# Manufacturing Condition and Properties Relationship on Carbon-Core/Polyimide-Sheath Composite Yarns Produced by the Friction Spinner(DREF 2)

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## 1. Introduction

Composite spun yarns generally have bicomponent structures. One of them forms the center axis or core of the yarn, and the other the covering. The core part is used usually a continuous multifilament yarn, while staple fibers used for the outer covering or sheath. Composite spun yarns have produced in order to improve the strength, durability and functional properties of fabrics.(1~3)

The DREF 2 is a friction spinning machine developed by Ernst Fehrer Co. in Austria. In this spinning machine, fibers are wrapped around the parallelized core fibers to impart structural integrity to the yarn. The fiber feeding in the core and sheath components for making the yarn is independently controlled to allow the selective combination and placement of different materials for the purpose of functional, economic and/or aesthetic characteristics.(4,5)

In this study, we have investigated the effects of manufacturing conditions on morphological structures and physical properties of carbon-core/polyimide-sheath(C/PI) composite yarn manufactured by DREF 2 friction spinning machine. The C/PI composite yarn produced may applied the wide range fields, required high strength and high heat resistance, such as gloves, bullet-proof jackets and so on.(6~8)

## 2. Experimental

### 2.1 Yarn preparation

For this study, we used carbon filaments(Torayca T-300) of linear density 66tex for core part and polyimide(PI 84®) fibers having 0.3tex in linear density and 51mm in fiber length for sheath part in order to manufacture C/PI composite yarn. In addition, polypropylene(PP) fibers having 0.2tex in linear density was used as carrier fibers for increasing carding efficiency.

After producing the C/PI composite yarn, two kinds of yarns are prepared to observe the yarn structure with the point of bonding shape and slippage behavior: PC/PI(plied C/PI composite yarn) and PC/PIF(plied C/PI composite yarn with PET filaments) composite yarns. Table I shows fiber contents for each samples. Where sample A and B are indicated difference sliver conditions(drawn and carded slivers, respectively) to compare fiber orientation efficiency in C/PI composite yarn.

Table I : Fiber contents for manufacturing the C/PI composite yarn.

| Fiber Contents / Linear Density(tex) | Polyimide (%) | Polypropylene (%) | Carbon (%) | Sliver type |
|---|---|---|---|---|
| A (245) | 59.2 | 14.8 | 26 | Drawn |
| B (245) | 59.2 | 14.8 | 26 | Carded |

2.2 Spinning machine and methods

All yarns were manufactured by using the DREF 2 friction machine. C/PI, PC/PI, and PC/PIF composite yarns were treated with different heating temperature, heating time, and TPI conditions to observe melting behavior of PP and PET fibers in the composite yarns, as shown in Table II.

Table II: Heating conditions of the C/PI composite yarn.

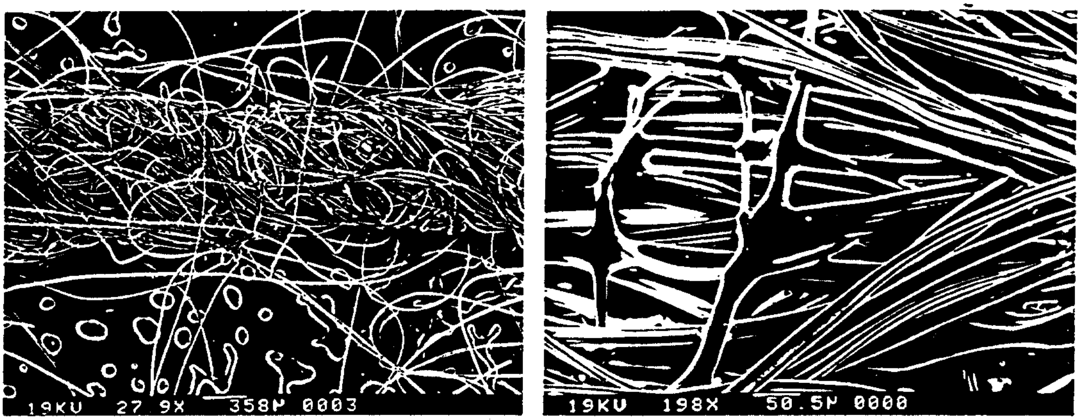
| Heating condition / Samples | Heating temperature(℃) | Heating time(min) | Twist density (twist/inch) |
|---|---|---|---|
| C/PI | 145, 150, 155 | 5, 10, 15 | ------ |
| PC/PI | 155 | 5, 10, 15 | 1, 2, 3 |
| PC/PIF | 270 | 5, 10, 15 | 1, 2, 3 |

The physical properties included breaking stress, breaking strain, initial modulus, peeling strength, and frictional characteristics, such as frictional coefficient(MIU), deviation of the friction coefficient(MMD), and geometrical roughness(SMD) were tested with various samples by produced different conditions.

Tensile properties and peeling strength of the yarns were measured on a Shimadra AGS-500B(Japan) and frictional characteristics were measured on a KES-FB-4 surface tester. The yarn structure were observed on a scanning electronic microscopy (JEOL JSM-T 100) as well as an optical microscopy.

## 3. Results and Discussion

SEM microphotograph of surface structure of heat treated C/PI composite yarn is shown in Fig. 1. From this photographs, polypropylene fibers were shown locally melting in the surface of the yarn. As this melting degree, tensile properties of the yarn showed considerable differance. The more melting degree of PET increases, The more bonding force between core and sheath is consolidated and increased cohesion.



(a) (b)

**Fig. 1. SEM photographs of surface structure of heated C/PI.**
**; (a) Longitudinal view. (b) Enlarged view.**
**(heating time : 15min, temperature : 155 ˚C)**

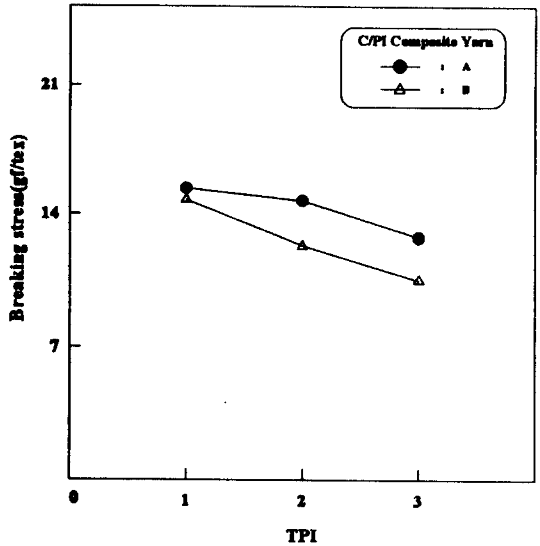



**Fig. 2. Effect of TPI on the breaking stress of the C/PI.**

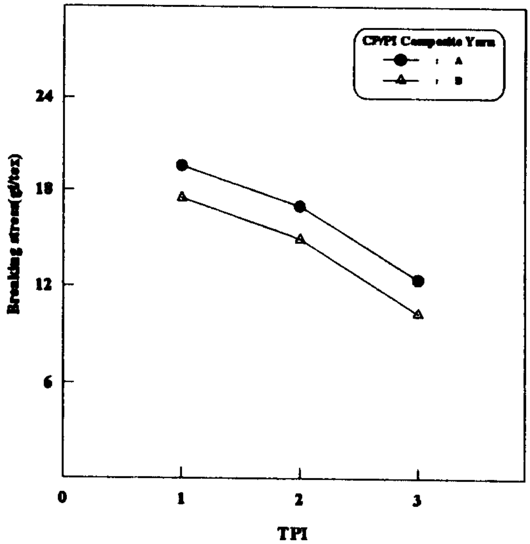



**Fig. 3. Effect of TPI on the breaking stress of the CP/PI.**
**(heating time : 15min, temperature : 270 ˚C)**

Fig. 2 and Fig. 3 show the effect of plied twist density on the breaking stress PC/PI and PC/PIF composite yarn with difference sliver conditions and heat treatments.

Heat treated C/PI yarn was more increasing than untreated that of the breaking stress. As stated above, this is because the fiber structure between core and sheath part has increased cohesion and consolidated by melting of PET. The breaking stress also was decreased with increasing the twist density, resulting in enforcement torque efficiency of core/sheath fibers.

The effect of heating time on the frictional coefficient of C/PI yarn is shown in Fig. 4. The frictional coefficient(MID) of the C/PI yarn has slightly increased with increasing heat temperature due to the bonding force of PP fiber in melting portion. This is because sheath structure of fiber has stiff by melting PP. That is, As increased heat temperature, PP is melted more perfectly and PP of melted into sheath fibers is brought about increasing of MID by stiff portion of sheath structure.

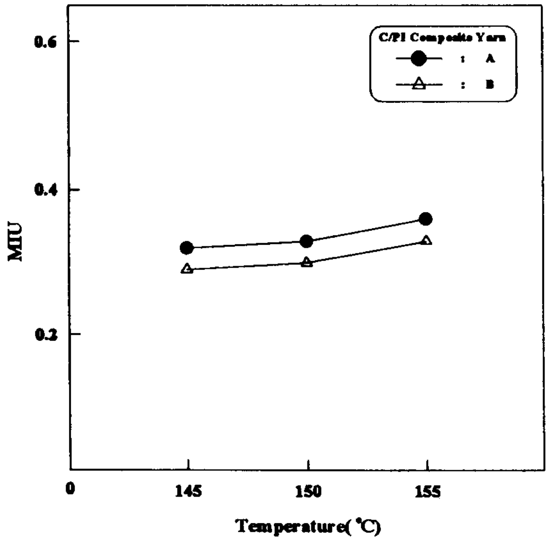



**Fig. 4. Effect of heating time on the MIU of the C/PI. (heating time : 10min)**

## 4. Conclusion

Melting degree of PET filaments affects physical properties of PC/PIF composite yarn. The more melting degree of PET has increased, The more bonding force between core and sheath fibers is consolidated and increased cohesion. This is brought about increasing of breaking stress of C/PI composite yarn. The breaking stress also is decreased with increasing the twist density, resulting in enforcement torque efficiency between core and sheath fibers. MID of the yarn is slightly increased with increasing temperature because of PP filament melting. This is because sheath structure of fiber is stiffed by melting PP. That is, As increased temperature, PP is melted more perfectly and PP of melted into sheath is brought about increasing of MID by stiffness of sheath structure.

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