STUDY ON THE PERCOLATION THRESHOLD of CONDUCTIVE HYBRID YARN

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Abstract: The aim of the project is to produce conductive hybrid yarns, in which conductive fibers are used as the sheath along with polyester fibers and Glass/PEEK filament yarn as the core. To produce the conductive hybrid yarn, at first blended sliver is produced in a conventional draw frame by mixing steel and polyester sliver. Then the hybrid yarns are produced by DREF 2000 friction spinning technique using the blended sliver and Glass/PEEK filament yarn. It is observed that the electrical properties of hybrid yarns are changed remarkably if the amount of sheath fibers is decreased or increased. The resistance of these yarns increases with the increase of length and decrease with the increase of the amount of yarn sheath. The relationship is nearly linear. It is also observed that the resistance of these yarns also depends on the core filament of the yarn. The characteristics of electrical resistance property of hybrid yarns are also explained from the view point of percolation threshold.

Key Words: Percolation threshold; Hybrid yarn; Friction spun yarn; Electric conductivity

1. INTRODUCTION

The use of fibers, yarns and textiles is rapidly increasing from the view point of electric conductivity for the production of industrial materials such as sensors, electrostatic discharge, electromagnetic interference shielding, dust and germ-free clothing, health monitoring, smart clothing, data transfer in clothing etc.

Conventional textiles i.e. yarn and fabrics are usually manufactured from electrically non-conductive fiber. In order to incorporate conductivity in conventional textiles, there are several methods available. One of the easiest ways is to use of conductive textile fiber. There are two different types of conductive fibers or filaments. One is naturally conductive and another one is treated to make them conductive. Carbon, metal fibers such ferrous alloys, nickel, stainless steel, aluminum, copper etc are the example of naturally conductive fibers [1]. Conductive fiber or filament can also be produced by special treatment such as metal coating. Synthetic fiber or filament is usually treated with copper, silver or nickel to produce conductive fiber or filament. In [2,3] silver (Ag) coating of non-conductive filament is described to produce conductive filament. It is also possible to mix conductive filament or staple fiber to produce yarns. Different spinning techniques such as core spinning technique, wrap spinning technique, DREF spinning technique, composite spinning technique or ring spinning technique can be used to produce conductive hybrid yarn [1]. In [4] the use of steel fibers with polypropylene for the production of conductive hybrid yarns is described.

In this experiment, conventional draw frame machine is used for the production of blended slivers using polyester (PES) and steel sliver. Conductive hybrid yarns are produced in DREF 2000 friction spinning machine. PEEK/Glass filament yarn is used as the core of the hybrid yarn and the blended sliver (i.e. PES and steel) is used to produce the sheath. Finally the electrical properties of the conductive hybrid yarns are measured and analyzed.

2. HYBRID YARN

Hybrid yarns contain two or more different fibers in its structure. The benefit of these yarns is that they have the properties of two or more different components at the same time.

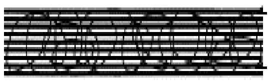
Hybrid yarn structure	Fibre arrangement geometry
	Reinforcing and matrix fibers are commingled.
	Parallel arrangement of reinforcing fibers in the core and spun fibers in the skin.
	Mixture of discontinuous reinforcing and matrix fibers surrounded by continuous matrix filaments.

Fig. 1 Structure of hybrid yarn with fibre geometry

The hybrid yarns can be produced by different technologies such as commingling process, friction spinning and schappe technology. The structures of hybrid yarn with fiber geometry are shown in figure 1.

Hybrid yarns can also be produced by twisting two or more components as shown in figure 2. Among different hybrid yarn manufacturing techniques, friction spinning technique is found more suitable for the production of functional/conductive hybrid yarn [5-7].

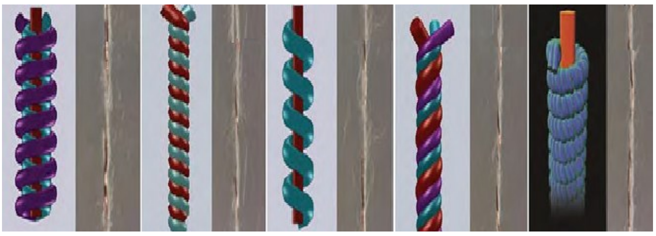


Fig. 2 Structure of hybrid yarn

3. EXPERIMENTAL DETAILS

3.1 Mixing of Sliver in Drawing frame

Two different types of sliver such as steel and polyester sliver are used in drawing frame for manufacturing a blended sliver. The sliver of steel fiber has a count of 4 ktex where as the count of polyester sliver is 5 ktex. At first three slivers of steel and three slivers of polyester as shown in figure 3 are fed in draw frame machine. The sliver is collected in six different cans, so that the process can be carried out further to get more uniform mixing effect of the blended sliver. The total draft given in drafting zone of draw frame is 6.046 and it is divided in three different zones such as Z1: 1.4, Z2: 2.59 and Z3: 1.78.

Fig. 3 Feed of slivers in draw frame for first passage

As the main object is to produce a blended regular parallelized sliver by mixing two different types of fibers, the blended slivers are fed in draw frame machine for second passage to produce a more uniform sliver. Finally a uniform blended sliver is manufactured in draw frame and the count of the blended sliver is measured.

3.2 *Production of Hybrid yarn in DREF Friction Spinning Machine*

By using DREF 2000 friction spinning machine as shown in figure 5, different types of hybrid yarns are produced by changing core yarn and applying different types of sheath count. 300 tex glass filament or 46 tex PEEK filament yarn is used as the core. The blended sliver from draw frame is used as sheath. The other parameters of the machine were same, such as delivery speed 50m/min, spinndrum speed 1500/min, opening roller speed 4500/min, central extraction 2000/min. Sheath counts used for PEEK filament core are 50 tex, 100 tex, 150 tex and 200 tex. In case of glass filament core sheath counts are 100 tex, 150 tex, 200 tex and 300 tex.

3.3 *Measurement of Electrical Resistance of Hybrid Yarn*

A digital multi-meter (FLUKE 8846A) is used to measure the electrical resistance of hybrid yarns. The resistances of eight different types of conductive hybrid yarns are measured, which are manufactured by DREF 2000 friction spinning machine. The two ends of the hybrid yarn are fixed with tension in a wooden frame as in figure 4. Then the resistance of the samples is measured at different distances between the ends of the specimen as for example 10 cm, 20 cm. 30 cm, 50 cm and 60 cm. At least 10 measurements are taken to get the average value for each length of hybrid yarns.

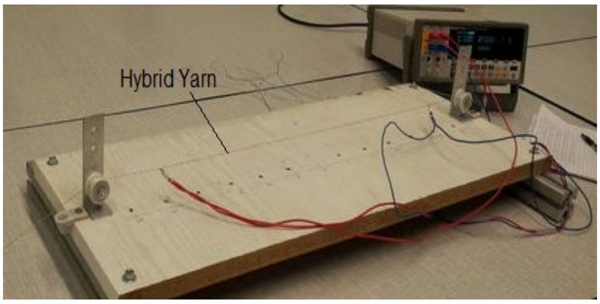


Fig. 4 Method of measuring electrical resistance

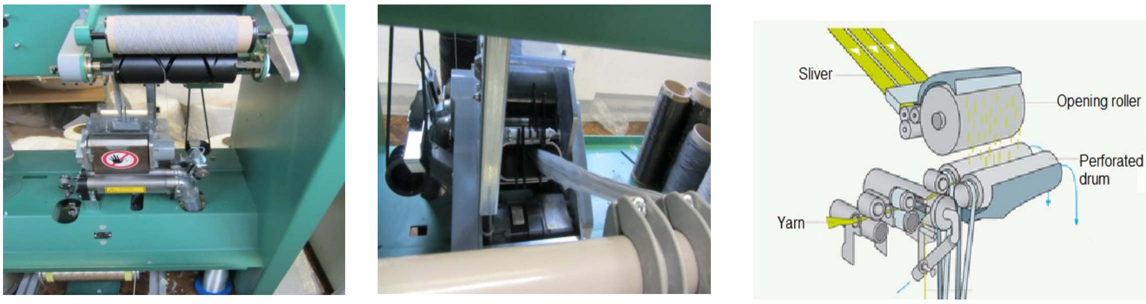


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Fig. 5 Manufacturing of hybrid yarn in DREF 2000 friction spinning machine

TABLE 1: Count of Hybrid Yarn Produced in DREF 2000 and % of Steel Fiber in Yarn

Sl. No.	Core filament	Count of core in tex	Sheath count in tex	Resultant yarn count in tex	Steel% in hybrid yarn on the basis of weight	Steel% in hybrid yarn on the basis of volume
1	Glass	300	100	425	10.5	3
2	Glass	300	150	485	13.7	3.9
3	Glass	300	200	540	16.5	4.6
4	Glass	300	300	665	20	5.6
5	PEEK	46	50	100	22.25	6.25
6	PEEK	46	100	168	26.5	7.4
7	PEEK	46	150	230	29	8.15
8	PEEK	46	200	307	29	8.15

4. RESULT AND DISCUSSION

4.1 *Count of the Sliver Produced in Draw Frame*

The count of sliver produced in draw frame by mixing steel and polyester fiber is measured by gravimetric method and it is found 4.4 ktex. The amount of steel fiber in sliver on the basis of weight and volume is 44.5% and 12.5% respectively.

4.2 *Fineness of Hybrid Yarn Produced in DREF 2000 Friction Spinning*

The fineness of the resulting hybrid yarns are determined by gravimetric method, which are listed in table 1. The amount of steel fiber% in the total yarn on the basis of weight and volume is also calculated.

4.3 *Result of Electrical Resistance Measurement*

It is observed in the figure 6 that the resistance of the hybrid yarn depends on the fineness of sheath and length of the yarn. From the figure 7 it is observed that the resistances of hybrid yarn increase with the increase of length and decrease with the increase of cross sectional area of the conductive yarn that is with the increase of sheath of the hybrid yarn. The larger the cross-sectional area of the hybrid yarn, the more electrons per unit length is available to carry the electricity. As a result the resistance is lower in larger cross-section of the yarn. The relationship, which is found in the experiment between length and resistance can be described as near about linear.

It is observed in figure 6 and figure 7 that there is a similarity in the change of resistance at different sheath fineness for both the core filament, though the cores have different fineness. It is due to the sheath of the hybrid yarn, which is made of conductive steel fiber and PES component. It is also observed that the resistance of conductive hybrid yarn depends on the type and count of core filaments. It is seen that the resistance of the hybrid yarns are not same for both types of core filament, when the length and sheath of yarn are constant.

4.4 *Behaviour of Electrical Properties in Terms of Percolation Threshold*

The electrical behavior of hybrid yarn due to the presence of highly conductive fibers can be discussed in reference to the percolation threshold of the fibers. The following curves as shown in figure 8 represent the conductivity of hybrid yarns vary on the amount of steel fibers in the sheath with different core filament when the length is constant. It is observed that the electrical resistance of the hybrid yarns dramatically decrease at a certain fiber concentration and after that it is continuous, which is termed as percolation threshold. From the result, it is also observed that when a certain amount of conductive fibers have been added to the hybrid yarn, then a continuous path of electrical current exist in the yarn. The percolation threshold of hybrid yarn produced using PEEK filament is 6.25% of volume or 22.25% on weight.

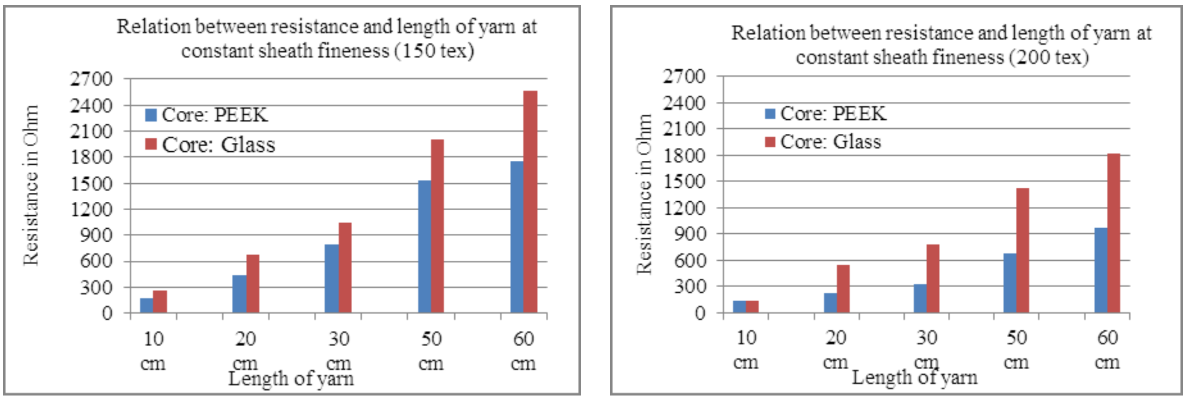

Fig. 6 Relation among resistance, length, sheath and core of hybrid yarn

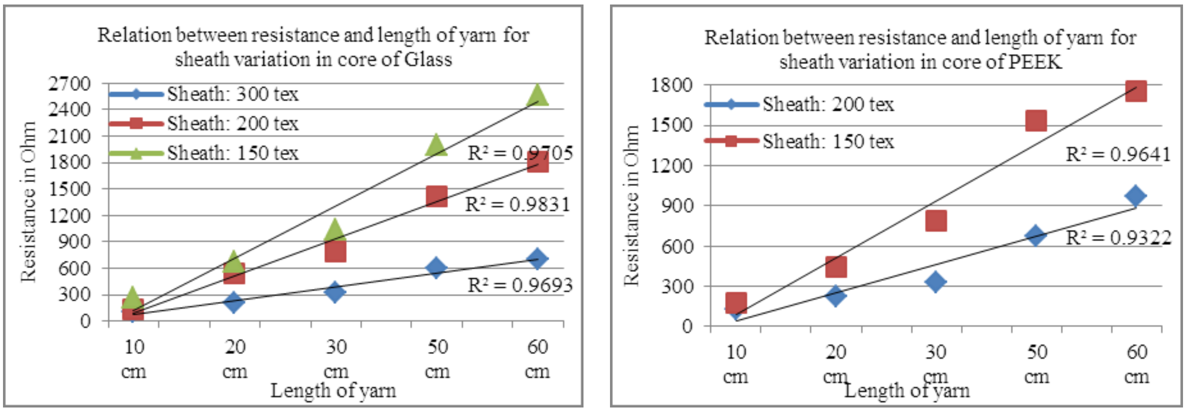

Fig. 7 Relation between resistance and length of hybrid yarn at different sheath fineness for two different core filament yarns.

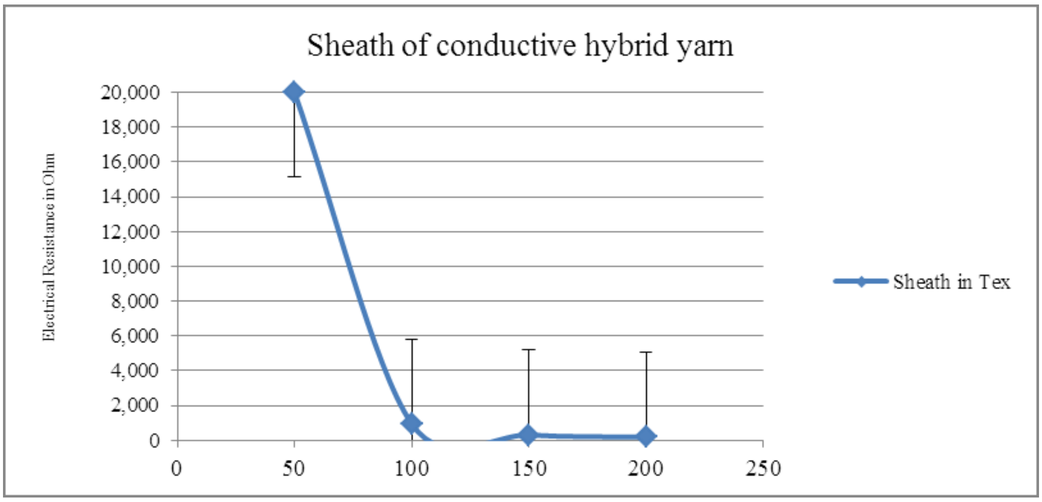

Fig. 8 Relation between electrical resistance and amount of steel fibers in sheath when core is PEEK and sheath is steel with polyester.

5. Conclusion

Blending of steel and polyester fiber with a core filament of PEEK or glass produces a conductive hybrid yarn, which were studied with respect to their electrical properties. It became obvious that in case of the steel, polyester and PEEK/glass hybrid yarns the conductivity was related to various factors such as steel fiber concentration, length of the yarn, type of core and sheath ratio. It is shown that dependence of electric conductivity on the length of yarn is linear. A correlation between the electric conductivity and the blend fibers of steel/polyester is revealed.

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References

[1] Steve Verstraeten, Jan Pavlinec, Pol Speleers, "Electrically conductive yarn comprising metal fibers" US Patent 6957525, Oct 25, 2005

[2] Onger T, "Silver (Ag) coating of Polyester yarn to modify yarn surface", Ph. D. Defense, Technical University Dresden, Germany, 2011.

[3] A.B.M Foisal, "Conducting coating of polyether ether ketone", Master theses no. 1420, Technical University Dresden, Germany, December, 2012.

[4] Veronika Safarova, Jiri Militky, "A study of electrical conductivity of hybrid yarns containing metal fibers", *j. of materials science and engineering B2*, Volume 2 pp. 197-202, 2012.

[5] M.M.B. Hasan, A. Matthes, P. Schneider and Ch. Cherif, "Application of carbon filament (CF) for structural health monitoring of textile reinforced thermoplastic composites", *Materials Technology*, volume 26, pp. 128-134, 2011.

[6] Mir Mohammad Badrul Hasan, Olaf Diestel and Ch Cherif, "Electromechanical properties of friction spun conductive hybrid yarns made of carbon filaments for composite", *Textile research journal*, volume 81, pp. 1603-1616, june 2011.

[7] M.M.B Hasan, Ch. Cherif, A. Matthes, "Early prediction of the failure of textile-reinforecd thermoplastic composites using hybrid yarns", *Compostie science and Technology*, volume 72, pp.1214, 2012.