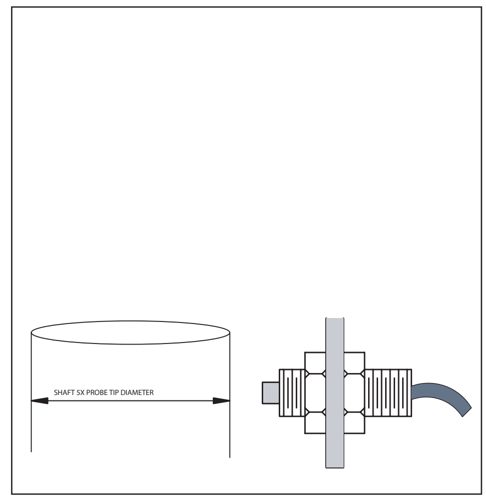
with similar electrical resistivity and magnetic permeability of 4140 should be used. Factory calibrations can be done for other conductive materials; however, the absolute range and linearity may be adversely affected.

Target Size

It is important to consider the target size and shape when selecting an Eddy Current probe. The coil emits a toroidal magnetic field that is approximately three (3) times the diameter of the coil; therefore, the target size should be at least three (3) times the probe tip diameter. Target thickness must be at least one (1) mm. When measuring shaft radial run-out, the curved surface of the target will distort the magnetic field and limit the full scale range of the system. See Figure 4 A&B below.



Axial Run-out
Figure 4A



Radial Run-out
Figure 4B

Summary

Non-contact displacement measurement is an integral part of any production environment. Selecting and deploying the correct measurement technology is critical to successfully monitoring each phase of a production process. Eddy Current sensors offer a low-cost, high-accuracy solution for many common displacement measurements. Understanding the principles of Eddy Current probe operation and the parameters affecting their performance ensures that the process engineer is gathering accurate and reliable data.

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