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Analysis of Dielectric strength of Laminates made from Conductive knitted fabrics

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Abstract – *The field of conductive textile can be viewed as an integration of technologies of materials, electronics and textiles in order to create a new generation of flexible/comfortable small or large multifunctional textile structures with conductive capabilities. Conductive textiles can be made with metal strands woven or knitted into the construction of the textile. There is also an interest in semiconducting textiles, made by impregnating normal textiles with carbon- or metal-based powders. As per selection of metal strand like – Copper, Silver, Aluminium, Steel, Carbon etc. material can explore its performance. Here in this study with use of copper wires of different gauge, knitted fabrics are developed and laminates are prepared for which Breakdown Voltage & Dielectric Strength are measured and analyzed for its applications in various fields.*

***Key words** – Breakdown Voltage, Dielectric Strength, Knitted Fabric, Laminates, Conductive textile*

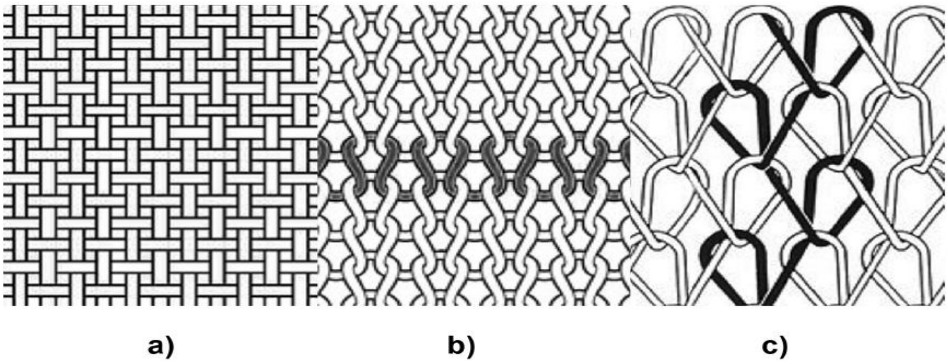
I. INTRODUCTION

1.1 Basics

In recent years, a new area of research has emerged on textile based conductive materials called "Conductive Textile". The field of conductive textile can be viewed as an integration of technologies of materials, electronics and textiles in order to create a new generation of flexible/comfortable small or large multifunctional textile structures with conductive capabilities. These structures can be made from new type of hybrid yarns with conductive characteristics, which can be produced using existing machine set up. These yarns can be used for the various applications in form of fabric and laminates (Thermoplastic yarn) which includes the range starting from antistatic material to shielding protection.

The interest in conductive textiles was renewed when the concept smart textiles emerged some fifteen years ago [1]. In the electronic industry, today ESD control/protective products need to meet various requirements [2]. Electronic components that are electrostatic discharge sensitive (ESDS) must be protected throughout the entire manufacturing cycle [3]. Development of products through woven or knitted process (Figure 1) for Electrostatic discharge control is greatest need of present market to avoid hazardous malfunctions in working area. (The terms conductive and static dissipative typically refer to resistance or resistivity ranges used in the evaluation of ESD control materials and products[4].)

"Figure 1: Illustration of plain textile constructions : A) woven B) weft and C) warp knitted"



1.2 Dielectric Strength

The dielectric strength of an insulating material is defined as the maximum voltage required to produce a dielectric breakdown. Dielectric strength is expressed in volts per unit of thickness [5]. All insulators allow a small amount of current to leak through and around themselves. Only a perfect insulator, if there is such an insulator in existence, can be completely free from small current leakage. The small leakage generates heat, providing an easier access to more current. The process slowly accelerates with time and the amount of voltage applied until a failure in terms of dielectric breakdown or what is known as puncture occurs. Dielectric strength, which indicates electrical strength of the material as an insulator, is a very important characteristic of an insulating material. The higher the dielectric strength, the better the quality of an insulator.

(A) Different Methods to measure Dielectric Strength

- Short time method

In this method, the voltage is increased from zero to breakdown voltage at uniform rate. The rate of rise is generally 100, 500, 1000, or 3000 V/sec until the failure occurs. The failure is made evident by actual rupture or decomposition of the specimen. Sometimes a circuit breaker or other similar devices are employed to signal the voltage breakdown.

- Slow rate of rise method

In this method, the test is carried out by applying the initial voltage approximately equal to 50 percent of the breakdown voltage. After this, the voltage is increased at a uniform rate until the breakdown occurs.

- Step by step method

The step by step test method requires applying initial voltage equal to 50 percent of the breakdown voltage as determined by the short time test and then increasing the voltage in equal increments and held for specified time periods until the specimen breaks down.

(B) Factors affecting the test results

- Specimen thickness

The dielectric strength of an insulator varies inversely with the fractional power of the thickness. The thicker specimen requires higher voltage to achieve the same voltage gradient. At higher voltage, a reduction in intermolecular bonds is observed resulting from thermal expansion created by heat generation.

- Temperature

Dielectric strength decreases with the increase in the temperature of the specimen.

- Humidity

Humidity affects the dielectric strength of the material. Surface moisture as well as moisture absorbed by hygroscopic material affects the results.

- Electrodes

Dielectric strength of a material is affected by the electrode geometry, the electrode area, as well as electrode base material composition. Generally the breakdown voltage decreases with increasing electrode area.

- Time

The rate of voltage application significantly alters the test results. Dielectric strength values obtained by step-by-step method are lower than those obtained by the short time test.

- Mechanical stress

Mechanical stress tends to reduce the dielectric strength values substantially.

- Processing

Defects such as poor weld lines, voids, bubbles, and flow lines brought forth by poor processing practices tend to reduce the dielectric strength anywhere from 30 – 60 percent depending upon the severity of the defect.

II. DEVELOPMENT OF LAMINATES

2.1 Raw Material

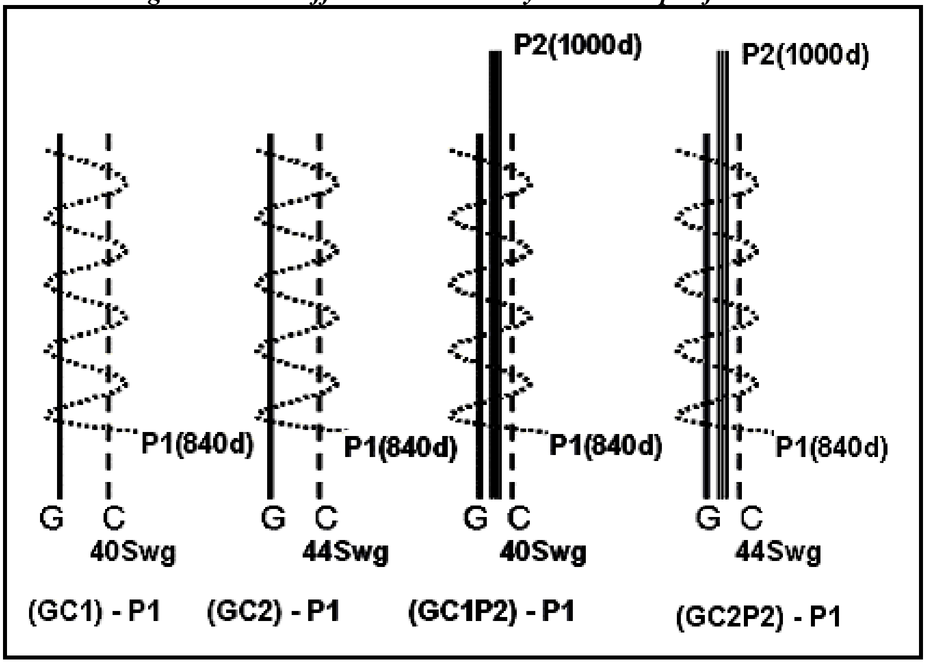
Glass filaments - 156T - E Glass Filaments
Polypropylene Filaments - 840d & 1000d
Copper Wire - 40Swg & 44Swg

2.2 Sample Preparation

Samples are mainly prepared in three stages – Yarn stage, Fabric stage and Laminate stage.

- Yarn Preparation : Conductive yarns are prepared on the Hollow spindle machine. In this work, four types of conductive yarns are produced which are shown below :

"Figure 2.2.1 – Different Conductive yarns with Specifications"



G - Glass Filaments (156T), C1, C2 - Copper wire & P1,P2 - Polypropylene Filaments

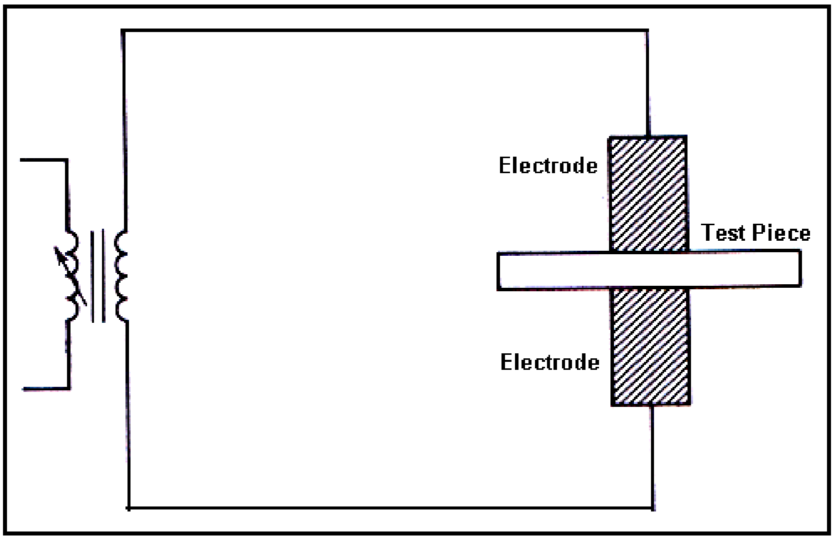
- Fabric Preparation : Conductive knitted fabrics are produced from above four types of conductive yarns on Simple Hand Knitting Machine.
- Laminate Preparation : Laminates are developed from these Conductive knitted fabrics using Hydraulic Press with Special Thickness Sample Plates.

III. TESTING OF DIELECTRIC STRENGTH OF LAMINATES

Dielectric Strengths of the various laminates are measured according to ASTM D149 method using pair of electrodes connected with transformer as shown in Figure 3. Ten readings are taken for each sample to carry out Dielectric Strength. The Dielectric Strength is calculated from given formula.

$$\text{Dielectric strength (KV/ mm)} = \frac{\text{Breakdown Voltage (V)}}{\text{Thickness (mm)}}$$

"Figure 3 – Schematic of Dielectric Strength measurement"



IV. ANALYSIS OF DIELECTRIC STRENGTH (KV/mm)

Dielectric Strength is the measure of the maximum voltage a material can withstand without conducting electricity through the thickness of material. The insulating and conductive characteristics of material depend on its dielectric strength. Higher the values better the insulation. The test results vary with Thickness of material, Rate of voltage, Test duration and Temperature. Table 4.1 and 4.2 show the value of Breakdown voltage (KV) and Dielectric strength (KV/mm) of different thermoplastic material sample with copper wire. Test has been done keeping constant thickness and uniform test condition.

- **Breakdown Voltage (KV) and Laminate Thickness (mm)**

"Table 4.1 - Breakdown Voltage (KV) and Laminate Thickness (mm)"

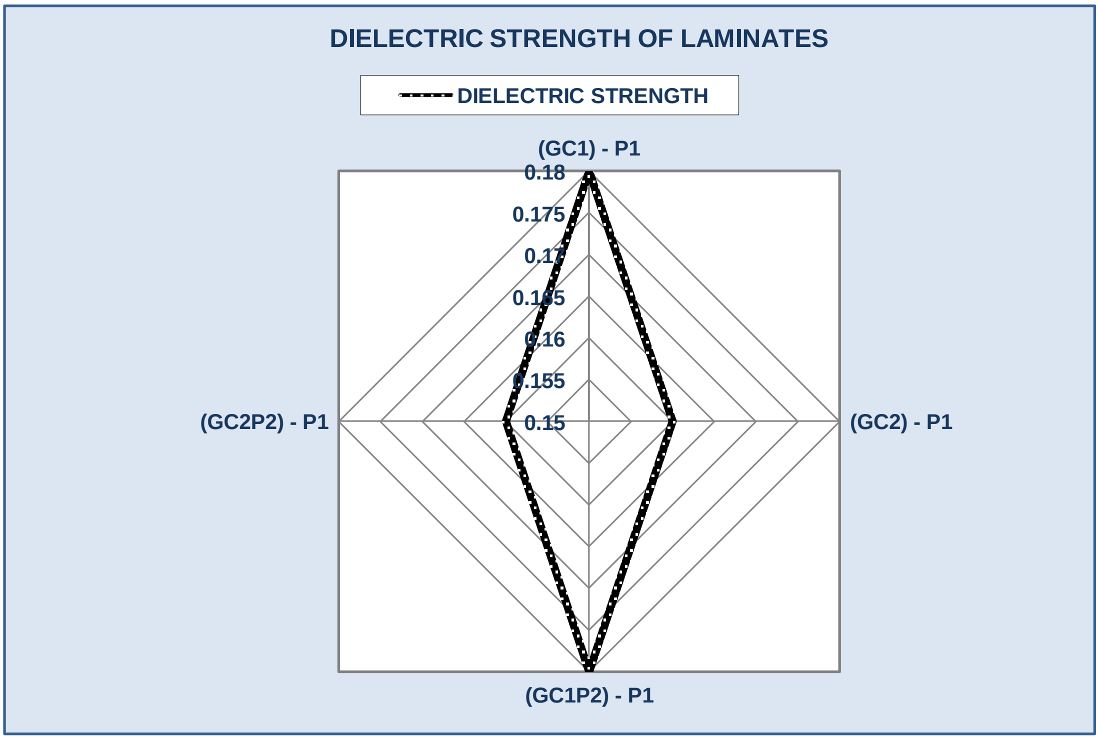
Samples	**Breakdown Voltage (KV)**	**Laminate Thickness (mm)**
(GC1) - P1	0.450	2.5
(GC2) - P1	0.400	2.5
(GC1P2) - P1	0.450	2.5
(GC2P2) - P1	0.400	2.5

- **Dielectric Strength (KV/mm)**

"Table 4.2 - Dielectric Strength (KV/mm)"

Samples	**Dielectric Strength (KV/mm)**
(GC1) - P1	0.18
(GC2) - P1	0.16
(GC1P2) - P1	0.18
(GC2P2) - P1	0.16

"Chart 4.3 - Dielectric strength of laminates"



V. CONCLUSION

It has been found that test samples get punctured around 450V which is lower in value. Hence materials prepared are good conductors. The two samples with 40Swg shows little higher value compared to 44Swg samples. The thickness of sheet is 2.5mm for all samples. Thus, we can conclude that materials prepared are conductive thermoplastic material.

Dielectric strengths of the laminates are in the range of 0.16 – 0.18 KV/mm, which indicates that the composite materials are conductive in nature. Also, Dielectric strength is not affected by the addition of polypropylene in the core.

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