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Study on different methodologies to impart Conductive characteristics in textiles for ESD/Radiation protection

H. N. Amin[1], D. V. Bihola[2]

[1]*Textile Technology Department, Sarvajanik College of Engineering & Technology, Surat-395001,Gujarat.*
[2]*Textile Manufacturing Technology, R.C. Technical Institute, Ahmedabad-380060, Gujarat.*

Abstract – *The evolution of electronics has led to the development of products in which increasing number of operations concerning an increasing amount of data can be performed faster and faster per each generation of devices. 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 find applications in Telephone components, Computer Enclosures, Medical Devices, Electronic Monitors, Navigation Equipment, Laser Calibration Equipment, Oscilloscope Housings, packaging, grounding, conductive gaskets, bonding straps, cables, connectors, screens and Modem Enclosures etc. In present study, different methods of imparting conductive characteristics in textiles for ESD/Radiation protection are studied at fiber stage, at yarn stage and at fabric stage with possible use of existing machine set up.*

Key words *– Fiber, Yarn, Fabric, Metal, Coating, Conductive textile*

I. INTRODUCTION

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/Electromagnetic radiation sensitive (ESDS) must be protected throughout the entire manufacturing cycle [3].

Hence, 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 or laminates (Thermoplastic yarn) which includes the range starting from antistatic material to shielding protection.

II. METHODS OF IMPARTING CONDUCTIVE CHARACTERISTICS

There are several methods of imparting conductive characteristics to textile materials at fiber, yarn or fabric stages.

(A) Imparting Electrical properties at Fiber stage :
Methods which can impart electrical properties at fiber stage are as follows :

➢ ***Draw blending of Metal and Textile Slivers :***
Relatively high conductivity (10^5 [ohm.cm]$^{-1}$) can be obtained by the draw blending metal slivers with slivers composed of textile fibers. The limitations are that metal fibers are as much as five times heavier than some textile fibers. Also, metal fibers are brittle and can abrade the spinning equipment. A final concern is that yarns that contain metal fibers can produce a fabric with a “Metallised hand”.

➢ ***Treatment with Metallic Salts :***
Copper sulphide and copper iodide are the two predominant metallic salts used to coat fibers. Here, only low conductivity can be obtained with this method. This method is primarily used in carpet industry, where antistatic performance is required. A variety of fibers have been used, including Nylon, Polyester, Wool and acrylic. Also, depending on the chemicals and the process used, conductivities can be achieved.

➢ ***Galvanic Coating :***

High conductivity, > 10^4 $[ohm.cm]^{-1}$ can be obtained by Galvanic coating. However, since the galvanic coating must be applied to a conductive substance, essentially it is limited to carbon and graphite fibers. Galvanic coatings are also different to process, as well as expensive. Because of these limitations, galvanic coating is little used in textile industry.

➢ ***Coating fibers with Conductive particles suspended in a Resin :***

In this method, fibers can be coated with a resin in which a high concentration of conductive particles has been dispersed. Some of the earliest conductive products were produced by applying high concentration of a carbon containing resin to a fiber. Carbon fibers have fairly high conductivity, especially if pure carbon is used. Unfortunately, carbon can be difficult to process and any significant amount of carbon will impart a black colour to the end product.

Acrylic and Nylon fibers have been coated with a rubbery adhesive containing dispersed silver. Nylon is believed to be the best fiber to coat with particles dispersed in an adhesive because it has a surface containing small cavities that serve as chelating points.

➢ ***Vacuum Spraying :***

Vacuum spraying is a relatively inexpensive method that produces metal coated fibers with conductivities as high as 10^4 $[ohm.cm]^{-1}$. Unfortunately, it has several limitations : there is low adhesion between the metal and fiber, creating an unstable construction ; the process is difficult ; and the fiber produced has low resistance to corrosion and wear. This method can also be used to coat fabrics with a metal. However, lack of adhesion and the limited thickness of coating make it difficult to achieve high conductivity.

➢ ***Other methods :***

Other methods for making fibers conductive like nano scale applications of Inherently electrically conductive polymers (ICP's) is also used for imparting electrical properties at initial stage [4].

(B) Imparting electrical properties at yarn stage :

At yarn stage, electrical properties can be imparted by various methods which are as follows :

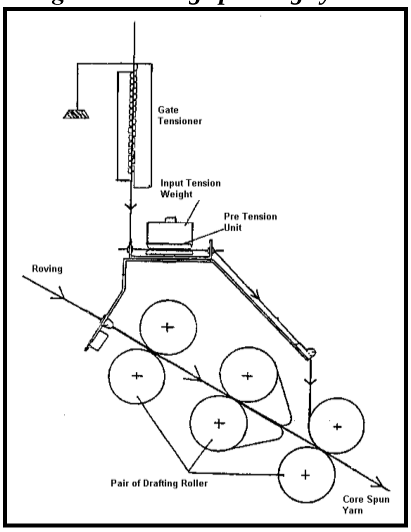
➢ ***Core Spinning :***

Core spun yarn usually consists of a high strength continuous filament core wrapped with a soft, low sheath of staple fibers. Core spun yarns can be manufactured by different methods like ring spinning, open end spinning, air jet spinning and friction spinning by the incorporation of certain attachments. Diagrams of different methods show highlight of the process which are given below :

1) Ring spinning system :

K. B. Cheng, M. L. Lee, R. Neelakandan and others had produced composite yarns of core sheath type on Ring spinning system. The metal wire was used as core and cotton was used as sheath in this method. The details of this system are shown here.

"Figure 1 – Ring spinning system"

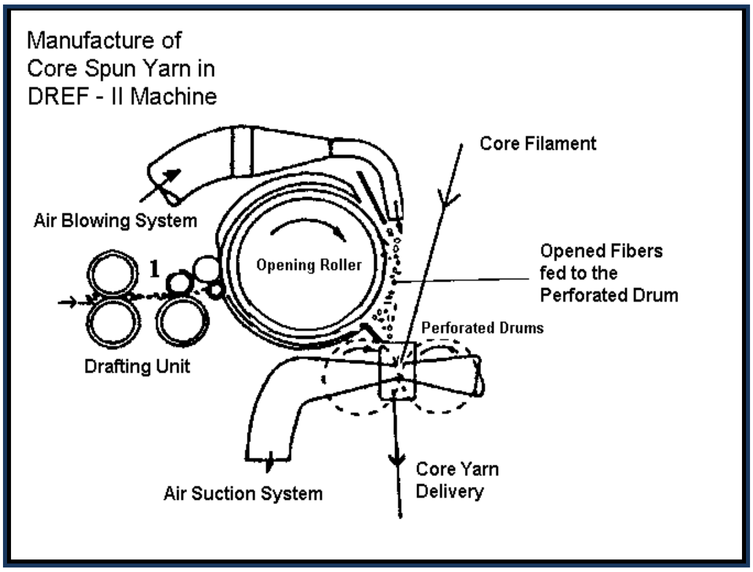


2) Open end spinning :

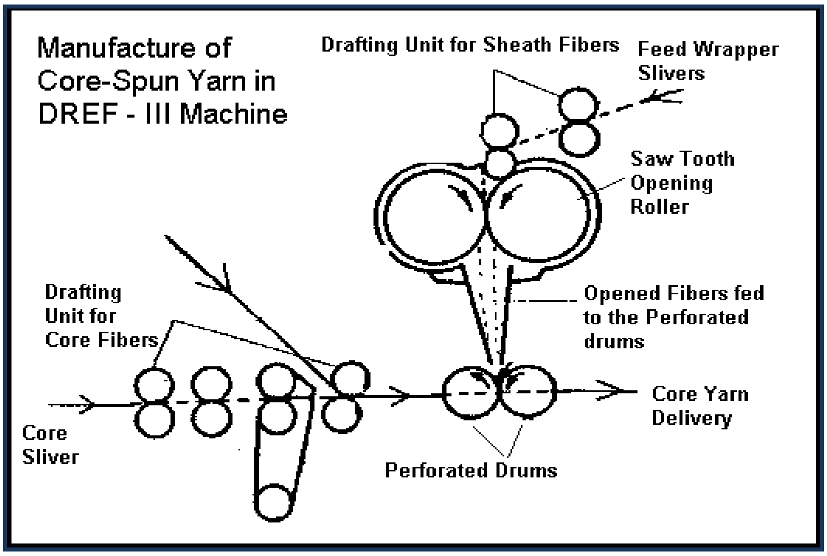
The another method, in which the metal wire is incorporated in the yarn as a core and wrapped by loose fibers by means of Rotor similar as open end spinning. As shown in Figure 2, the core yarn is passing through the center and ring of fibers formed by the Rotor. This type of technique can also be used to produce conductive yarn with fiber cover. But due to some technical difficulties friction spinning is widely used compared to open-end spinning.

3) Friction spinning :
In this method, the yarn can be manufactured by both Dref 2 and Dref 3 machines. As shown in Figure 3.1 and 3.2, metal wires are incorporated as core directly between perforated drums or in drafting unit [5]. Some of the work done by SITRA mention producing the Hybrid yarns by Dref 3 incorporating copper wire in the core and wrapped by cotton, polyester and polypropylene fibers and found good results of conductive yarns.

"Figure 3.1 – Dref 2 machine"



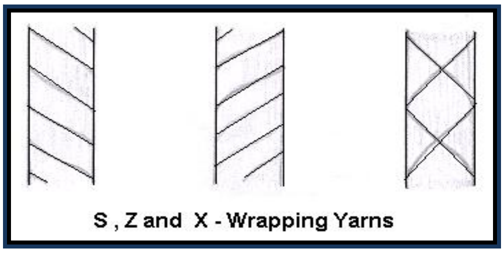
"Figure 3.2 - Dref 3 machine"

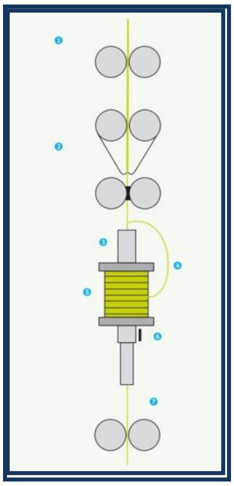


- ***Yarn Wrapping :***

Wrapping a mono or multi filament around a twisted or a twistless fiberous core produces a wrapped yarn. The yarn can be wrapped in either s or z manner. Also, yarn wrapped with both s and z twist directions called as x – configuration which was reported to give higher strength and elongation compared with similar s or z wrapped yarns. Hsin – Chuan Chen, Jia – Horng Lin, J. H. Lin and others had used this wrapping method in terms of rotor twister or rotor wrapping twister or hollow spindle machine to form conductive yarns [5].

"Figure 3.3 – Different types of Wrap yarns & Wrap spinning (Hollow spindle) system"

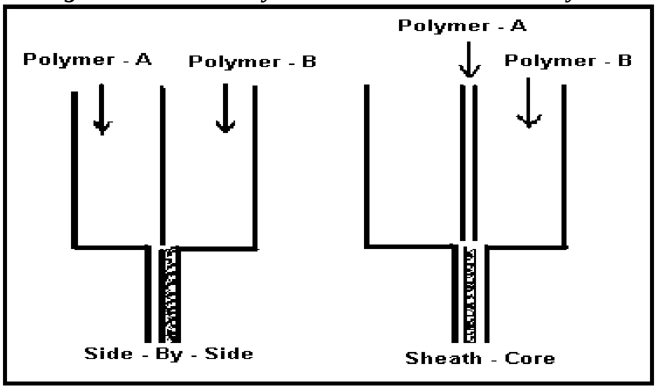




- ***Production of yarn from Bicomponent fibers :***

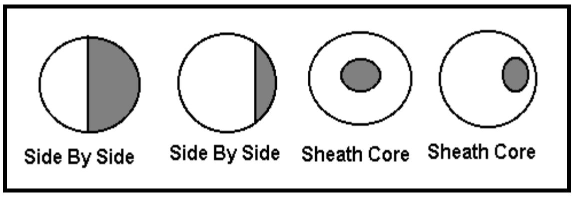
Bicomponent fibers can be wet, dry or melt spun. It is important that the two component polymers have adequate surface bonding and that the viscosities of both solutions and melts are compatible. The different polymers are joined at the point of extrusion through the spinneret. Figure shows the principle of the technology for forming the basic side-by- side and sheath - core bicomponent fibers. To maintain uniformity throughout the length of the filament, pumping pressures must remain constant and the flow of liquids must be non - turbulent.

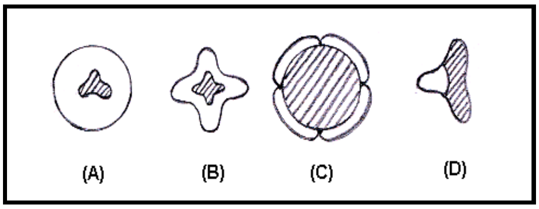
"Figure 3.4 - Side – by – Side and Sheath – Core yarn"



By altering the spinneret configuration, a variety of other cross sectional forms can be produced. Some variations of circular cross section side-by-side and sheath core bicomponent fibers are shown in Figure 3.5. Also, more complex cross sectional configurations can be obtained by using shaped, non-circular orifices in the spinneret. (A), (B) and (C) represent possible configuration for a sheath core bicomponent fiber and (D) represent a possible side-by-side type.

"Figure 3.5 - Different yarn cross sections & types of Speciality yarns"





An electrically conductive bicomponent filament yarn was also produced by melt spinning, where the sheath included an electrically conductive fine power of carbon black and the core was a synthetic polymer. Also, stainless steel was used as conductive filler to produce hybrid yarn. More recently, various metal oxides have been incorporated into the sheath of a bicomponent yarn. Unlike, carbon, metal oxides are often colourless and can be doped to greatly increase conductivity.

Other methods of producing an electrically conductive bicomponent material include using a high concentration of a metal compound in the core of the yarn.

- ***Braiding :***

Braiding, by the diagonal interlacing of yarns, is one of the oldest methods for producing fabric and cords. Flexible braided yarn like cord can be made electrically conductive simply by substituting one or more of its component yarns by fine metal wire or a yarn treated with an electrically conductive material.

- ***Plying and cabling of composite yarns :***

Single yarns can be twisted together to form plied yarns, which can be further twisted together to form cabled yarns. As with braiding, during manufacture, there is the opportunity to substitute a conventional yarn by an electrically conductive one.

- ***Novelty yarn production :***

Novelty yarns are generally used for decorative, rather than functional purposes. However, some novelty yarn constructions again offer opportunities for replacement of conventional yarn components by one that conduct electricity. A number of yarn constructions that might be used are shown here :

- ***Other methods :***

Other methods for making yarns electrically conductive is also used for imparting electrical properties in the material.

(C) Imparting electrical properties at fabric stage :
Fabric conductivity can be imparted as follows :

- Laminating conductive layers onto the surface of the fabric, such as conductive coatings, zinc are sprays, ionic plating, vacuum metallized sputtering , and metal foil binding.
- Adding conductive fillers such as conductive carbon black, carbon fibers, metallized fibers, metal fibers (stainless steel, aluminum, copper), and metal powders and flakes (Al, Cu, Ag, Ni) to the insulating material.
- Incorporating conductive fibers or yarns into the fabric; because the fibers are closely spaced, conductive paths can be easily established.
- Coating the surface of the fabrics by various methods like – Electroless plating, Sputtering, Evaporative deposition, Conventional coating technique (direct coating) and coating fabrics with conductive polymers.

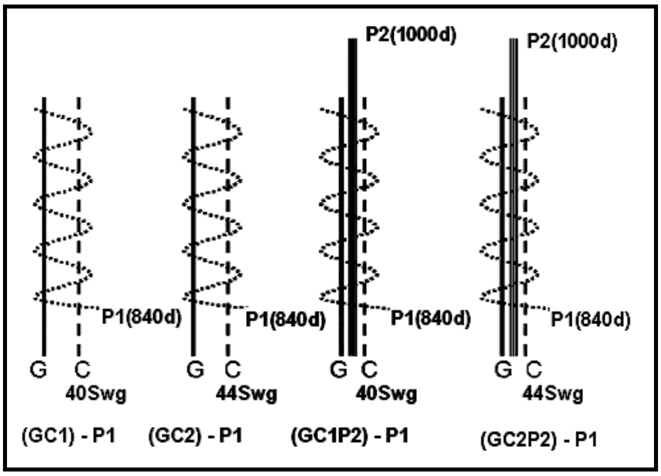
III. CASE STUDY
IMPARTING ELECTRICAL PROPERTIES AT YARN STAGE FOR DEVELOPMENT OF CONDUCTIVE LAMINATES

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

3.2 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 3.2.1 – Different Conductive yarns with Specifications"



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

IV. CONCLUSION

Four different varieties of Conductive yarns prepared on the Hollow spindle machine have successfully imparted conductive characteristics into yarns and then into fabrics prepared from above four types of conductive yarns on Simple Hand Knitting Machine. Laminates are also developed from these Conductive knitted fabrics using Hydraulic Press with Special Thickness Sample Plates. Final analysis from this case study also justify conductive characteristics as - the low values of Dielectric strengths and high values of Surface and Volume resistivity indicate that the composite materials are of conductive with good insulating characteristics. In same manner different methodologies are applied to enhance/impart conductive characteristics in ESD/Radiation protective materials.

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