Comparison of Thermocouples in Knitted Structures

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Abstract*: Recent development in textiles has led the researchers to a variety of fabrics manufacturing. These developments includes spacer fabrics, embroidered fabrics, embedded sensors in fabrics, ECG vest and the series goes on, so much so electronic components are also being knitted within fabrics. The present work is one such effort, where an arrangement of thermocouple based upon Seebeck Effect has been formulated. Thermocouples were embedded into the main knitted structure so as it is a part of the main structure. The knitted fabric was tested against a variation of temperature; also variation in the material of thermocouple was tested. Promising Test results are presented in this article. After performing the tests it is also known that certain combinations of knitting material may result into positive and negative temperature coefficients of the fabric.*

Keywords: *knitted fabric, Seebeck Effect, technical textiles, thermocouple, temperature sensing.*

1. INTRODUCTION

A washable and reusable fabric has been developed, the earlier versions of it has emerged in the form of either embedded sensors or by a combination of embedded and printed electrodes[1,3,4]. These fabrics carry the advantages of individuality and adaptability to varying climatic conditions. These are also useful in conditions such as post operation, athletics, firefighting and law enforcement [2]. The fabric under consideration is developed by utilizing conducting yarns to act as basic Thermo Couple (TC) knitted arrangement. These TCs act as array of temperature sensing elements at each junction of knitting stitches. Therefore, it is capable of sensing temperatures variations in its vicinity or in the surface to which it is subjected. The fabric is in the knitted form, hence can easily be adjusted to become a part of any knitted structure. The two basic yarns which act as scaffold to knitted structure are having different enrichment metals doped into them. Therefore, when these yarns are incorporated in a knitted structure, they start acting as a loose form of a thermocouple junction. This suffices to the appearance of variation in impedance at the output terminals of the fabric. This variation in impedance is a function of change in temperature. The change can be linear or exponential, depending upon the choice of conducting yarns.

2. DESCRIPTION

Basic knitting stitches can be utilized in various combinations and beneficial ways. This can be done by using a variety of conducting and semi conducting material enriched filament yarns. In basic categories of flat bed knitting there exists weft and wharf knitting methods. Basic weft knitting stitches are shown in figure 1, whereas, figure 1(**A**) shows a tuck stitch within weft knit. This is the very stitch used for the realization of fabric under consideration.

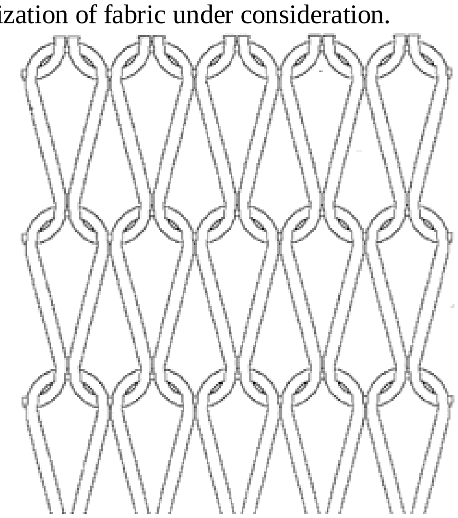

Figure 1. Basic weft knit.

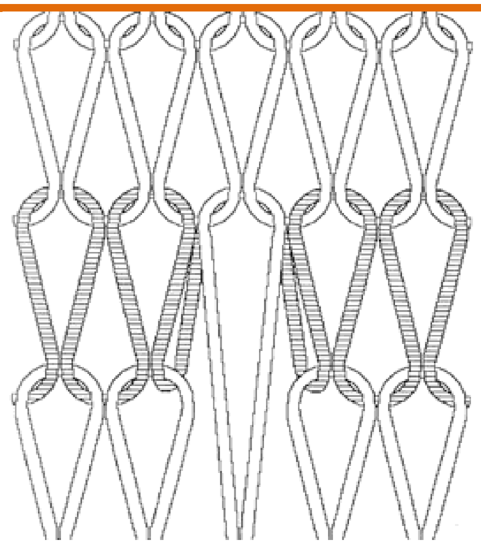

Figure 1(**A**). A tuck stitch within weft knit.

The Seebeck effect is supposed to work very effectively when there is a strong connection/conductive bonding between two different metals. However, in the experiment under consideration, a loose connection between two metals has been inevitable due to knitting process. This led to a number of promising results, whereas, the connection between the two yarns has been in the loose form. The idea was incorporated into knitted structures by using a few combinations of metal and metal enriched yarns. These yarns were used as a part of knitted structures Photos 1, 2, 3, 4, 5 and 6 below.

Photo1. Sample using Stainless steel and tungsten yarns.

International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2000-000X
Vol. 2 Issue 7, July – 2018, Pages: 48-56

Photo 2. A sample using 2 tungsten yarns but of varying diameter.

Photo 3. Silver enriched yarn with Stainless Steel wire 0.15 mm.

Photo 4. Stainless steel yarn and wire 0.15 mm.

Photo 5. Sample using Stainless Steel and Nickel coated yarns.

Photo 6. Silver and nickel coated yarns.

Due to the knitted pattern both the metal yarns made loose connection to each other, so that each crossing of the yarns acted as a loose thermocouple. These loose connections thus behave as a large number of thermocouples connected to each other in a series arrangement. Therefore, a small change in impedance happens at each junction, which then adds up to show a considerable change in reading at the output terminals of the fabric. The knitted fabric as a result of this technique is having a number of advantages over the conventional thermocouple. The resulting fabric in turn is washable, wearable and durable and flexible, therefore, opening more avenues for thermocouple applications. The range of applications would include from very basic to sophisticated applications such as in the fields of medical and sports.

3. The Experiment

A number of samples for the knitted fabric were developed, the difference between these samples being the variation of metal yarn used in them and the knitted patterns. The output terminals of each sample were attached directly to a digital Ohm meter. A Fisher Scientific hot plate was used for gradual heating of each sample. Each sample when placed on the hot plate was covered with a plane piece of ceramic, so that rigidity and uniform environment to the sample could be provided. Depending upon the type of metal used in each sample, some combination showed direct generation and variation in impedance across the output terminals.

4. Results and Discussion

i). Figure 2, shows a result for a knitted combination of a fine Stainless Steel and Tungsten wires. Due to the nature of the combination as mentioned above, a limitation in the range has been found. A near linear relationship between the temperature and the observed impedance may be seen, however, the range covered is from 31-63 ^{o}C.

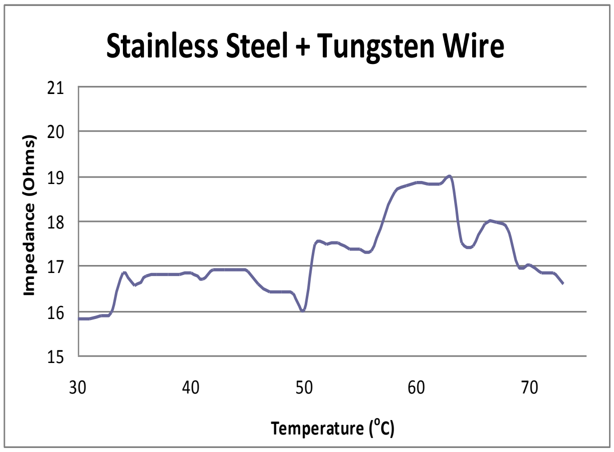

Figure 2.

ii). Figure 3(a), shows the results gained by using same material i.e. Tungsten wire, however, the diameter chosen for the two wires have been different, as mentioned in the graph. The result in this case was very encouraging, that it showed more linearity in impedance variation *w.r.t.* the changes in temperature. The temperature range covered in this case is from 35 to 90 ^{o}C.

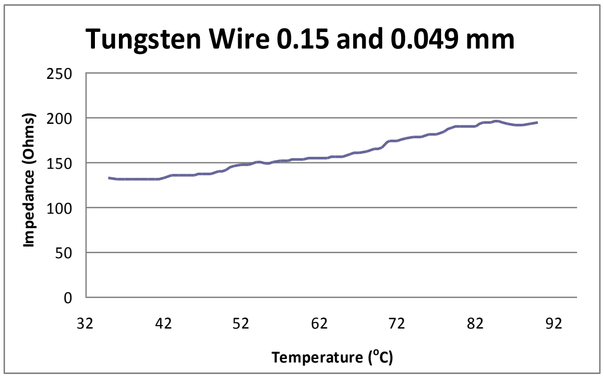

Figure 3(a).

Figure 3(b), shows the results for same fabric and material used, however, the output was measured in terms of dc voltage and can be observed that this combination has shown a negative temperature coefficient.

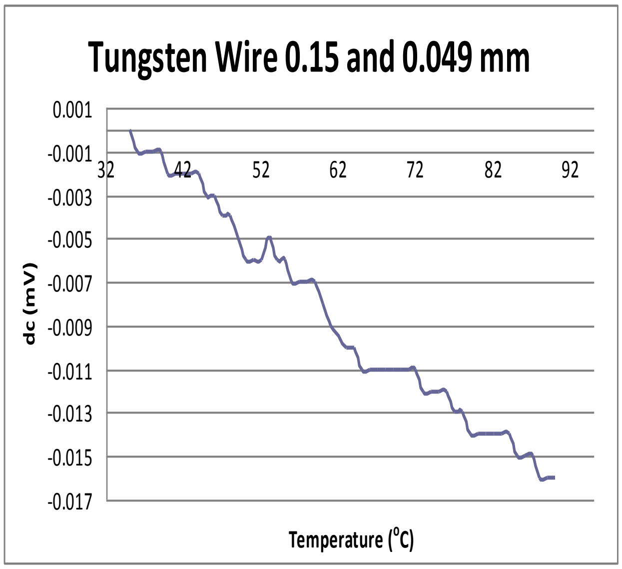

Figure 3(b).

iii). Figure 4(a), presents the results for the combination of Stainless Steel and Silver enriched yarns. For the sake of experimentation, bonding of 50% junctions was tried. The bonding was carried out with the help of conducting adhesive. The variation in impedance was also observed in a linear fashion however, the results for dc voltage output seems more stable and effective as shown in figure 4(b).

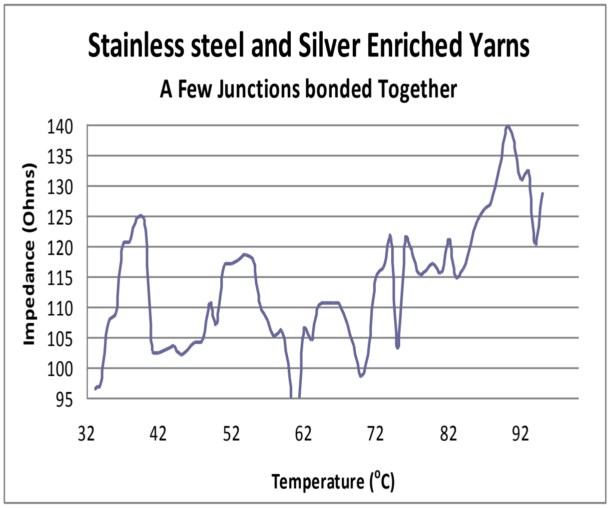

Figure 3(**A**).

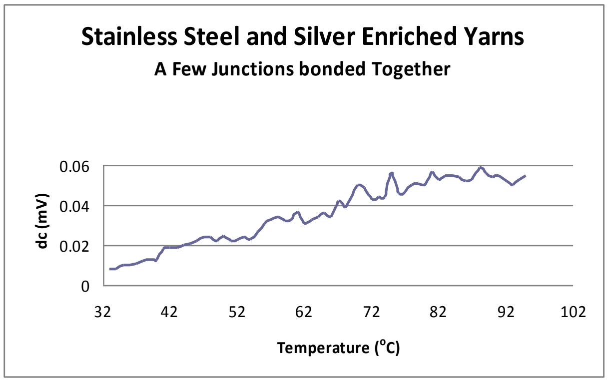

Figure 4(b).

iv). Figure 5, depicts a linear relationship between temperature variation and the dc voltage at the output terminals of the fabric. However, the combination of stainless steel enriched yarn and a 0.15mm diameter stainless steel wire shows a negative temperature coefficient.

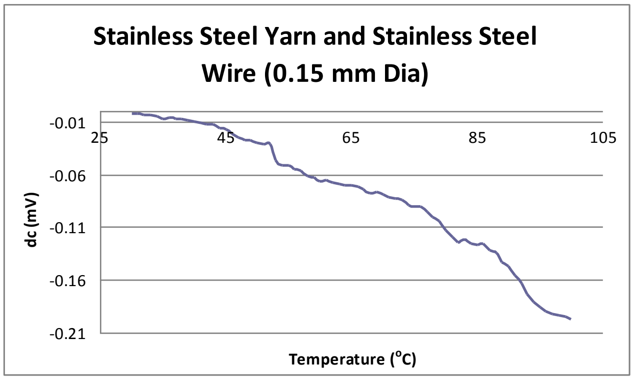

Figure 5.

v). An interesting combination of materials, i.e. stainless steel yarn and 27% nickel coated Copper filament was tried. Two knitted structures were developed under this combination, these structures being complete knitting pattern and a pattern with a miss out of 3 stitches. Excellent linear relationship was observed in both the cases as shown in figures 6(a) and 6(b).

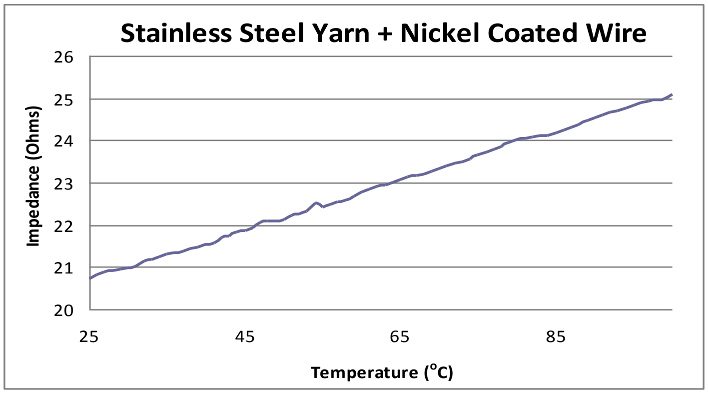

Figure 6(a).

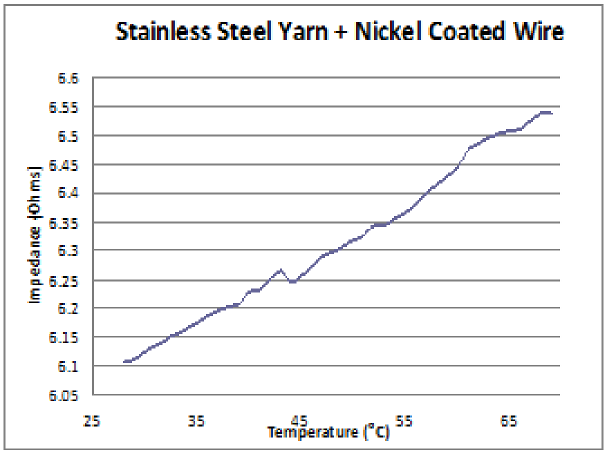

Figure 6(b).

vi). A further combination was tried to achieve a good linear relationship between the temperature and impedance variation. In this case a round trip of temperature variation was carried out; the results so received are shown in figure 7.

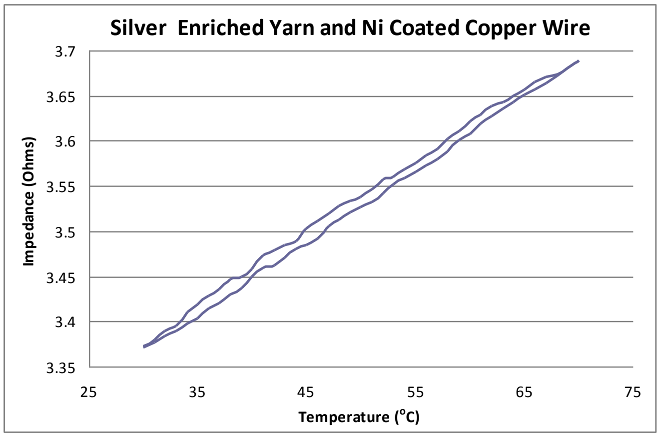

Figure 7.

5. CONCLUSIONS

Results of Knitted structures have been found satisfactory and are published here. The structures are long lasting and can be utilized for temperature sensing in various applications with access difficulties. These applications include the fields such as medical, sport and other high tech applications.

6. ACKNOWLEDGEMENTS

This work was carried out at William Lee Innovation Center of the University of Manchester under the management of Professor Tilak Dias.

7. AUTHOR CONTRIBUTION

The idea of knitted thermocouple was elaborated by the author, who carried out the experimentation and wrote the script of this article.

8. CONFLICTS OF INTEREST

The author declares no conflict of interest.

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