Electrical resistance of jute fabrics

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Electrical resistance of jute canvas, hessian and cross-laid needle-punched nonwoven fabrics has been measured in a laboratory made set-up. Effect of gauge length, voltage, moisture, fibre orientation, temperature, area density has been studied and analysed. It is observed that electrical resistance increases with the increase in gauge length and decreases with the increase in input voltage, moisture, temperature and area density. Jute hessian, canvas and nonwoven fabrics show the resistance value in descending order. Length-wise electrical resistance is higher than width-wise resistance of jute needle-punched nonwoven fabric, whereas in case of canvas and hessian the effect is reversed.

Keywords: Canvas, Electrical resistance, Hessian, Jute, Needle-punched nonwoven

1 Introduction

The electrical resistance of an object is a measure of its opposition to the passage of a steady electrical current. The resistance of an object determines the amount of current passing through the object for a given potential difference across the object in accordance with Ohm’s law \( I = \frac{V}{R} \), where \( R \) is the resistance in ohm; \( V \), the potential difference across the object in volts; and \( I \), the current in ampere.

For a long time, different textile materials are used as insulator. From the ancient age, the conductive wire is wrapped with cotton or silk yarns for insulation. The use of textile material has been reduced with the extensive use of synthetic polymers. It has reduced the cost of insulation also. But still there is enough scope of using textile material as insulator where heat is generated during current flow through wire in high voltage because heat can melt the polymeric insulator. It can be used in case of high voltage phenomenon where high current passes through conductor. Specially designed textile material can also be used as gloves, jackets (apron) for electrical work or as floor covering in the room where high voltage electrical appliances are kept.

The measurement and understanding of electrical resistance of textile material is complex in nature. For the textile material (i) uniform cross section is not achievable and impractical, (ii) it can absorb or desorb moisture in the atmosphere, and (iii) its structure is not uniform and depends on the processing parameters. Hence, it is expected that the electrical resistance of the textile material varies with raw material and its construction parameters.

It is of interest to know that the first material to insulate the conducting thread was silk\(^1\) used by Stephen Grey in 1729. Since then, different textile materials have been used as insulating purpose and commendable research has been carried out on insulation by textile materials from the beginning of twentieth century\(^2,4\). Recently, some electro-physical properties of textile samples having different forms and raw material compositions were studied by Asanovic \textit{et al}\(^5\). For determining the electric resistance, a measuring device, based on the measurement of direct current through textile samples, was developed. The dielectric loss tangents and relative dielectric permeability were measured for some of the textile samples tested. The dielectric properties were measured using specially designed capacitance cells. Hains \textit{et al}\(^6\) tested electrostatic properties of polyurethane coated textiles used for

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protective clothing. Gonzalez et al.\textsuperscript{7} proposed mathematical modeling of electrostatic propensity of protective clothing systems. Ghosh and Dhawan\textsuperscript{8,9} reported the developments in the field of electronic textiles, focusing on the current state-of-the-art of electro-textile products and the research being carried out in this field.

In the literature, the information regarding use of jute as insulating material is scanty. Keeping this in mind, an attempt has been made to measure the electrical resistance of different jute fabrics in order to understand the effect of processing parameters or fabric structure on the electrical resistance of jute fabric. It will help to design technical textiles from jute where electrical resistance property is required during use.

2 Materials and Methods

2.1 Materials

Two types of jute fabrics (woven and needle-punched nonwoven) were used to measure the electrical resistance.

\textit{Woven fabric} – Two types of such fabrics were obtained commercially and used for the study. One fabric is called hessian, which is openly interlaced having low area density and basically used as packaging. The other fabric is densely interlaced having high area density called canvas. The construction of both the woven fabrics is shown in Table 1.

\textit{Needle-punched nonwoven fabric} – Needle-punched nonwoven fabrics having 300, 450, 600, 750 and 900 g/m\textsuperscript{2} were prepared and used for the study.

2.2 Methods

2.2.1 Preparation of Nonwoven Fabric

Jute reed was subjected to softening treatment with 4\% jute batching oil-in-water emulsion and then processed in a breaker card. To make jute needle-punched nonwoven, the breaker card sliver was fed to Dilo nonwoven plant comprising a roller and clearer card, a camel back cross-lapper and needle loom (Model number OD II/6). 300, 450, 600, 750 and 900 g/m\textsuperscript{2} nonwoven fabrics were prepared with 200 punches/cm\textsuperscript{2} and 12 mm depth of needle penetration. Their thickness values were measured in Prolific thickness tester and are found to be 2.83, 4.51, 5.47, 6.64 and 7.44 mm respectively.

2.2.2 Measurement of Electrical Resistance

A circuit for measuring current-voltage (V-I) characteristics of textile material has been set up according to Fig. 1. It consists of sample holder (S), variac (B), rectifier unit (D), ammeter (A), voltmeter (V) and 10 M\textOmega discrete resistance (R). Two bulldog-clips are used between which the sample is placed (Fig. 2) with gauge lengths 2.54, 5.08 and 10.16 cm. The sample is in series with a known resistance (10 M\textOmega) and is connected to a D.C. power supply. The voltage is varied from 80V to 220V in 5 steps and corresponding current through the sample is measured after 10s to calculate the resistance. The measurement is done at 27ºC and 65\% relative humidity. Five sets of voltage-current readings are taken for plotting V-I characteristic curves. The slope (voltage/current) or resistance for each V-I characteristic is determined. Specific resistance has been calculated normalising the resistance by thickness [multiplying/dividing the resistance (Mohm) by thickness, (cm)].

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|c|c|}
\hline
Fabric & Area density g/m\textsuperscript{2} & Thickness mm & Ends/inch & Picks/inch \\
\hline
Hessian & 244 & 2.59 & 16 & 8 \\
Canvas & 510 & 3.17 & 30 & 16 \\
\hline
\end{tabular}
\caption{Construction of woven fabric}
\end{table}
3 Results and Discussion

3.1 Effect of Voltage

Electrical resistance tests were carried out for canvas, hessian and 450 g/m² nonwoven fabrics in three different gauge lengths, viz 2.54, 5.08, 10.16 cm and in five voltage levels, viz 80, 109, 148, 203 and 228 volts. The result (Table 2) shows that with the increase in input voltage, specific resistance decreases. This effect is higher in longer gauge length as gauge length is directly proportional to resistance. The significant fall at high voltages is usual breakdown of insulation. For ohmic material, resistance remains constant with the increase of voltage as current also increases proportionately with voltage. But with jute nonwoven fabric, current is not increasing proportionately and hence resistance decreases. It signifies that if input voltage increases, caution must be taken regarding the use of jute fabric as insulator.

3.2 Effect of Type of Fabric

Table 2 shows that specific resistance is highest in hessian and lowest in 450 g/m² nonwoven, keeping canvas in between. Structure wise, canvas is more compact with higher cover factor than that of hessian, resulting in better conductor and worse insulator. Woven fabric (hessian and canvas) is made with two sets of compact and twisted yarns which are arranged along the length and width in a systematic way. There is always one set of yarn which is not directly participating in the electrical conduction, e.g. if measurement is done in warp direction, the weft yarns are not directly participating in conduction. Therefore, the reason of lower resistance of canvas than Hessian is the higher ends/cm (Table 1). On the other hand, nonwoven fabric structure shows that all the fibres are arranged and interlinked in such a way that their discrete nature does not exist in consideration with electrical behaviour and most of the fibres are contributing towards electrical conduction. Inter-fibre void space which creates lower fabric density compared to woven fabric does not play much because of the inter-fibre contacts which act as a whole in conduction of electricity. This is the probable reason for lower resistance of nonwoven fabric. Furthermore, needle-punched nonwoven absorbs moisture even in the innermost layer, whereas compact yarns have lower moisture in the inner part, resulting in higher conductivity in nonwoven. Therefore, to get better insulation, hessian may be used among the different fabrics studied.

3.3 Effect of Gauge Length

Table 2 shows resistance against different gauge lengths in different input voltages from 80V to 228V. It shows that specific resistance increases with the increase in gauge length. This trend is true for all types of fabric tested, i.e. canvas, hessian and nonwoven. From this, we can say that insulating property of fabric increases with the increase in length between two measuring jaws.

It proves that textile material also follows the conventional relation between resistance and specimen length for conducting material. To get a required insulation by jute fabric, the distance between electrical source and insulating point is an important parameter.

3.4 Effect of Moisture

Canvas and nonwoven fabric samples are kept in the humidifier chamber at 40°C with varying relative humidity. With the varying humidity, the moisture content of samples is changed. The samples are taken within the plastic packet, measured their moisture content and tested for specific resistance under this condition with 2.54 cm gauge length and 80 V potential difference. Figure 3 shows that as the moisture content increases, the specific resistance decreases. The increase in moisture content increases the current flow, resulting in decrease in resistance. The relation follows the equation $y = -612.8 \ln(x) + 1277.6$ having

<table>
<thead>
<tr>
<th>Gauge length cm</th>
<th>Potential difference Volt</th>
<th>Specific resistance, M Ω/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.54</td>
<td></td>
<td>Canvas</td>
</tr>
<tr>
<td>80</td>
<td>385</td>
<td>499</td>
</tr>
<tr>
<td>109</td>
<td>364</td>
<td>470</td>
</tr>
<tr>
<td>148</td>
<td>361</td>
<td>451</td>
</tr>
<tr>
<td>203</td>
<td>339</td>
<td>438</td>
</tr>
<tr>
<td>228</td>
<td>328</td>
<td>400</td>
</tr>
<tr>
<td>5.08</td>
<td></td>
<td>Canvas</td>
</tr>
<tr>
<td>80</td>
<td>558</td>
<td>752</td>
</tr>
<tr>
<td>109</td>
<td>493</td>
<td>706</td>
</tr>
<tr>
<td>148</td>
<td>493</td>
<td>639</td>
</tr>
<tr>
<td>203</td>
<td>465</td>
<td>618</td>
</tr>
<tr>
<td>228</td>
<td>420</td>
<td>571</td>
</tr>
<tr>
<td>10.16</td>
<td></td>
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</tr>
<tr>
<td>80</td>
<td>765</td>
<td>1381</td>
</tr>
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<td>148</td>
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</tr>
<tr>
<td>203</td>
<td>677</td>
<td>1051</td>
</tr>
<tr>
<td>228</td>
<td>630</td>
<td>984</td>
</tr>
</tbody>
</table>
R² value 0.92 for canvas, and \( y = -237.62 \ln(x) + 624.89 \)

having R² value 0.99 for nonwoven. Therefore, fabric should be moisture resistant to make it suitable insulator and the product should be either polycoated or made with chemically treated fibres so that jute cannot absorb moisture.

3.5 Effect of Fibre Orientation

In cross-laid needle-punched nonwoven fabric, the fibres are arranged inclined to width direction. It is observed that the length-wise specific resistance is higher than width-wise specific resistance (Fig. 4). Hence, current flows easily in the cross direction of fabric due to lower specific resistance compared to that in machine direction. In canvas and hessian fabrics, width-wise specific resistance is higher than length-wise specific resistance. As the picks/cm is lower than ends/cm, the specific resistance in cross direction is higher for canvas and hessian. Resistance is lower in the direction of fibre orientation. This may help in designing the product.

3.6 Effect of Area Density

As area density of needle-punched nonwoven increases, specific resistance decreases (Fig. 5). The trend equation is \( y = 11.5x^2 - 145.1x + 765.6 \) with \( R^2 = 0.97 \). With the increase in area density, the number of fibres in the cross-section increases, resulting in decrease in resistance. With the increase in area density, bulk density also increases due to strong fibre peg formation as more number of fibres are arranged vertically. The increase in area density causes the increase of fibre to fibre contact and therefore results in the decrease in resistance. To get a required insulation by jute fabric, the area density or bulk density is an important parameter.

3.7 Effect of Heating

Samples are kept in the humidifier chamber with 65% relative humidity and varying temperature. The samples are taken within the thermocol cover and tested for resistance in this condition. Figure 6 shows that as temperature increases, the resistance decreases. After 60°C, resistance comes to an equilibrium. The trend equation and R² value are shown in figure. The initial decrease in resistance may be due to higher mobility of atoms at higher temperature, which increases the current flow, resulting in decrease of resistance. Temperature may rise during application.
of jute fabric in the electrical system. So, the effect of temperature is to be kept in mind so far as insulation is concerned.

4 Conclusion

4.1 Electrical resistance of jute fabric decreases with the increase in input voltage, ambient temperature, moisture content and area density of fabric. It also increases with gauge length of fabric. The decrease of electrical resistance due to increase of input voltage is higher in longer gauge length. Fabric should be moisture resistant/repellent to make it suitable insulator.

4.2 Electrical resistance is highest in hessian and lowest in nonwoven keeping canvas in between.

4.3 Length-wise electrical resistance is higher than width-wise resistance of jute needle punched nonwoven fabric. In case of woven fabrics, the effect is reversed.

4.4 All the above phenomena will help to design technical textiles out of jute where it can be used as electrical insulator.

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