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REVIEW ARTICLE

DEVELOPMENT OF SPECIALTY FABRICS FOR INTELLIGENT GARMENTS

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ABSTRACT

The Present paper describes the ways to make intelligent fabrics by making them conducive materials, i.e. breaking away from its traditional use as electrically insulating materials. For this purpose synthetic core /cotton sheath friction spun and disk spun yarns were used and incorporated in the fabric. Two models represented structures combining sensory materials others represented structures combining highly conductive materials with traditional fibrous material production trials in producing the electric wire core/cotton – polyester sheath yarns showed more challenges than the case of optical fiber core/cotton –polyester sheath yarn.

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INTRODUCTION

This paper represents a study in which specialty-textile product models, which exhibit a combination of inherent and artificial intelligences were developed. Some models represented structures combining sensory materials with traditional fibrous materials. Others represented structures combining highly conductive materials with traditional fibrous materials. In all models, the inherent intelligence stem from the use of traditional fibrous materials through their molecular and physical structures and the manipulation of these materials to provide optimum functional characteristics in the final product model. The artificial intelligence stems from the incorporation of smart materials such as sensory materials (e.g. piezoelectric sensors and nano-indenters), and electrical conductor matrixes.

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The key problematic issue of this study was to achieve a harmonized combinational structure with dual functional performance

- Inherent comfort & conformity
- Artificial sensing and electronic capabilities.

This problem was addressed through fundamental analysis of the interactive nature of traditional fibrous materials and artificial materials. Due to the complexity and lengthy details of the subject, our focus of this part will be on the analysis of the multi-component interactive nature of intelligent yarns.

The Concept of Functionality Elements Integration Cycle (Figure 1)

A value-added textile structure should be based on integrating traditional textile materials in a well-designed functionality cycle of product development. As shown in Figure 1, this cycle involves textile structures, human, and environment.

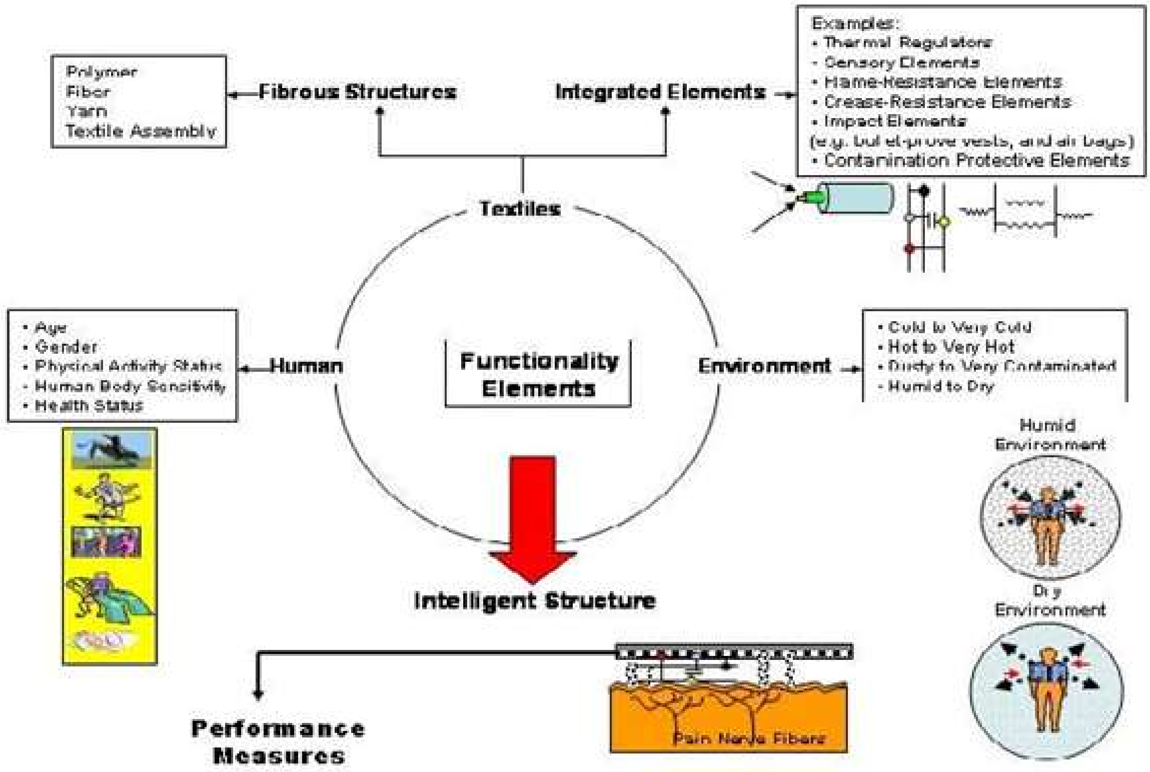

Figure 1. Functionality Elements Integration Concept (El Mogahzy, 2002)

Traditionally, textile products have been developed to provide mono-functional roles primarily driven by fashion and basic functionality (comfort and protection). In recent years, the development of a wide range of smart fibrous structures has resulted in a revolutionary revival of the concept of value-added textile design. From the early development of polymeric intelligent gels and shape memory silk yarn (Hongu T and Phillips G O, New Fibers, NY, Ellis Horwood, 1990) to the wide range of wearable information infrastructures available today (Smart Fibers, Fabrics and Clothing, The Text. Inst., CRC, 2001) progress in value-added textile structures has never ceased.

Challenges facing the Developments of Integrated Textile Structures

- Short-term durability
- Long-term reliability

Compatibility between traditional fibers and industrial components. Sensitivity to external handling (e.g. repeated washing and drying) and utilization conditions

One Approach that has not been fully utilized in this critical field is the development of wearable functional textiles that combine both the artificial intelligence provided by implanted elements (sensory, thermal regulatory, or electronic) and the inherent intelligence provided by natural and synthetic fibrous materials with the goal being to provide dual functionality of conformity/comfort/light weight, and intended functional performances.

Efforts in this direction have been hindered by the inability of some smart materials to conform and fit within traditional textile structures as a result of surface incompatibility and deficiency in the resistance to routine applications such as laundering, drying, and harsh handling. Other hindering factors included the lack of technology that can combine artificial elements with fibrous structures in such a way that can allow optimum dual functionality. Such technology can only be developed if the fundamental aspects of the interactive behavior of these materials are resolved (see Figure 2).

Experimental

Core/Sheath Yarn Developments in the Study

Three types of bi-component yarns were used, namely:
Dref-3 Friction yarn: Figure (3)
Murata MVS yarn
NRC-Disk yarn: Figure (4)

Objective: Developing a core/sheath yarn forming system suitable for making industrial and high-tech fabrics

We used a research Dref3 Friction Spinning Unit located in Auburn University Laboratory (see Figure 3). In this unit, drafting was achieved using a drafting roll system. The incoming fiber strand was changed to accommodate a single sliver, multiple slivers, and a combination of a sliver and continuous filament yarn. The consolidation mechanism was achieved by twisting fibers against friction drums.

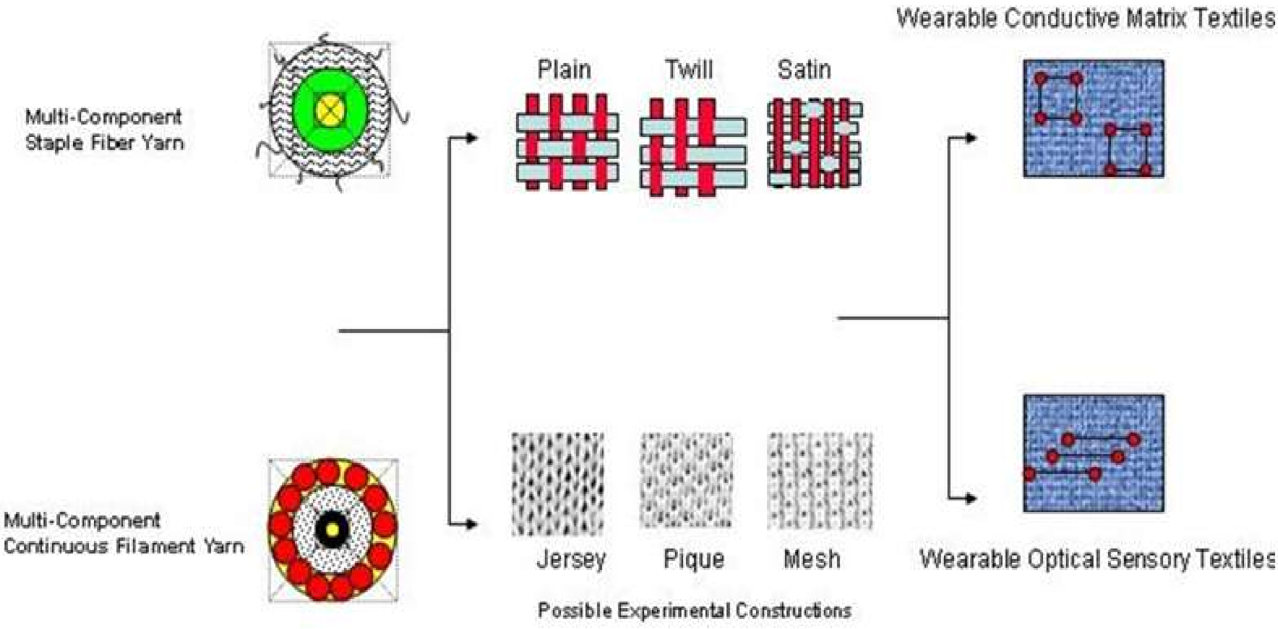

Figure 2. The Development Scheme of Specialty Inherent/Artificial Textiles

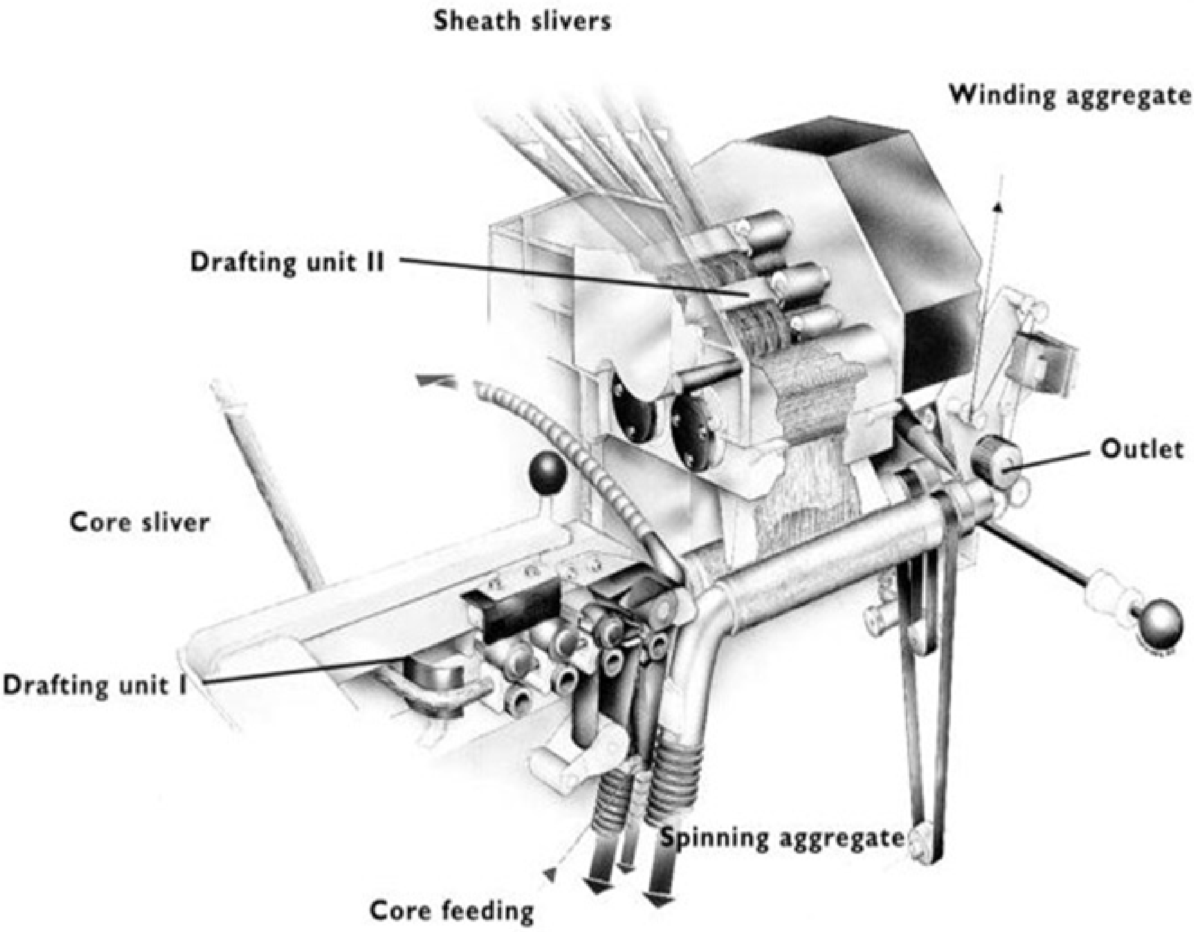

Figure 3. Dref-3 Friction yarn

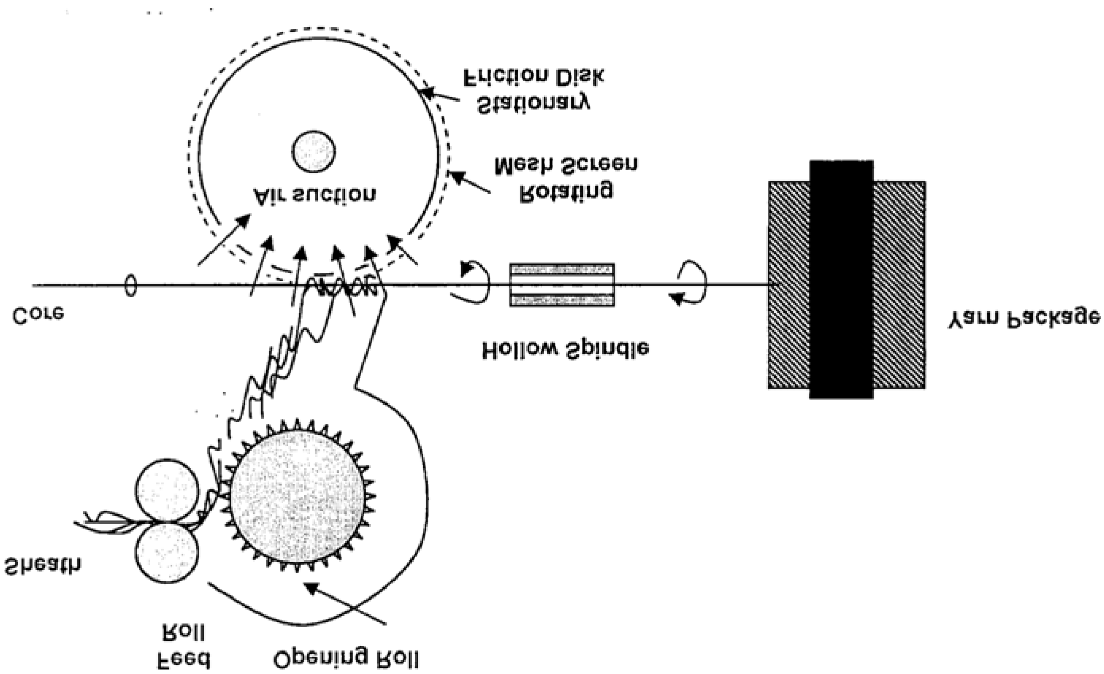

Figure 4. Core/sheath unit developed by the National Research Center (NRC) of Egypt

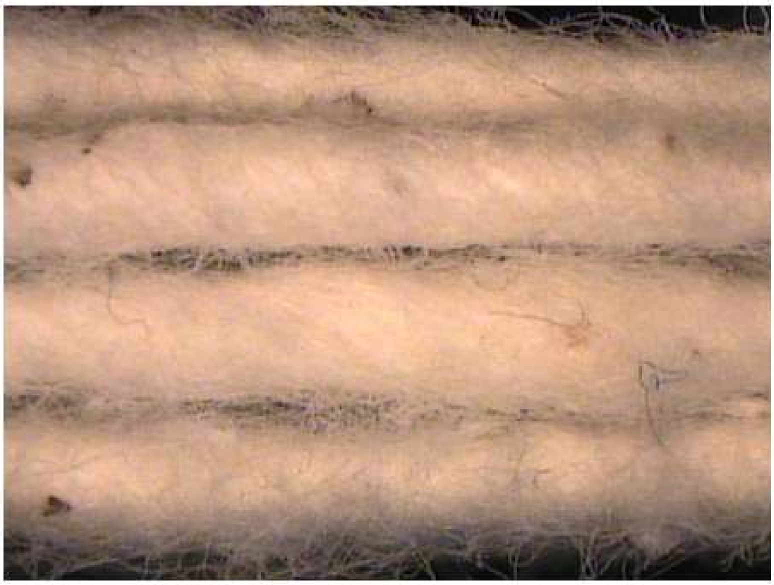

Figure 5. Mop Yarn 85% Egyptian cotton waste fibers /15% Polyester [Dref3 Friction Spinning]

Upon drafting of the input sliver, fibers were carried by means of air current to a collecting point between two friction drums rotating in the same direction. At this point, twisting formed the yarn. The twist was imparted by the relative rotation between the surface of the drums and the yarn. Thus, the rotating element in this case was the yarn itself with a very high rotational speed due to the very high drum/yarn diameter ratio. The amount of twist in the yarn was determined on the basis of this ratio, and it was estimated by the ratio of the yarn tail rotational speed to the drum surface speed. To make a core/sheath yarn, fiber materials were fed to the spinning unit from two different drafting units. The first unit was a 4/4 roller drafting system.

This system allowed a draft ratio in the range from 100 to 150 (a factor of the study). The drafted sliver was then fed to the twisting unit to form the yarn core. The other drafting unit represented a separation system, which consists of a pair of wire-covered drums that separates the fibers. An air current then carried the fibers down to the twisting zone. These fibers were wrapped around the core strand by the action of the friction drums. A filament or staple yarn was fed to the twisting unit with the core staple fibers to form a composite core strand. In this study, we focused on a combination blend of Egyptian cotton and two types of synthetic fibers:

- Polyester Micro-denier fibers made in the U.S. (Welman Corp, SC),
- Optical-coated nylon filament.

DREF 3 can handle a wide range of raw material. The core fiber from the first drafting unit can be almost any synthetic fiber including industrial fibers (e.g. aramid and carbon); these fibers can be pure or blended. Cotton can be used as a component in a blend with synthetic fiber, or it can be used independently. The second drafting unit uses the same fibers with the addition that it can use carded cotton sliver. We used a variety of filaments that can be used include metallic wire, glass filament, elasto-meric filament, monofilament, textured filament, and high tenacity filament. The sliver weight range for the drafting units is 2.5-3.5 ktex (35-50 gr/yd) for each sliver. The fiber fineness may range from 0.6 to 6.7 dtex (0.5-6.0 denier).

The staple length is limited to 1.25-2.5 inch. DREF 3 can produce yarns in a count range from 0.18's to 18's (667-33 tex).The delivery speed may reach up to 300 m/min depending on fiber type and yarn count. In the initial phase of this study, we made several spinning trials in which yarns were spun from two Egyptian cotton varieties Wastes (Giza 70 and Giza 80) used as sheath with polyester yarn used as core. The sheath/core ratio was85%/15% A Microscopic image of the yarn produced in this stage of work is shown below Figure (5). This yarn has a fineness of 0.7s (or 842 tex). Testing the yarn revealed strength of 21.69 lb. and elongation % 31.52. In line of industrial application, the yarn was plied using Z on S twist and twist ratio of 1.4/4.5 turns/inch. This qualifies the yarn to industrial applications such as utility ropes and mop yarns. In the second phase we developed two sets of core/sheath yarns, one by the Disk-Spinning system developed by the center (Figure 5) and another by Auburn Dref3 unit.

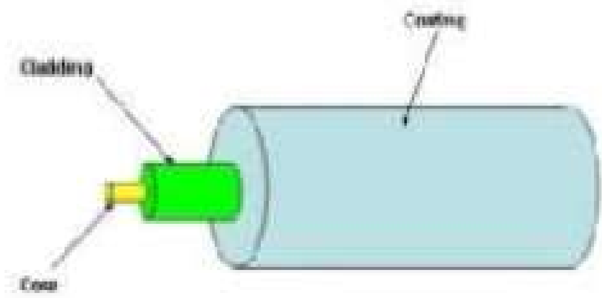

Figure 6. Structure of Optical Fiber

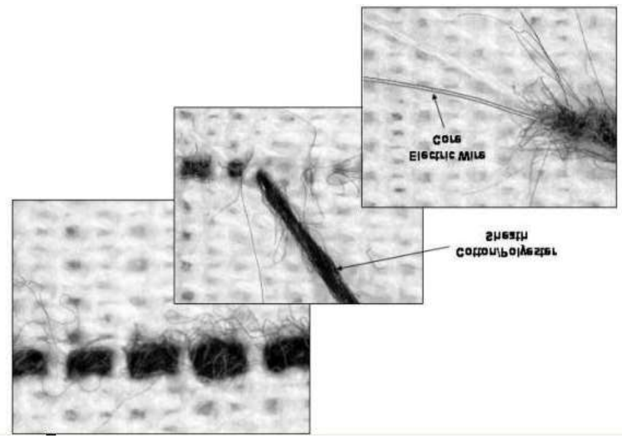

Figure 7. Interwoven Specialty Core Wire –Sheath Fibers Yarns

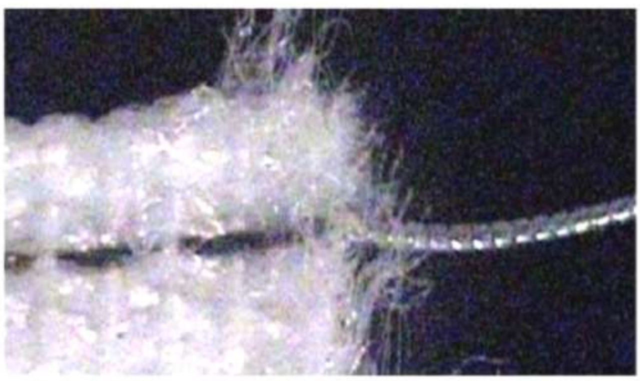

Figure 8. Interwoven Specialty Core Optical Fibers/Sheath Cotton/Polyester Yarns Wire –Sheath Fibers Yarns

In addition, we examined the influence of frictional characteristics of core and sheath on structure, twist and tensile properties of DREF-3 friction spun yarns and disk-spun yarns. The results of this examination have resulted in optimizing the systems to produce finer core/sheath yarns suitable for high-tech applications. One particular aspect that has been optimized was yarn strength with respect to sheath slipping resistance. Based on the second phase work, it was realized that in case of filament-coreDREF-3 friction spun yarns, the friction between the core and the sheath and the inter-fiber friction with in the sheath can be changed by either modifying the core-filament surface character through twisting and air-jet texturing process or by changing the sheath fiber friction through the application of different level and type of spin finish over the fibers. The frictional characteristics of core and sheath components was measured by using a new approach developed on the basis of measurement of friction between fibre fringes (El Mogahzy and Broughton). The frictional characteristics, namely, fiber-to-filament friction and fiber-to-fiber friction were therefore measured to investigate the influence of fiber friction onyarn structure, twist and tensile properties. In the third phase of the study, we shifted our attention to making industrial fabrics from core/sheath fabrics. The idea was to develop two specialty-textile product models that exhibit a combination of inherent and artificial intelligence. The first model was a structure combining sensory materials (optical fiber) with traditional fibrous materials. The Figure below (6) shows the structure of optical fibers, which was obtained from Zaks-Sensory Corporation.

The second model was a structure combining highly conductive materials with traditional fibrous materials. In both models, the inherent intelligence stemmed from the use of traditional fibrous materials that are inherently smart by virtue of their molecular and physical structures and the manipulation of these materials to provide optimum functional characteristics in the final product model. The artificial intelligence stemmed from the incorporation of smart materials such as sensory materials (e.g. piezoelectric sensors and nano-indenters), and electrical conductor matrixes in a more recent phase of work,

Two different yarns types were designed

- Electric wire Core/Cotton-Polyester sheath using Dref System (see Figure 7).
- Optical fiber Core/Cotton-Polyester sheath using both Dref and MVS systems (see Figure 8).

In producing the Electric wire Core/Cotton-Polyester sheath yarn, major challenges had to be overcome. The biggest challenge was the need to use two materials that were fundamentally and inherently different.

The copper wire and the fibrous material, while the fibrous material is flexible and stretchable, the metallic wire was stiff and un-stretchable. To make matters more complex, the two materials exhibited completely different surfaces with the metallic surface being smooth and slippery and the fibrous surface exhibiting its familiar morphology. The goal at the end was to produce a homogenous core/sheath yarn that can withstand the various stresses involved in the weaving process. This was accomplished through optimization of a number of processing parameters including air pressure at the friction drum zone, sliver draft, and metallic wire Fineness. The key design aspect was a very fine metallic wire of 8 micron diameter. In order to enhance the core/sheath adhesive integrity, it was important to alternate feeding polyester slivers and cotton slivers in the fiber stream. This created some form of a braided effect which was useful in enhancing the adhesive interaction between the metallic core and the fiber sheath.

Conclusions

- Core/sheath yarn is obtainable using Dref 3 Friction Spinning, MVS air spinning and recently development Disk Spinning system.
- Challenges in producing the electric wire core/cotton – polyester sheath yarns are managed. This can be achieved by optimizing a number of processing parameters including air pressure at the friction drum zone, sliver draft, and metallic wire fineness.
- Enhancing the core/ sheath adhesive integrity is reachable by alternating feeding polyester slivers and cotton slivers in the fiber stream in order to obtain a braided effect, which is useful enhancing the adhesive interaction between the metallic core and the fiber sheath.
- Fewer challenges were encountered in the optical fiber core / cotton- polyester sheath yarn.

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