TO INVESTIGATE THE EFFECT OF OPERATING PARAMETERS ON INDUCED EMF OF THERMOCOUPLE

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Abstract— *Thermocouple is a basic types of temperature measuring sensors, which measure the temperature by sensing some change in physical characteristic.it has been widely used due to its unique technical advantage. In the present study an attempt has been made to investigate the effect of various operating parameters such as Temperature, wire diameter and exposed length, on the induced EMF by thermocouple. In the present study, it has been proposed to prepare the thermocouple using Copper-constantan. These prepared thermocouples are further assessed with regards to its accuracy and calibrated using laboratory developed set up. Furthermore an attempt has been made to investigate the effect of various parameters on the induced emf by these thermocouples were investigated. To carry out experimental work statistical software Minitab 17v has been used. To assess the effect of various parameters such as temperature, wire diameter and exposed length on the response variable proper interaction of various parameters were carried out using Design of experiments technique based on the Taguchi L9 approach. Based on the design of experiment, an interaction of the various parameters were carried out. Response variable in terms of induced EMF for all the materials were observed with all the conditions as proposed by design of experiment. To further assess the interaction and the result obtained by experimentation Taguchi analysis was carried out on the result obtained from the experimentation. It was observed that the temperature is a significant parameters which effects the induced emf followed by wire diameter and exposed length.*

Keywords— Thermocouple; Taguchi approach; Sensors; Temperature

1. INTRODUCTION

Temperature is an important factor that should be taken into account in the majority of energy exchange processes, thermometers are instruments specifically designed to measure temperature, there is a wide variety of thermometers today and their operating principles are equally extensive [1]. The thermometers are the instruments that are used for temperature measurement, a type of them, contact thermometers, should be placed in physical contact in the middle of the medium from which you want to know the temperature[2-3]. The thermocouples are mostly used in modern power generation industry, Kiln industry, Gasoline, Boiler based plants, Furnaces, Gas turbine exhaust and other industrial processes etc., are to be used for the testing purpose [1-8]. The thermocouple is made up off two different wires with varied dimensions Thermocouples are a type of contact temperature gauges; they are widely used in the industrial branch due to their capacity of measuring a wide range of temperatures, their reliability, easy operation and the possibility of registration of the measurement automatically [5]. A thermocouple is composed of two conducting wires made of different material; these cables have a point in common. This union works as measuring point (sensing joint), which comes in contact with the medium in which you want to determine the temperature, at the other end, wires are connected to an electronic circuit that delivers a reference voltage (the voltage is usually associated with a temperature of 0 °C). When thermocouple wires are subjected to a difference in temperature between the measuring joint and the end connected to the reference circuit, there is a potential difference based on the change of temperatures (Seebeck effect) [6,9-10]. The commercial cost of these devices is high, although the material to build them is usually inexpensive; the cost of the commercial product rises considerably, up to eight times[11-15].

In the present work an attempt has been made to prepare the thermocouples based on three materials such as Copper-constantan, Chromel-constantan and Iron-Constantan using laboratory developed set up for preparation and calibration of thermocouple. Furthermore the objective of this work is to present the effect of variation in the operating parameters of the thermocouples on the induced EMF. Experimentation was further carried out on the basis of Taguchi L9 approach. Further to assess the effect of various parameters on thermocouple Taguchi analysis was carried using Minitab 17V software.

2. MANUFACTURE OF THERMOCOUPLE

The thermocouple manufacturing was carried out with the help of two wires were which were selected out from a section of 0.30 m length, Out of it 0.005 m of the insulation material is removed from the end of wires and common junction was prepared among them with the help of mercury which is used for sensing the temperature. For preparation of the junction, one end of the two wires were connected with the variac and another end of the wires was dipped in the mercury for very short span of time simultaneously, with the help of variac voltage supply is increased upto 130 Volts which helps in making a joint which senses the temperature. The thermocouple was withdrawn from the device making sure that the molten tip was perfect, i.e. that a small ball with both wires, free of

any kind of fracture, had been formed wires was dipped in the mercury for very short span of time simultaneously

3. EXPERIMENTAL SET-UP

Fig.1.Working set up for thermocouple preparation and calibration

In the thermocouple preparation and calibration set up various instruments such as Variac, Voltmeter, Digital Temperature indicator, mercury and A.C supply are used. To prepare the thermocouple wires of different materials were prepared on the range of parameters as depicted by using Taguchi L9 approach.By using variac junction for sensing the temperature was prepared as already discussed in upper section.Further more, digital temperature indicator and voltmeter is used to measure the response parameter in terms of EMF induced as shown in Fig. 1.

4. EXPERIMENTAL DESIGN

The equations are an exception to the prescribed For design of experimentation Minitab software 17V was used. Design of Experiments (DOE) capabilities helps researchers to improve the processes. It is used to carry out the effective interaction of all the parameters taken for study. Taguchi approach was chosen for predicting the design of Experiments.

Experimentation is further carried out as per the run proposed by the Taguchi approach. Taguchi L9 approach was selected instead of conventional approach, in conventional approach 27 trial runs has to be carried out for analyzing the effect of various parameters, but in L9 approach nine experiments are sufficient for carrying out the testing.

TABLE 1. DIFFERENT PARAMETERS AND LEVELS TAKEN FOR THE PRESENT STUDY

S.No	Temperature (°C)	Wire Diameter (mm)	Exposed Length (mm)
1	0	0.5	1
2	50	1	3
3	100	2	5

In the present study, for proper interaction of various parameters in the study Taguchi Approach has been used. Table 2 shows the design of experimentation using L9 orthogonal array .

5. EXPERIMENTATION

In this work thermocouple prepared from three materials were selected for investigation Copper-constantan, Chromel-constantan and Iron-constantan. The different parameters and the levels which were taken for present study are described in Table No.1 . In this work, experimental variables such as Temperature, wire diameter and exposed length were considered for the study purposes. Effect of various parameters with respect to EMF induced was studied out. The interactons which were carried out for experimental investigation are presented in Table 2. In experimentation part firstly setup was prepared using variac and mercury for preparation of thermocouple from different materials. Further Digital temperature indicator was used to calibrate and check the accuracy of the thermocouple. In second part, to investigate the effect of operating parameters on the EMF induced in depth investigation was carried out.

6. RESULTS AND DISCUSSIONS

In this work thermocouple prepared from three materials were selected for investigation Copper-constantan, Chromel-constantan and Iron-constantan. The different parameters and the levels which were taken for present study are described in Table No.1 . In this work, experimental variables such as Temperature, wire diameter and exposed length were considered for the study purposes. Effect of various parameters with respect to EMF induced was studied out. The interactons which were carried out for experimental investigation are presented in Table 2. In experimentation part firstly setup was prepared using variac and mercury for preparation of thermocouple from different materials. Further Digital temperature indicator was used to calibrate and check the accuracy of the thermocouple. In second part, to investigate the effect of operating parameters on the EMF induced in depth investigation was carried out.

a. Effect of Temperature

To establish the relationship of temperature with the induced emf, the experiments were conducted by selecting the various parameters. Range of temperature (0°C, 50°C and 100°C) has been taken for comparative study. With respect to these parameters, study was carried out to find out the effect of range of parameter on emf induced. So that a relationship will be established which will able to predict the response of emf induced with respect to magnetic flux density. In this study, the three thermocouple materials named as copper-constantan, Chromel-constantan and Iron-constantan are taken for experimentation. It was observed that the EMF induced is more with the higher range of temperature as shown in Fig. 2. From the observation it is concluded that temperature is directly proportional to the emf induced.

b. Effect of wire Diameter

To establish the relationship of wire diameter with the induced emf, the experiments were conducted by selecting the various parameters. Range of wire (0.5mm, 1mm and 2mm) has been taken for comparative study. With respect to these parameters, study was carried out to find out the effect of range of parameter on emf induced. So that a relationship will be established which will able to predict the response of emf induced with respect to wire diameter. In this study, the three thermocouple materials named as copper-constantan, Chromel-constantan and Iron-constantan are taken for experimentation. It was observed

that the EMF induced is more with the medium range of wire diameter as shown in fig. 3. From the observation of copper-constantan and chromel-constantan Thermocouple, it is concluded that wire diameter is directly proportional to the emf induced upto certain limit after the critical value of wire diameter it started to decreases. But for iron-constantan thermocouple result had varied it increases upto 1mm and after that it started to decrease with further increase in wire diameter.

c. Effect of Exposed length

To establish the relationship of exposed wire length with the induced emf, the experiments were conducted by selecting the various parameters. Range of exposed wire length as (1mm, 3mm and 5mm) has been taken for comparative study. With respect to these parameters, study was carried out to find out the effect of range of parameter on emf induced. So that a relationship will be established which will able to predict the response of emf induced with respect to exposed wire length. In this study, the three thermocouple materials named as copper-constantan, Chromel-constantan and Iron-constantan are taken for experimentation. It was observed that the EMF induced increases for all the thermocouples , with the 1mm exposed wire length as shown in fig. 4. In case of copper-constantan and chromel-constantan thermocouple, it was noticed that with higher value of exposed length emf induced decreases.Similarly in case of iron-constantan thermocouple it decreases upto 3mm and after that it increases further with increase in value of exposed length

TABLE-2. DESIGN OF EXPERIMENT USING THE TAGUCHI APPROACH

Run No.	Temperature (°c)	Wire diameter (mm)	Exposed wire length (mm)
1	0	0.5	1
2	0	1.0	3
3	0	2.0	5
4	50	0.5	3
5	50	1.0	5
6	50	2.0	1
7	100	0.5	5
8	100	1.0	1
9	100	2.0	3

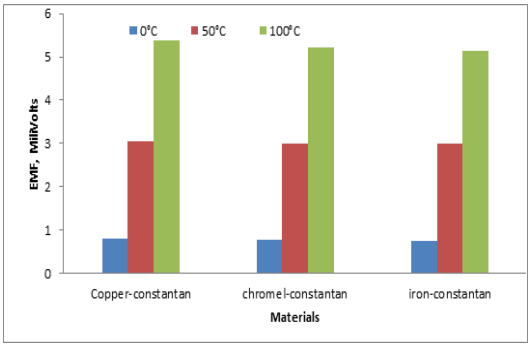

Fig. 2 Effect of change in temperature on EMF induced

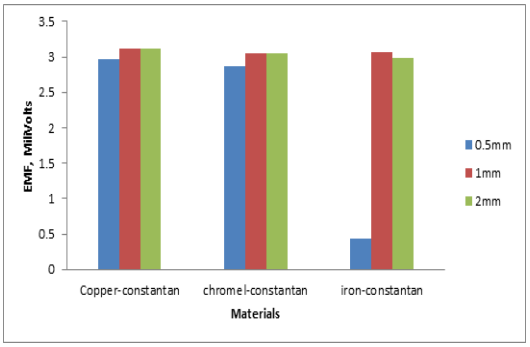

Fig. 3 Effect of Wire diameter on EMF induced

d. Main Effect plots

It has been depicted from the fig. 5-7, which shows that the prepared thermocouple is significantly affected with the temperature as seen in the figure, it is observed that increase in temperature causes S/N ratio to increase, it is maximum at temperature of 100°C.

In the main effect plot with respect to Wire Diameter, it has been observed that at 0.5mm SNR ratio is lesser, with further increase in diameter upto 1mm it increases SNR ratio but with further increase in value of wire diameter, i.e. 2mm, SNR started to decrease, it can be suggested that there is a critical value of wire diameter beyond which SNR ratio decrease.

Similarly for exposed wire length, it has been seen that in case of copper-constantan and Chromel constantan, SNR is higher at lower values of exposed wire length, i.e. 1mm, with further increase in value i.e. 3mm, it started to decrease and with further increment in the value upto 5mm it remains constant. This trend has been changed in case of Iron-constantan thermocouple. It decreases with increased in exposed wire length.

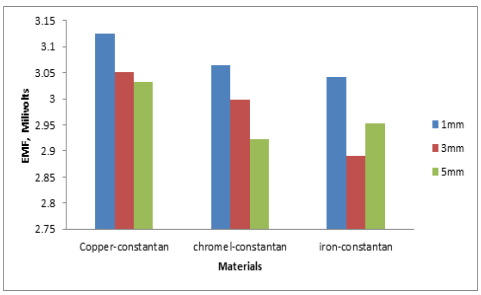

Fig. 4 Effect of Exposed wire length on EMF induced

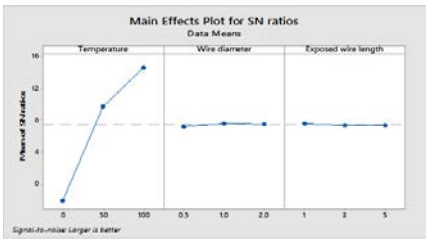

Fig. 5 Main effect plots for Copper-constantan Thermocouple

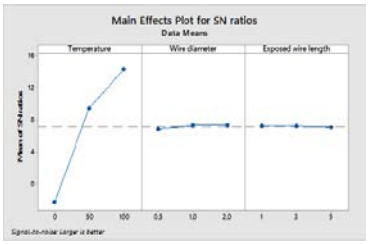

Fig. 6 Main effect plots for Chromel Constantan Thermocouple

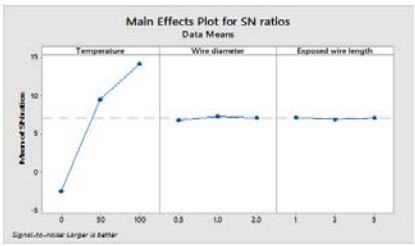

Fig. 7 Main effect plots for Iron Constantan

7. CONCLUSION

It was found that copper-constantan, chromel-constantan and iron-constantan Thermocouple can be prepared by laboratory developed set up. It gives the possibility of developing these thermocouples for application in various temperature measuring work.

It was found that the temperature around 100 °C gives the maximum induced emf for all thermocouple material used in the present study.

In case of wire diameter, it was observed that maximum induced emf is generated in medium range of wire diameter, with a further increase from this critical value it started to decrease the induced emf values.

In case of exposed length it was observed that with increase in exposed length, emf value started to decreases as seen in case of copper-constantan and chromel-constantan thermocouple. It was seen that trend changes in case of iron-constantan thermocouple, it decreases upto medium range but with further increase in value of exposed length emf increases.

It has been found that thermocouple used in present study for emf induced follows the below trend under all Runs:

Copper constantan > Chromel constantan > iron constantan

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