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Simulation of Knitted Structure using CAD Software and Virtual Analysis of Heat Transfer

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***Abstract*: This paper's main goal is to study the application of a finite element technique (FEM) to textile issues, specifically the heat transfer behavior of simple knitted cotton materials. A heat transfer measurement device is originally set up for the experimental investigation for this reason. A simple weft knitted fabric model is then created using SOLID WORKS, and it is then loaded into ANSYS Workbench for analysis. The FEM model created for the heat transfer measurement containing simple knitted cotton fabric offers extremely promising results, according to a comparison of the experimental measurements with the numerical solutions. Additionally, it has the potential to obtain textiles made of novel fibers like bamboo, soybean, chitosan, etc. that some of which have good heat conduction coefficients.**

***Keywords*: Finite Element Method (FEM), heat transfer, weft knitted fabric.**

1. Introduction

It is well acknowledged that understanding the dynamic thermal comfort of clothes while being worn necessitates a thorough understanding of the coupled heat and moisture transport in textile fibers. Recently, modeling mechanical characteristics, particularly stiffness and tensile has become quite popular. The processing features of knitted fabric-reinforced thermoplastics, however, are still poorly known since there is a dearth of literature on their forming property characteristics. In actuality, knitted reinforcements are less frequently discussed in the literature on forming qualities than unidirectional, predominantly woven, and to a lesser extent, braided reinforcements.

Araujo et al. simplified and depicted a planar weft-knitted fabric based on the straightforward loop structure using a 2D hexagonal structure made of non-linear truss members. An analytical technique that transformed a loop into a FEM model was used to derive the properties of the truss components using experimental data. A planar knitted fabric was deformed to match a semi-spherical shape in a three-dimensional (3D) scenario, as well as for two-dimensional (2D) in-plane elongations in one, two, and multiple directions. The research demonstrated the FEM's effectiveness for doing intricate analysis of textile structures like knitted textiles.

The present work was undertaken in an effort to model the heat transfer measurement unit for cotton plain weft knitted textiles using FEM. This was motivated, in particular, by the paucity of literature on FEM. Given its encouraging findings, it is anticipated that the work may serve as a starting point for more research on FEM applications to knitted structures.

2. Experimental Details

Using the formula in 1, Lee's disc method has been used to gauge the heat conductivity of materials. The cloth was placed between two stainless steel plates in this way, with the top plate progressively being heated to 100oC and the bottom plate remaining at ambient temperature. The temperatures of the hot and cold plates at the saturation point have been recorded for computation. After removing the cloth and top plate, the cooling rate of the bottom plate was measured. These values have been used to calculate the heat conductivity of a series of fabrics.

$$K = MSR\ d\ (2h+r)\ /A(T1-T2)\ (2h+2r)\ \text{Unit: (W/mK)} \quad (1)$$

Where, K – Thermal conductivity of fabric (W/mK), M – Mass of the disc (Kg), S – Specific heat of the material of the disc (370 J/ Kg/s), R – Rate of fall of temperature 5 (kelvin/sec), h – Thickness of the lower disc (m), r – Radius of the lower disc (m), d – Thickness of the fabric (m), A – Area of a cross-section of fabric (m^2).

Polarized Light microscope:

It is used to measure the dimensions of a single loop and yarn diameter of the fabric.

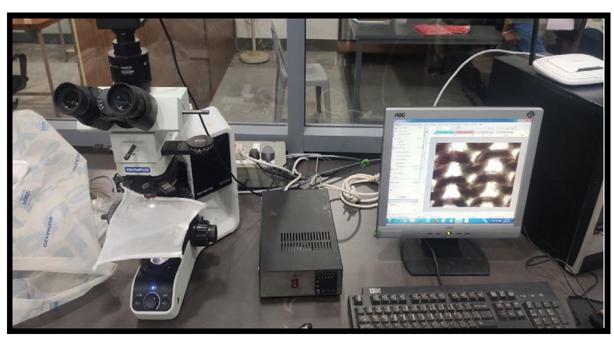

Fig. 1.

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Model Creation:

Solid works are used to design 3D Models of the parts we design and allow us to visualize what the automation will look like once it is built. The procedure of knit loop design formulation is discussed below.

- Step. 1 In Solid Works a part was created by using a 3D representation of a single loop.
- Step. 2 Dimensions were created by specifying the length & diameter of each component.
- Step. 3 Sweep to the given diameter of yarn.
- Step. 4 Yarn loop has been bent to 120o (bend at YY' axis) by using the flex command.
- Step. 5 Then a path has been drawn to form a curve drive pattern.
- Step. 6 A curve drive pattern was created.
- Step. 7 Finally two plates were added to the model according to the dimensions of the mode.

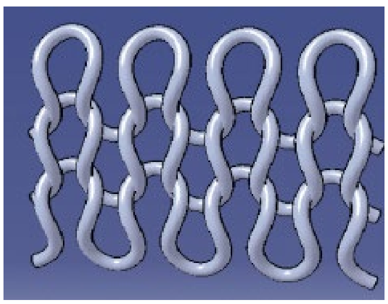

Fig. 2.

While the measurement is traced down in AutoCAD as a 2D schematic to compute loop length for verification, the model is constructed using Solid Works. Using the formula 2, where c=angle of arc covered, determine the length of an arc.

Arc length = 2πR /C ×360

FEM Analysis:

The final system model was loaded into ANSYS Workbench. The interlacing of the loops in the fabric model caused significant dynamic contact issues. Although ANSYS Workbench automatically specified the contact areas between the plates and loops those between the loops (due to interlacing) had to be defined manually. The model was prepared for meshing once the contact areas were defined. A hexahedral finite element mesh of the fundamental cell was developed to achieve this goal. The mesh size was first set at a pretty high level, however, the outcomes were not found to be adequate. The mesh size was consequently reduced to 0.00008 m.

To determine the heat flow through the fabric model, temperature boundary conditions on the plates were required. As a result, the software was updated with the results from the experimental setup's heat transfer measuring device. The heat conduction coefficients of the materials, including the plates, should have been specified in the software in order to compute the heat flow through the fabric. The computer automatically allocated steel's heat conduction coefficient because steel was a defined material for the program and the plates were constructed of steel.

However, the program required manual entry of the heat conduction coefficient of the fiber used to make the cloth as a new material. Since cotton fiber's heat conduction coefficient in the literature is listed as 0.03 W/mK, this number was inserted into the software to enable the system to determine the fabric's heat conduction coefficient.

3. Results and Discussion

The model's temperature distribution. The locations where the fabric model came into touch with the hot plate were those where the greatest temperature values were recorded, as can be shown. The lowest temperature readings, on the other hand, were discovered where the cloth model came into contact with the cold plates, as was predicted. The heat flow pattern in the z-direction is also shown in Figure 8. The minimal heat flux value for the fabric model was found at the hot plate contact locations, while the maximum value was found at the cold plate contact points.

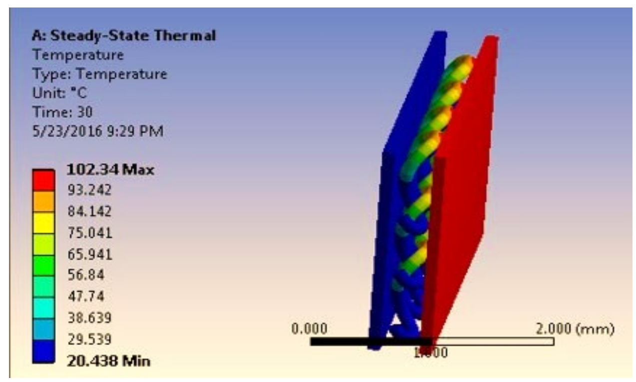

Fig. 3.

When analyzing the nodes with a heat flux value of -0.531 103 W/m^2, a comparable distribution was also discovered. The conduction coefficient of the fabric model (k), which was determined using the heat flow equation created for the heat transfer measurement setup, was calculated to be 0.037 W/mK. The experimental conduction coefficient, which was 0.0364 W/mK, and the conduction coefficient determined by FEM analysis, which was 0.037 W/mK, were very similar, indicating that the model of the experimental setup discussed above could be used to determine the heat conduction coefficient of other fiber types, including modal, soybean, bamboo, and others.

4. Conclusion

The primary goal of the study was to determine if FEM analysis might be used to solve textile issues, particularly those involving the heat transfer behavior of simple knitted cotton materials. As a result, we performed research that led to the early development of a heat transfer measurement unit for the experimental investigation. Following that, we used SOLID WORKS to model a plain weft knitted fabric, and ANSYS Workbench to simulate the heat transfer measurement setup (unit) containing the fabric model. When the findings from this simulation were compared to those from experiments, we found that FEM analysis produced results that were rather accurate.

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