Design and Development of Automated & Programmable Testing Rig for Sensor Characterization

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***Abstract*—The aim of this research is to design and develop proximity sensor characterization testing rig for industrial preventive maintenance application and academic laboratory application. A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact. Popular proximitysensor types include inductive, capacitive, photoelectric, magnetic and ultrasonic. Proximity sensors often are employed in manufacturing industries in which the Sensors are exposed to harsh environmental conditions. By way of example, proximity sensors are utilized in conjunction with robotic welding to sense the position of work pieces and/or robot components during welding processes. The welding environment subjects the sensor to abrasion, chemical exposure, intense heat, and scorching particles that cause slag build-up. The environmental effects cause the sensor to deteriorate rapidly and eventually fail. In order to prevent problems before they occur, many industries have come to rely on preventative maintenance - minimizing unexpected downtime by performing inspections, parts replacement, and other maintenance activities, at predetermined intervals. The proposed testing rig called APTR (Automated & Programmable Testing Rig) can be used in industry as a preventive maintenance sensor test rig to test a field sensor for its characteristics changes due to exposed to harsh environmental conditions and it is repaired or replaced if their characteristics are deviation than recommended range. The proposed APTR can be used in academic learning application to understand proximity sensor characteristicsin detail. APTR is a testing device and precisely measuring proximitysensor longitudinal & transverse sensing distance, reduction factor, hysteresis, switching frequency application like measurement of motor speed and results are stored, processed and displayed using PLC and HMI or Webserver.APTR can test inductive, capacitive, magnetic, photoelectric and ultrasonic sensor whose sensing range less than 400mm. The present research focuses on the characterization of inductive sensor and can be extended to other above mentioned sensors in the future scope.**

Keywords—automation, static characteristics, inductive sensor, sensing distance, reduction factor, hysteresis, switching frequency, PLC, HMI and Webserver.

I. INTRODUCTION

Various types of proximity sensors are used for detecting the presence or absence of an object. Common types of non-contact proximity sensors include inductive proximity sensors, magnetic sensor, capacitive proximity sensors, ultrasonic proximity sensors, and photoelectric sensors. Such sensors, for example, may be used in motion or position applications, conveyor system control applications, process control applications, robotic welding applications, machine control applications, liquid level detection applications, selecting and, counting applications, as well as other known applications.

Proximity sensors often are employed in manufacturing industries in which the sensors are exposed to harsh environmental conditions. By way of example, proximity sensors are utilized in conjunction with robotic welding to sense the position of work pieces and/or robot components during welding processes. The welding environment subjects the sensor to abrasion, chemical exposure, intense heat, and scorching particles that cause slag build-up. The environmental effects cause the sensor to deteriorate rapidly and eventually fail.

A proximity sensor is a well-known device that maybe used in a system for detecting the presence of a metallic target within a threshold distance from the sensor.

A proximity sensor has complex impedance and is electrically equivalent to an inductor in series with a small resistor. Such proximity sensors are often referred to as "variable reluctance' devices because the presence of the metallic target in close proximity to a sensor inductively varies the sensor impedance. This variation in sensor impedance can be sensed by electronic circuitry, which can thus provide an indication of the presence or absence of the target in close proximity to the sensor. Because most such sensors have two leads for connecting the sensor to the electronic circuitry, they are known as "two-wire' sensors. Some proximity sensors, however, include a third lead that allows the electronic circuitry to compensate for the resistance of the wires connected to the other two leads. Such sensors are known as "three-wire' sensors. Proximity sensors are commonly used aboard aircraft to detect

II. EXPERIMENTAL SET-UP FOR TESTING PROXIMITY SENSOR

A testing set-up called APTR is shown in figure 1.Test programs to test sensing distance, reduction factor, hysteresis and switching frequency application like motor speed of field inductive sensor (FS) are stored in PLC using PC Ethernet communication. Six different standard target materials (MT) of dimension 40x20x1mm are preloaded in the indexing unit and it controlled by indexing motor (IM). By selecting a specific program (sensing distance or reduction factor or hysteresis or switching frequency application like motor speed) from local HMI screen or global webserver screen, APTR initiates testing field/target sensor to be tested.In all test procedure, metal targets are brought close to sensor using motor controlled linear guide(LGM) and record the actual position when field/target sensor is ON/ OFF with the help of high precision draw wire sensor (feedback sensor). High precision feedback sensor (HPFS) output range is 0-5v. Sensing range of APTR is 400mm.

whether a mechanical device, such as a cargo door, landing gear, control surface, or thrust reverser, is properly positioned. The electronic circuitry may be connected to a status light in the cockpit to provide the pilot with an indication of the position of the mechanical device

Practitioners have developed methods for testing proximity sensors, such as measuring sensor resistance, to isolate the cause of sensor problems. However, the rigging gap is often difficult or impossible to measure because the sensor and target may be inaccessible when the mechanical structures in which they are installed are in close proximity, such as when a cargo door is in the closed position. Moreover, the target issometimes completely embedded in the structure where it is not only inaccessible but also hidden from view. Therefore a test rig proposed to test sensor characteristics on target material specific and reduce field problems

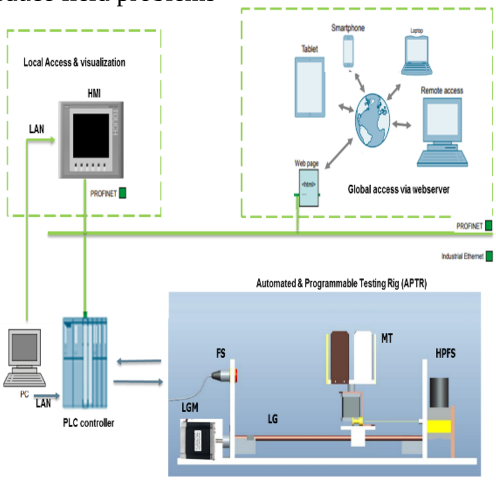

Fig. 1: Diagrammatic illustration of Automated & programmable testing rig (APTR)

III. CALIBRATION OF APTR

Step 01:Reference value of measurement is equal to the value of high precision feedback sensor (HPFS) sensor when there is zero gap between field sensorand metal targets. Therefore its value called$f(refernce\ position)\ or$ $f(Maximum)\ or$ at f(reference) is 294mm using external measuring scale.

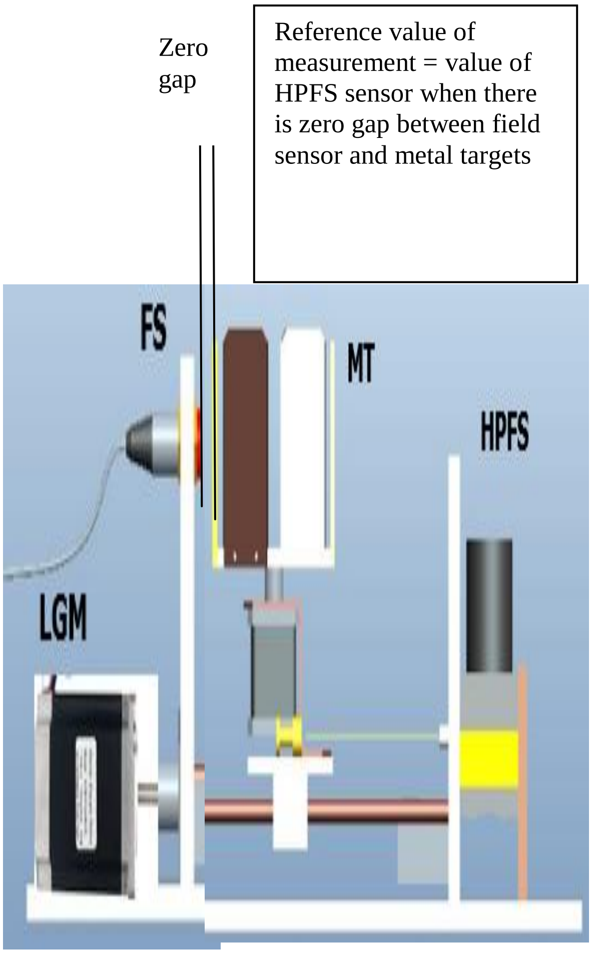

Fig. 2: Diagrammatic illustration of Automated & programmable testing rig (APTR) at zero gap between metallic target and sensing face of sensor.

Step02:To define the measuring range, select any second point called as minimum point but not the point where HPFS is zero. Therefore its value called$f(min)$ or $f(137)$ or $f(a) = 0.5865volts$. Measuring range of APTR is now defined between f (reference) and f (min). Length of stretch of HPFS at f (min) is 137mm using external measuring scale.

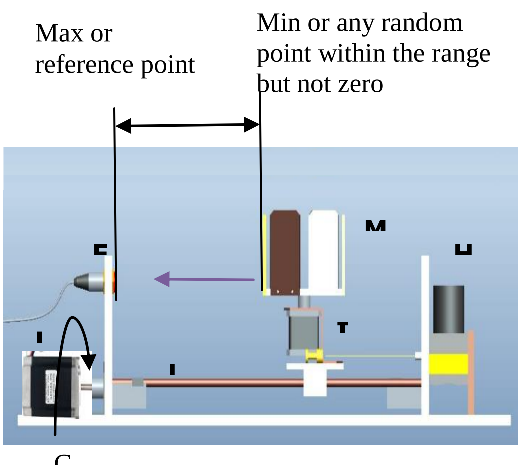

Fig. 3: Diagrammatic illustration of Automated & programmable testing rig (APTR) at random pint to create measuring gap

Step03:To find the value of in between the range [a, b] at x, for a continuous function following equation is used.

$$x = \frac{(b-a)(f(x)-\min)}{(max-\min)} + a$$

For example, if$f(x) = 1.441volts$, then

$$x = \frac{(294-137)(1.441-0.5865)}{(1.497-0.5865)} + 137$$

x = 172.432$(1.441 - 0.5865) + 137$

x = 284.343mm

Sensing gap = reference value – x
= 294 – 284.343 = 9.656mm

IV. TESTING SEQUENCE FOR MEASURING SENSING DISTANCE OF PROXIMITY SENSOR

Step01:By selecting a sensing distance test program from HMI or webserver, PLC sends signal to linear guide motor to rotate in clockwise direction and linear guide which carries indexing unit with metal targets moves towards the inductive field sensor(FS) for the measurement of sensing gap/distance.

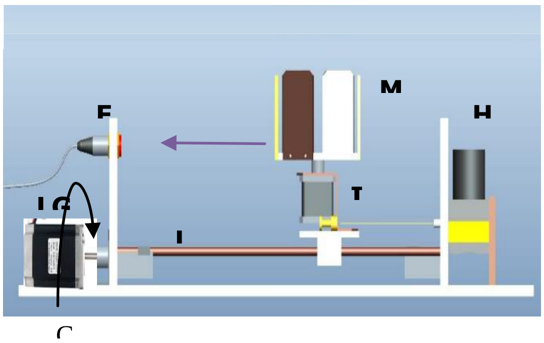

Fig. 4: Diagrammatic illustration of Automated & programmable testing rig (APTR) moving towards sensor for measurement.

Step 02:PLC sends signal to linear guide motor to stop its rotation when inductive field sensor is at ON condition as per the program. Sensing gap is measured using high precision feedback position sensor and it is displayed in HMI screen.

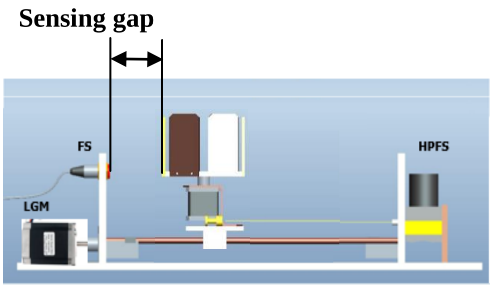

Fig. 5: Diagrammatic illustration of Automated & programmable testing rig (APTR) showing sensing gap or distance

Step 03:After measurement of sensing gap/distance, PLC will send signal to linear guide motor to rotate in counter clockwise direction to reach its reference position (home position)

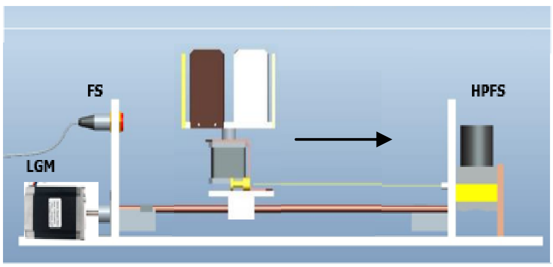

Fig. 6: Diagrammatic illustration of Automated & programmable testing rig (APTR) moving to reference position after measurements.

V. SIGNAL FLOW DIAGRAM (SFD)

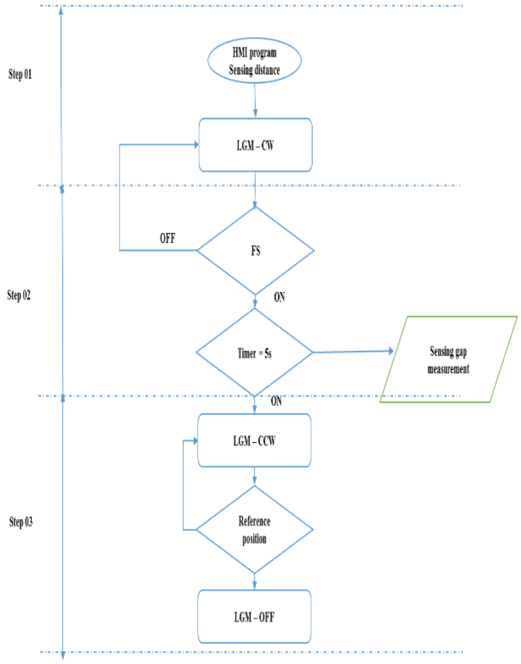

Fig. 7: Signal flow diagram for sensing distance PLC program.

VI. RESULTS AND DISCUSSION

Sensing distance depends on the following.

- Target material type with reference to standard material
- Target material dimensions with reference to standard material dimension.
- Thickness of the target material.
- Target material moving direction.
- Ambient conditions.

Table 1.1: Standard data and measured data.

SL No	Sensor characteristics	Sensor Manufacturer catalogue data before use in application	APTR measured values
1	Maximum Sensing distance	8mm	7.6mm
2	Reduction factor for Aluminum material	0.5	0.45
3	Reduction factor for copper material	0.4	0.4
4	Hysteresis	Typically 5%	8%

In this research paper, changes of sensing distance with respect to changes in target material type is measured and plotted. This property is called reduction factor.

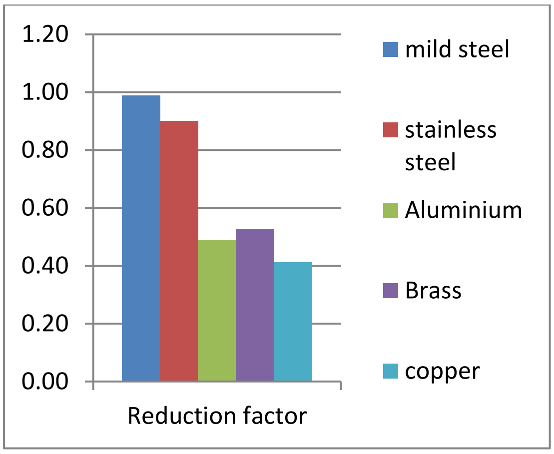

Fig. 8: Reduction factor for different metallic targets.

Based on figure 7.1, sensing distance of inductive proximity sensor reduces for metallic material other than steel or standard target materials. This is due to the fact that permeability of materials are not same for all materials.

By selecting a reduction factor PLC program from HMI or webserver, APTR checks for sensing distance or gap for each materials which are loaded in indexing unit and test results are stored in PLC. Test results can be accessed locally using HMI or global access using webserver internet communication.

VII. CONCLUSION

In summary, characteristics of proximity sensor changes by using especially by exposing to harsh environments like high temperature and pressure as shown in table 1.1.The proposed experimental setup called APTR help in testing above sensor characteristics and indicates deviation from standard values to take corrective action as a part of preventive maintenance in industrial applications.

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