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Survey on Sensors in an Industrial Application

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***Abstract*-This paper proposes the more information about different types of sensors with its application in diverse environments. Nowadays, sensors are standalone in wireless technologies for monitoring the changes physically of the equipment or environment. There are various types of sensors available depends on the purpose and usage of it. These sensors are ease of use, ease deployment capacity, and low cost with limits on the size. Thus, few types of sensors have been discussed in this paper.**

Keywords: Types of sensors, Sensors, Temperature sensors, Displacement sensors.

I. INTRODUCTION

Sensors are nothing but it is used for sensing or monitoring the physical changes and atmospheric changes in the different environments. These sensors convert the physical quantity into a signal which can read by an observer or an instrument. Generally, sensors are used to monitor the fire, sound, temperature, displacement, humidity, pressure, acceleration, etc. We can store this sensing output for the future actions. The sensing output will show to the observer by using LCD display, computer, or any other display system. These sensors are said to be as transducers. Transducers are defined as that converts the non electrical quantity into electrical quantity. There are a number of sensors like transducers introduced in the market for commercial and industrial purpose. In the industrial application, to monitor the unexpected firing, temperature, pressure, displacement occurrence and acceleration in the machine can be done by using sensors. Plenty of sensors are produced by the manufacturers on the basis of user requirements. By characterizing the parameters of each sensor, we picked out the correct one which suit for our application.

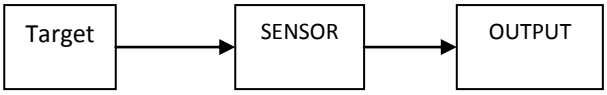

Fig. 1. Sensor setup

II. CLASSIFICATION OF SENSORS

Specialized sensors are used for monitoring the regular features of equipments or environments. In industrial basis, the physical changes in equipments can affect the operation process of the company and as well as environmental changes or atmospheric changes also affect the regular process of industries. Commonly, manpower is not preferred to monitor the fault of machine, it is not possible too. Based on this, transducers like sensors are required for monitoring purpose in industrial applications, not just in industries it is also helpful in commercial environments such as school, colleges, offices, buildings in the way of preventing from unexpected accidents. But it plays an important role in industries, helps to prevent from huge damage or fault losses; it's used under the basis of prevention process. There are a number of sensors available for monitoring the temperature and displacement.

III. DISPLACEMENT SENSORS / POSITION SENSORS

For monitoring the displacement of conveyors or shuttles, these displacement sensors are employed. As same like that, to sensing the nearby objects can also be done by using the displacement sensor. The characterization of displacement sensors such as LVDT, Proximity sensor, Eddy current sensor, Resistive position sensor, and Capacitive sensor has been discussed in the following. These sensors are helpful to find the position of objects also.

TABLE 1. DIFFERENT TYPES OF SENSORS

SENSORS	TYPES	PURPOSE
Temperature sensor	Thermistor Thermocouple RTD's LM 35	Sense / monitor the temperature
Pressure sensor	Fibre optics Vacuum Elastic liquid based manometer	To measure the level of liquid / position sensing
Displacement sensor	LVDT Photoelectric Capacitive Magnetic Ultrasonic Resistive Accelerometer	To measure the displacement / acceleration of conveyor such as.
Gas & Chemical sensor	Semiconductor Infrared Conductance Electrochemical	To sense / monitor the gas or chemical substances leakage

A. Linear Variable Differential Transformer (LVDT)

LVDT is a type of electrical transformer used for measuring linear displacement (position). It converts the rectilinear motion of an object into electrical signals. It measures the displacement of material. It gives an accurate and reliable for measuring linear distance. The output of the LVDT is proportional to the position of movable magnetic core, suitable for non contact type measuring, its operating frequency range is from 1 to 10 KHz, and measuring range of this sensor is from 0.01 to 24 inches.

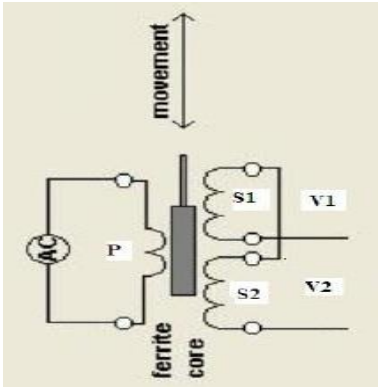

Fig. 2: LVDT operation

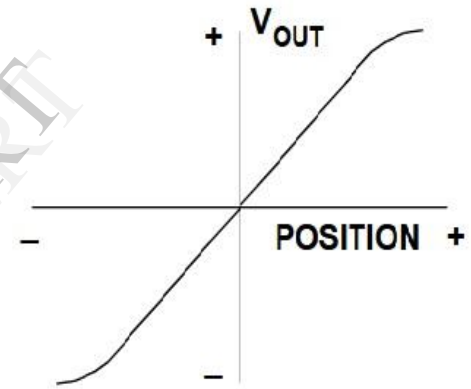

Fig. 3: Output signal of LVDT

LVDT consists basically of a primary coil and two secondary windings, wound over a hollow tubular, and positioned so that the primary is between two of its secondary. i.e., the primary is placed between two secondary. When an AC excitation signal is applied to the primary, the voltages induced in the secondary. Therefore, the output voltage is proportional to the position of movable magnetic core; the output is taken under the three different cases.

Case i: When core at the centre of the primary and secondary coil, the output voltage of V_1 and V_2 is equal.

$$\therefore Vout = 0 \qquad -----(1)$$

Case ii: When core move towards S_1, the voltage in V_1 is greater than V_2, then the output voltage increases.

$$\therefore V1 > V2, Vout\ increases \quad ----(2)$$

Case iii: When core move towards S2, the voltage in V1 is lesser than V1, then the output voltage decreases.

$$\therefore V1 < V2, Vout\ decreases \quad ----(3)$$

There is a variety of LVDT applicable; a few of them are DC operated, AC operated, and armature. DC operated type are ease of installation, it can operate with dry cell batteries with lower system cost. Comparing with DC operated type, AC operated type is smaller and it has been given more accurate output even operate at high temperatures. Armature type is split into three divisions. Unguided armature is fit loosely in frictionless movement with high speed application for short range measurements. Captive armature is used in low friction movements for a longer measuring range. Spring extended armature is used in low friction machine, but it maintains reliable contact with the body to be measured and suitable for static slow moving applications. The primary advantages of LVDT are, it has limited noise, low risk of damage, longer duration, but it is the more expensive one comparing to other types. Application areas of LVDT are power turbines, hydraulics, automation, aircraft, satellite, nuclear reactor and automation machinery etc.

B. Proximity Sensor

Proximity sensors are able to detect the pressure of the nearby object without any physical contact i.e., it performing the non detection with any metal object. By emitting the electromagnetic radiation or electromagnetic fields and depends the changes occurring in the return signal, then the output will be generated as an electrical signal.

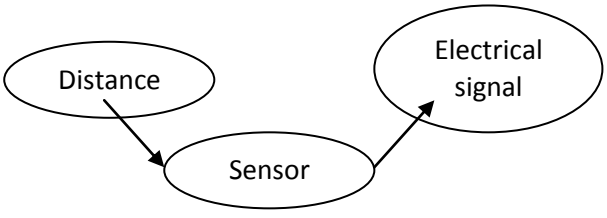

Fig. 4: Sensor connection

A proximity sensor consists of oscillator circuit, amplitude detecting circuit and output circuit as inbuilt in it. A high frequency magnetic field is generated by coil L in the oscillator circuit. When a target approaches the magnetic field, the induction current flow increases in target due to electromagnetic induction. This causes increase the loads on the oscillator circuit, then the sensor detects the change in the oscillation status with the amplitude detecting circuit and gives the detecting electrical signal as outputs. It is also used to measure a relative distance.

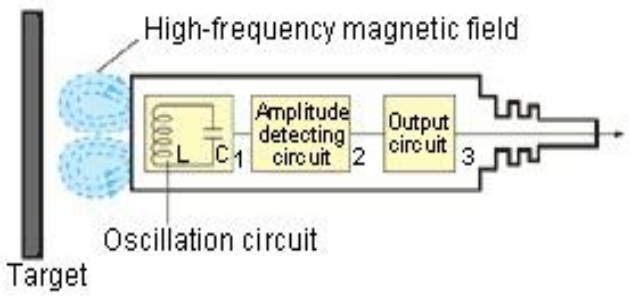

Fig. 5: Proximity operation

There are few types of proximity sensors which including inductive, capacitive, resistive, infrared and sonar. These proximity sensors are advantageous in fast response, not sensitive to material changes with higher resolution, but it has the drawbacks of, its senses slower than other sensors and not well in dirty or wet environments. It is used in the applications of metal detectors, traffic lights, level detectors. For example., used as level detectors in water tank, oil tank, etc., to prevent the accidents between two cars using the warning system by proximity sensor and used as object detectors in latest mobiles etc.

C. Accelerometer

An accelerometer is a device that same as sensors used to measures proper acceleration, as well as used for analysis of velocity and displacement. It has multiple applications in industry and science. Accelerometers are used to detect and monitor vibration in rotating machinery. Single and multi axis models of accelerometer are available to detect magnitude and direction of the proper acceleration and can be used to sense orientation, vibration, shock. Micromachined accelerometers are increasingly present in portable electronic devices and video game controllers, to detect the position of the device. In commercial devices, piezoelectric, piezoresistive and capacitive accelerometers are commonly used to convert the mechanical motion into an electrical signal. Modern accelerometers are often small micro electro mechanical systems (MEMS). The application of accelerometers in the different fields such as engineering (to measure vehicle acceleration, vibration, seismic activity, inclination, dynamic distance and speed, gravity), biology, industry (condition monitoring), building and structural

monitoring, medical applications, navigation, transport, volcanology (remote sensing device).

There are different types of accelerometers available such as Capacitive, Piezoelectric, Piezoresistive, Hall Effect and Magnetoresistve (MR). Piezoelectric accelerometer works on the basis of piezoelectric effect, the material such as crystals which generate electric potential from an applied stress. This is known as Piezoelectric effect. When stress is applied between the two piezoelectric crystal, an electric charge is created. i.e., the charge is proportional to the acceleration, even it works in high temperature environment. Piezoresistive accelerometer is defined as that measuring the electrical resistance of a material by applying the mechanical stress. It gives the output as voltage beneath the operation of voltage divider. Hall Effect sensors are measuring the voltage variation with the change in magnetic field during acceleration. Magnetoresistive (MR) accelerometer measure the change in resistance due to the magnetic field. The function and operation of both the hall effect and magnetoresistive accelerometers are same, instead of measuring voltage in Hall effect sensor measures the resistance in magnetoresistive type.

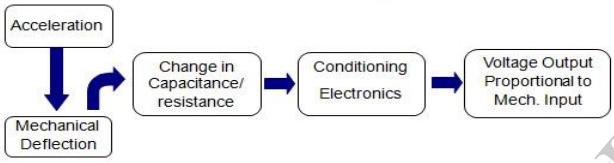

Fig.6. Acceleration measurement

Three main types of Magnetoresistive sensors are namely Anisotropic MR (exhibits larger MR effect), Ordinary MR (exhibits weaker MR effect), and Giant MR (nanostructured and multilayered device). MR accelerometers are not suitable for noisy environment and reduce detectivity in low frequency, but comparing with Hall Effect sensors, it has high sensitivity. Fibre optic accelerometer work by measuring the change in gathering amount of reflecting light by receivers with applied the light on the acceleration area. Although, it operates in high temperature, but interference occur in noisy environment. Capacitive accelerometer senses a change in electrical capacitance with respect to acceleration. It consists of two capacitive electrodes plates which placing on the either side of the moving element. By applying the electric field to one of the plates, then the charge is induced between the two plates. When the plates move closer to each other, capacitance between two plates increases and capacitance increases with increasing gap between the plates. It is non contact device having the capable of high resolution measurement of the position and change in position of nonconductive target. It is used in a wide variety of applications such as precision positioning, non-conductive targets, machine tool metrology, assembly line testing etc.

IV. TEMPERATURE SENSORS

Measurement of temperature is critical in modern electronic portable and mechanical devices. Knowledge of system temperature can also be used to control the over heat dissipation as well as prevent damage to expensive portable devices and instruments. Accurate temperature measurements are required in many other measurement systems such as process control and instrumentation applications. The measurement of temperature is important in many different applications, such as, building steel and petrochemical, as well as requires in different physical construction and often different technology. Temperature is changing by variation occurs in heat, heat is a measure of energy contained in a body due to the irregular motion of its molecules or atoms, temperature variation in the mechanical parts due to the improper lubrication at industrial application. In industrial and commercial applications, the measurement point is frequently far away from the indication or control point. Such applications are unsuitable for using direct indicating thermometers it requires devices which convert temperature into another form, an electrical signal. To provide this remote electrical signal, employ the temperature sensors like RTD's, thermistors, thermocouples and LM35. These sensors have the ability to measure temperature through sensing in diverse environments.

A. Thermocouples

A thermocouple is a temperature sensitive device which works on the basis of Seeback effect. Seeback effect is defined as that a voltage is generated in a circuit containing two different metals by keeping between them at different temperatures.

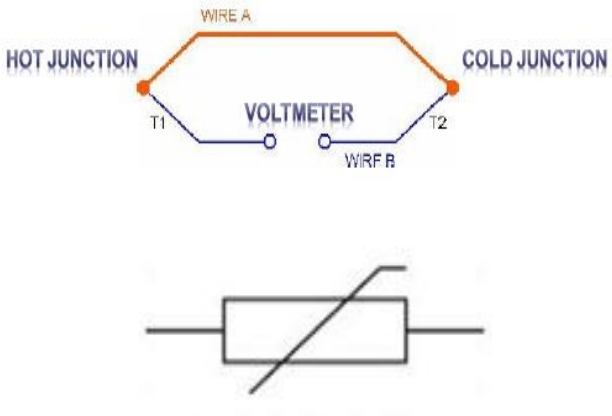

Fig.8: Thermistor symbol

temperature, they are called as negative temperature coefficient (NTC).

The resistance measurement is given by an equation,

Fig. 7: Thermocouple function

It consists of two junctions namely cold junction and hot junction, the voltage developed between these two junctions is called Seeback voltage. The voltage generated by the thermocouple is given by the equation.

$$V = S * \Delta T \qquad ----(4)$$

where, V=voltage measured (V), S=seeback coefficient (V/°C) and ΔT=difference in temperature between two junctions.

There are different types of thermocouples used depends on the junction containing metals, namely type K (chromel-alume), type J (iron-constantan), type E (chromel-constantan), type N (nicros-nisil) and type T (copper-constantan). Selection of right thermocouple is based on the range of measuring temperature. It is important to note that these thermocouples differentiate the temperature between two junction points, not measuring the absolute temperature. It is suitable for measuring the large difference in temperature, not for smaller temperature variations.

B. Thermistor

Thermistor is referred as thermal resistors; a mixture of different semiconductor metal oxides is used for manufacturing of thermistor. It works on the basis of the resistance that changes with temperature, (i.e., resistance decreases with increasing temperature). Because of the resistance characteristic falls off with increasing increasing

where R_t=resistance at temperature t, R_0=resistance at standard temperature t_0, and α=temperature coefficient of resistance (°/C).

Because of the resistance characteristic increases with temperature, this is called as positive temperature coefficient (PTC). RTDs are the most accurate sensors for industrial applications. The output voltage of RTD is larger compared to thermocouple. These RTDs are used in some applications such as, precision process temperature control, and used directly in recorders, transmitters and digital ohm meters.

D. LM 35

LM 35 is used as temperature sensor to sense the temperature. It will sense the temperature in its environment, the advantage of this sensor has more memory, processing, and communication capabilities than other sensor. It possesses own amplifier to change the temperature value

$$R = R\theta * e^{b\left[\frac{1}{T}-\frac{1}{T0}\right]} \qquad ----(5)$$

where R=resistance at temperature T (deg kelvin), R_0=resistance at reference temperature T_0 (deg kelvin) and b=calibration constant (deg kelvin).

Thermistor can be used as a liquid level indicator and to measure temperature in different applications such as, consumer electronics, automotive, medical electronics, industrial electronics, military and aerospace, food handling and processing.

C. RTD

RTD (Resistance Temperature Detectors) is also resistance thermometers, temperature sensors that exploit the predictable changes in electrical resistance linearly with temperature. These are manufactured from metals whose resistance increases with temperature. It requires current excitation to produce an output voltage.

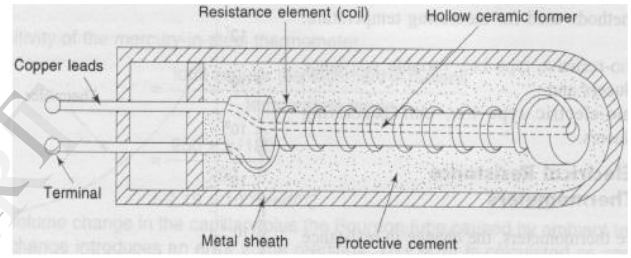

Fig. 9: RTD sensor

The resistivity increases linearly with temperature is given by the equation,

$$R_t = R_0[1 + \alpha(t - t_0)] \qquad ----(6)$$

(Celsius) into output voltage; it is a precision integrated circuit temperature sensor. It does not require any external calibration to maintain the accuracy of +/-0.4°C at room temperature and +/-0.8°C over a range of 0°C to 100°C. For each degree Celsius change in temperature will changes the sensor output by 10mV. Its temperature measurement range is -55°C to +150°C and operates over -55°C to +150°C. The output of the sensor changes from 0 to 1000mV. It has a sensitivity of 10mV/°C and less self heating capacity, so it works well in harsh environment. The voltmeter is used to measure the output voltage which is proportional to temperature Celsius.

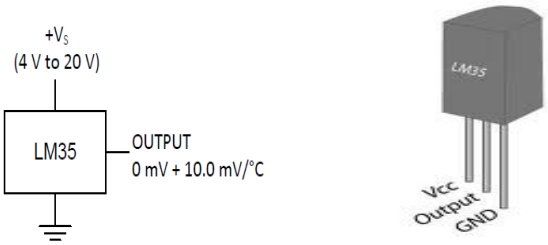

Fig.10. LM35 temperature sensor

The output voltage is converted to temperature value (°C) by using simple conversion factor.

$$Temperature\ (℃) = Vout * (100℃/v) \quad ----(7)$$

TABLE 2. DIFFERENT TYPES OF DISPLACEMENT SENSORS

Displacement sensors	Operating voltage	Operating Frequency	Measuring range	Application
LVDT (Linear Variable Differential Transformer)	1 to 24V	1– 10KHz	0.01–24 inches	Modern machine tool, robotics, avionics, Computerized manufacturing
Proximity sensor	10 – 30V	5 –300 Hz	0 – 4 mm	Touch screen, potentiometer, level detectors, metal detectors, automatic car wash
Accelerometer	2.2–3.6 V	1–10 KHz		Motion sensing in robotics, gaming, pedometer, image stability in cell phone, tilt sensing

TABLE 3. COMPARISON OF DIFFERENT TYPES OF TEMPERATURE SENSORS

Temperature sensor	Cost	Temperature range	Stability	Accuracy	Sensitivity
Thermocouple	Low	Very wide	Fair	Medium	Low
Thermistor	Low	Medium	Poor	Medium	Very high
RTD	High	Wide	Good	High	Medium
LM 35	Low	Low	Good	High	High

CONCLUSION

This survey report has been discussed about the few types of displacement and temperature sensors. The characteristics, applications and limitations of those sensors also mentioned. With this, the type of sensors, the conversion factors of temperature values were explained. It will helpful for the selection of right sensors.

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