Development of Nylon Sportswear Fabrics by Composite Spinning

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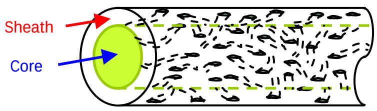
Abstract

This study surveys to develop multi-functional nylon sportswear fabrics by composite melt spinning technology. Nylon multi-functional garment with light weight, quick drying and heat-insulating properties has been developed by using hollow filaments. The light weight and good quick drying properties are needed for making high added value nylon fabrics for multi-functional garment. For getting these properties of nylon fabrics, spinning, weaving and fabric reduction technologies as an elution have to be considered. For this purpose firstly composite spinning technology with polyester and nylon conjugate structure has been studied. Multi-functional nylon high hollow filament was developed by application of high reduction technology to the PET in a core part. The reduction conditions such as concentration of NaOH, bath temperature and reduction time are chosen. The physical properties of the various eluted filaments are measured and discussed with various elution conditions. And then the nylon sportswear fabrics are woven by using nylon hollow filament reduced with various process conditions, the mechanical properties of this fabric are measured using KES-FB system, and these mechanical properties are discussed with various process conditions.

Keywords: nylon, sportswear, composite spinning, eluting condition, hollow filament, quick dry fabric

1. Introduction

The manufacturing of the hollow filament is composed of spinning and elution technologies for making hollows on the yarn cross section. It is a high technology being widely used for PET and Nylon. Hollow filament is used as multi-functional garment material because of its light weight, and quick drying properties. Hollow filament is now available in polyamide, and lighter than conventional filaments, by 20 to 25%, furthermore their improved thermoregulating property also makes them more comfortable to wear.[1-4] The light weight and quick drying properties are also needed for making high added value nylon fabrics for multi-functional garment. Fig. 1 shows the schematic of hollow filament and hollow fabric.



(a) Schematic of hollow filament (b) Hollow fabric

Fig. 1. Schematic of hollow filament and fabric

For getting these properties of nylon fabrics, spinning, weaving and weight reduction technologies as an elution have to be applied. But the hollows are damaged during the yarn texturing and weaving process makes it difficult to develop hollow filament because of weak textured filament.

Recently Unitika developed Wincall® hollow filament, and the C type hollow filament developed in this study is compared with the material characteristics of Wincall®. This study is aiming to develop multi-functional nylon high hollow filament by application of high reduction technology to the PET in a core part. For this purpose, the elution conditions are chosen as concentration of NaOH, bath temperature and elution time. The yarn physical properties such as thermal shrinkage, tensile property and reduction rate are measured and discussed. And then the nylon fabrics are woven by using nylon hollow filament yarns reduced with various process conditions, the mechanical properties of these fabrics are measured using KES-FB system[5], and these mechanical properties[6,7] are discussed with various process conditions.

2. Experimental

2.1 Specimens

Table 1 shows specimens of nylon high hollow filaments used for this study. Wincall® is textured to DTY 50d/16f using POY 70d/16f. C type hollow filament is made by SDY 70d/48f in KTDI spinning m/c. And also SDY 80d/48f, EEP like Wincall® is made in KTDI spinning m/c.

Table 1 Nylon high hollow filaments

	Hollow filament	Remark
Wincall®	POY 70d/16f DTY 50d/16f	JAPAN (UNITIKA)
C type	SDY 70d/48f	KOREA (KTDI)
EEP	SDY 80d/48f	

Table 2 shows the weaving condition. The 9 specimens of 3 types of hollow fabrics were woven for specimens.

2.3 Eluting conditions

Table 3 shows the eluting condition of tube knitted fabric and fabric. The tube knitted fabrics were eluted before weaving to determine the eluting condition of hollow filament.

2.4 Dyeing and finishing conditions

Table 4 shows dyeing and finishing conditions of nylon woven fabrics by composite spinning. Hollow fabrics made of C type and Wincall® were eluted by CPB. C types can be eluted by CPB but not Wincall®. So, Wincall® hollow fabrics were eluted by Rapid. EEP hollow fabrics developed by KTDI were also eluted by Rapid.

2.2 Weaving conditions

Table 2 Weaving conditions

		Denier		Density (/inch)		Fabric width (inch)		Weave	Tube knitting condition	Remark
		warp	weft	warp	weft	grey	finishing			
Wincall®	HH-1	N/DTY 50/16 SD		141	110	62	59	Plain	Stocking knitting M/C Needle gauge : 24 gauge	JAPAN
	HH-2			141	120					
	HH-3			156	110					
	HH-4			156	120					
C type	THH-1	N/F 70/48 SD		124	92	62	59			KOREA
	THH-2			124	102					
	THH-3			136	92					
	THH-4			136	102					
EEP	THH-5	N/F 80/48 SD		136	70	62	59			

Table 3 The eluting condition of hollow filament with tube knitting and fabric

	Tube knitting			Fabric		
	C type	Wincall®	EEP	C type	Wincall®	EEP
NaOH (g/l)	20, 30, 40	30, 40	40	30, 40	30, 40	30, 40, 50
Bath temp. (℃)	40, 50, 60	room temp., 50, 60, 85	room temp., 85	room temp., 50, 60, 85	room temp., 50, 60, 85	85, 95
Elution time (min.)	30, 60	24 hr, 60, 120	24 hr, 60, 120	24 hr, 30, 60	24 hr, 60, 120	60, 120

Table 4 Dyeing and finishing process conditions

<table>
<tr><td colspan="4">CPB (Cold Pad Batch)</td><td colspan="3">Rapid</td><td>Finishing</td></tr>
<tr><td>Scouring</td><td>Padding</td><td>Desizing</td><td>Aging</td><td colspan="2">Eluting</td><td>Dyeing</td><td>Tenter</td></tr>
<tr><td rowspan="2">· 2 times
· H_2O 30ton
· NaOH 45% 3,000kg</td><td colspan="2">H_2O 2,000L</td><td rowspan="2">48hr</td><td>1st</td><td>· H_2O 1,500L
· NaOH 98% 12kg
· 120℃×30min</td><td rowspan="2">110℃×30min</td><td rowspan="3">170℃×80min</td></tr>
<tr><td>NaOH 98% 25kg</td><td>desizing agent 4kg</td><td>2nd</td><td>· H_2O 1,500L
· NaOH 98% 12kg
· 100℃×40min</td></tr>
<tr><td colspan="4">C type, Wincall®</td><td colspan="3">Wincall®, EEP</td></tr>
</table>

2.5 Measurement of physical properties of specimen

The physical properties of each sample were measured with the method shown in Table 5.

Table 5 Measurement of physical property of specimens

	Measuring equipment	Remark
Denier	Warp Reel	Sample length : 90cm
Thermal shrinkage	Dry-heat Chamber (dry) Water Bath (wet)	180℃, 30min 100℃, 30min
Tensile strength	Testometric MICRO 350	Sample length : 100mm Test speed : 100mm/min
Fabric property	KES-FB system	Sample size : 20×20cm
Yarn cross section	SEM	

3. Results and discussion

3.1 The physical properties of high hollow filament

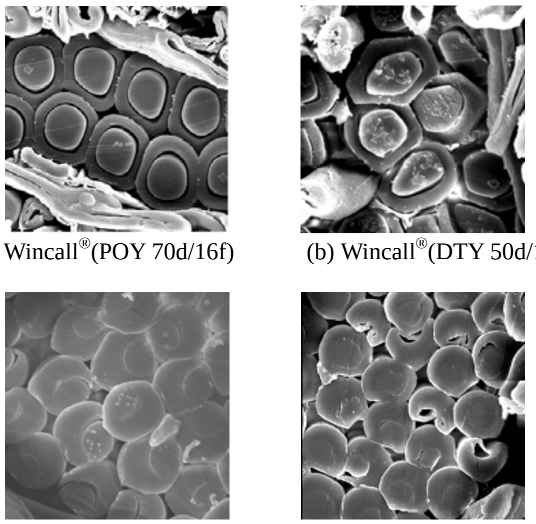
Table 6 shows the physical properties of Wincall® developed in Japan and C type hollow filament developed in Korea Textile Development Institute.

It is shown that there is no difference of denier between Wincall® and C type hollow filament. C type hollow filament has higher wet shrinkage and dry shrinkage than Wincall® POY. This is because they are drawn with additional heat treatment during fiber spinning processes, which results in high shrinkage due to increased orientation during drawing. It is also shown that the difference of wet and dry thermal shrinkages between DTY and POY of Wincall® shows 25% and 35%, respectively. C type hollow filaments have higher initial modulus than Wincall® POY and Wincall® DTY. As for tenacity, C type hollow filament has higher tenacity than Wincall® POY and shows similar tenacity to that of Wincall® DTY.

Fig. 2 shows the cross sections of hollow filaments used for this study. In Fig. 2, (a) and (b) are Wincall® developed in Japan, (c) is C type hollow filaments, and (d) is EEP hollow filaments.

Table 6 Physical properties of hollow filaments

		Wincall®		C type
		POY 70d/16f	DTY 50d/16f	SDY 70d/48f
Denier(D)		68.3	48.0	68.7
Thermal shrinkage	Wet(%)	7.80	33.14	12.94
	Dry(%)	3.78	39.17	8.86
Tensile property	Initial modulus(g/d)	1.41	8.01	10.57
	Tenacity(g/d)	2.28	3.39	3.45
	Strain(%)	124.66	55.27	58.28



(a) Wincall®(POY 70d/16f) (b) Wincall®(DTY 50d/16f)

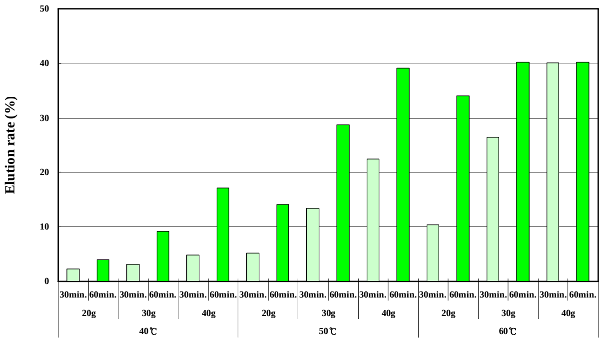
(c) C type(SDY 70d/48f) (d) EEP(SDY 80d/48f)

Fig. 2. Cross section of hollow filaments by SEM

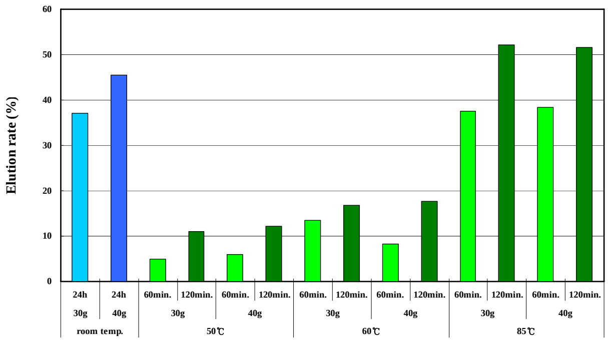
As shown in Fig. 2, the elution place of Wincall® is shown on the center of the filament. But, eluting shapes of C types and EEP made in KTDI showed an eccentricity.

3.2 Elution rate of the tube knitted fabric according to the eluting condition

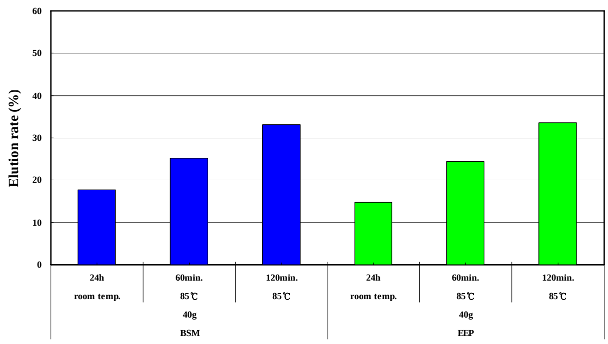
Fig. 3 shows the eluting rate of hollow filament in the tube knitted fabric according to eluting condition. Tube knitted hollow fabric is eluted according to eluting conditions in Table 3.



(a) C type



(b) Wincall®



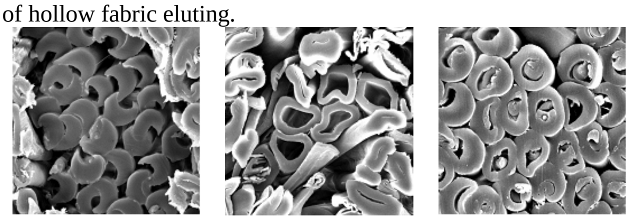
(c) EEP

Fig. 3. The eluting rate of hollow filament according to the eluting condition

In Fig. 3, (a) is C types developed by KTDI, (b) is Wincall® developed in Japan, and (c) is EEP developed by KTDI. As shown in Fig. 3 (a), the elution rate shows 40% when the bath temperature is 60℃ and concentration of NaOH is 30 and 40g/l. In Fig. 3 (b), Wincall® DTY with the eluting condition of C type hollow filament was also eluted. Wincall® shows the same property as C type hollow filament. Fig. 3 (c) shows the elution rates of EEP according to eluting conditions. Under the same conditions, EEP has less elution rates than C types and Wincall®.

The concentration of NaOH, bath temperature and elution time as a condition to determine the eluting condition were chosen. It is shown that the elution rate of hollow filaments is increased with increasing the concentration of NaOH, bath temperature and elution time in C type, Wincall® and EEP.

Fig. 4 shows the cross sections of tube knitted hollow fabrics. In Fig. 4, (a) is C types developed by KTDI, (b) is Wincall® developed in Japan, and (c) is EEP developed by KTDI. It is shown that C type and Wincall® are almost eluted inside of the filament, on the other hand, EEP does not make a complete elution. Therefore, EEP needs more intensive conditions in case of hollow fabric eluting.

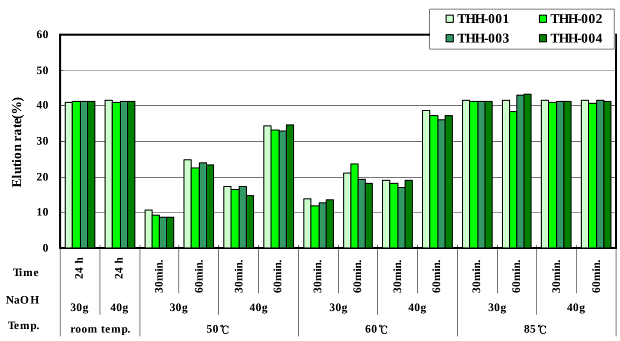


(a) C type (b) Wincall® (c) EEP

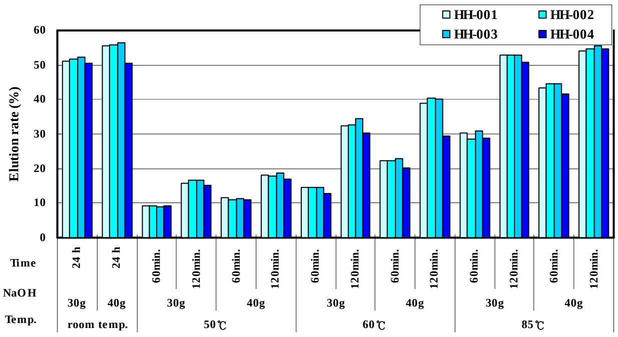
Fig. 4. Cross section of tube knitted fabrics with hollow filament by SEM

3.3 Elution rate of hollow woven fabrics according to the eluting condition

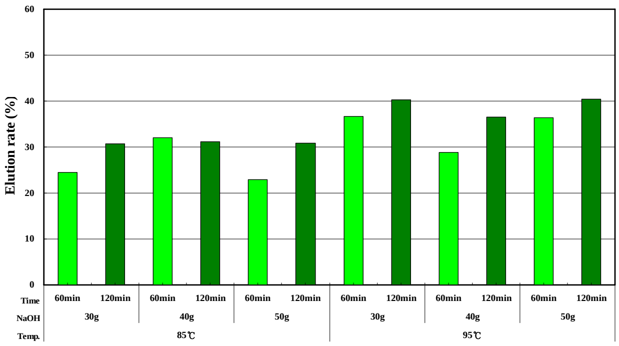
Fig. 5 shows elution rates of hollow fabrics woven by Wincall®, C types and EEP. Fig. 5 (a) shows the elution rate of C type hollow fabrics. When the bath temperature is 85℃, elution rate was ranged from 38% to 43%. And it is shown that the elution rate is increased with increasing the concentration of NaOH, bath temperature and reduction time. This result is just same to the elution of tube knitted fabric. Fig. 5 (b) shows the elution rate of Wincall® fabric according to eluting condition. It is shown that the elution rate of Wincall® fabric is higher compared to C type hollow fabric. The excessive elution rate of more than 50% was shown under the elution condition of 85℃ and 120 minutes. In the case of HH-004 which was woven with lower density than the other fabrics, elution rate was the lowest. Fig. 5 (c) shows the elution rate of EEP hollow fabric. As shown in Fig. 5 (c), when eluting temperature is 95℃ with NaOH concentrations of 30g/l and 50g/l and eluting time of 120min., respectively, elution rate of 40% was shown. But, these conditions showed lower elution rates under higher eluting conditions than C type and Wincall® hollow fabrics.



(a) C type



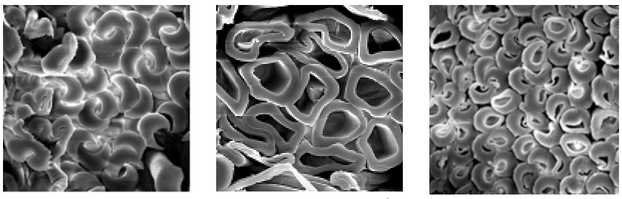
(b) Wincall®



(c) EEP

Fig. 5. The eluting rates of hollow fabrics according to the eluting conditions.

Fig. 6 shows the cross sections of hollow fabrics woven by hollow filaments. It is shown that C types and Wincall® are remained as the hollow state after elution. As shown in Fig. 5, even though EEP has much severe eluting conditions in the elution temperature of 95℃, NaOH concentration of 50g/l and eluting time of 120 minute than C types and Wincall®, eluted areas of EEP seem to be small.

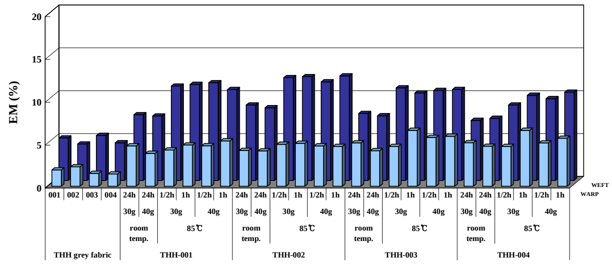


(a) C type (b) Wincall® (c) EEP

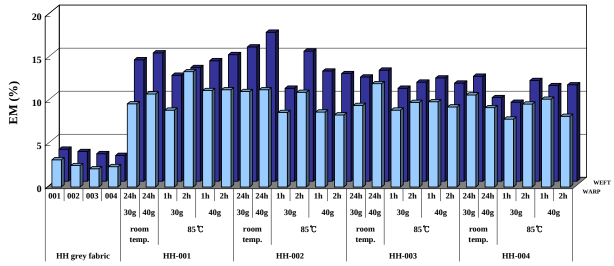
Fig. 6. Cross section of hollow fabrics by SEM

3.4 The mechanical properties of hollow woven fabric according to the eluting condition

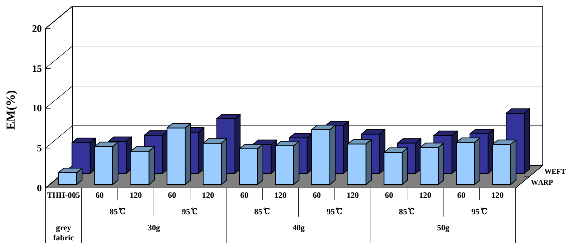
Mechanical properties of hollow fabrics according to eluting conditions are measured by KES-FB system. Fig. 7 shows the extensibility of hollow fabric measured by KES-FB system.



(a) C type hollow fabric



(b) Wincall® hollow fabric

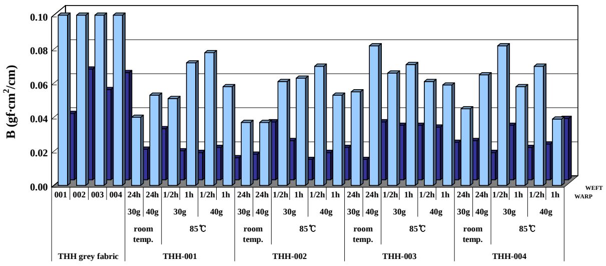


(c) EEP hollow fabric

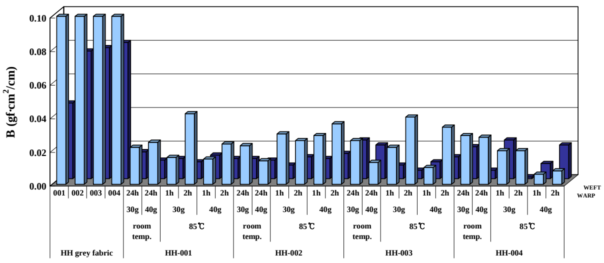
Fig. 7. EM of nylon high hollow fabrics.

In Fig. 7, (a) is the extensibility of C type hollow fabric, (b) is Wincall® fabric and (c) is EEP hollow fabric. After eluting, the EM values of fabrics are increased. It is shown that the extensibility of Wincall® hollow fabric is higher than the C type and EEP hollow fabrics. And weft direction has higher EM value than warp direction.

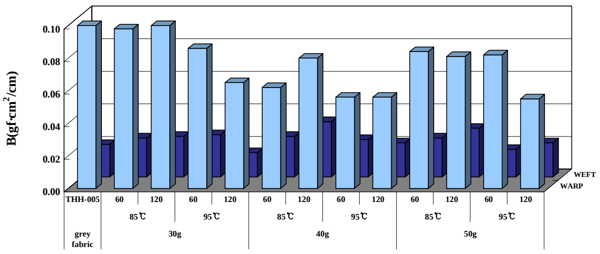
Fig. 8 shows the bending rigidity of hollow fabrics measured by KES-FB system. In Fig. 8 (a) is the bending rigidity of C type hollow fabric, (b) is Wincall® fabric and (c) is EEP hollow fabric. Compared to grey fabrics, after eluting, the B value of fabric is decreased. And weft direction has lower B value than warp direction. It is shown that the bending rigidity of Wincall® hollow fabric is lower than the C type and EEP hollow fabrics.



(a) C type hollow fabric



(b) Wincall® hollow fabric



(c) EEP hollow fabric

Fig. 8. B of nylon high hollow fabrics.

3.5 The physical properties of hollow fabrics according to the dyeing and finishing condition

Fig. 9 shows elution rates of C type and Wincall® fabrics according to the dyeing and finishing conditions shown in Table 4. Eluting rate of C type hollow fabric by CPB is ranged from 37% to 40%. However, Wincall® is not eluted by CPB. So it was rapid-dyed. Then, it showed over 50% of excessive elution rate. Therefore, it is thought that Wincall® fabric is thin as paper and has a low tearing strength.

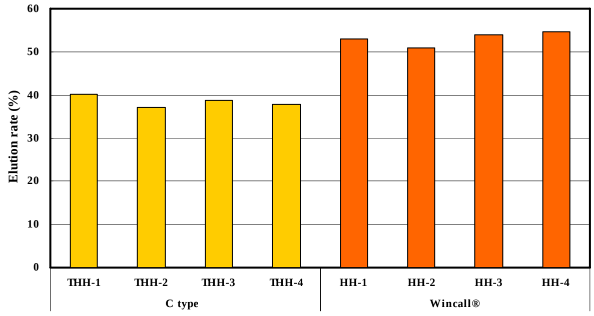
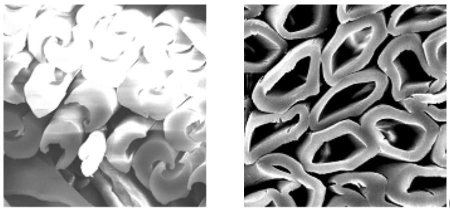


Fig. 9. The eluting rate of hollow fabric after the dyeing and finishing.

Fig. 10 shows the cross sections of fabrics after dyeing and finishing processes. C types and Wincall® were almost eluted after dyeing and finishing processes.

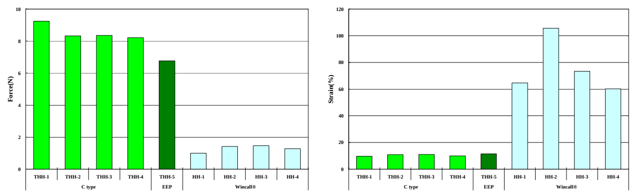


(a) C type

(b) Wincall®

Fig. 10. The cross section of hollow fabric after dyeing and finishing.

Fig. 11 shows the tensile properties of hollow fabrics after dyeing and finishing processes. Fig. 11 (a) shows the tenacity of hollow fabrics. Due to its excessive elution rate, Wincall® shows lower tenacity than C types and EEP fabrics. Fig. 11 (b) shows breaking strain of hollow fabrics. Wincall® shows higher breaking strain than C types and EEP.



(a) Breaking force (b) Breaking strain

Fig. 11. The tensile property of hollow fabric after dyeing and finishing.

4. Conclusion

The purpose of this study is to develop nylon hollow sportswear fabric by composite spinning. To do this, after spinning hollow filaments, hollow fabrics were woven. The physical properties of hollow fabrics were analysed according to eluting conditions such as NaOH concentration, eluting temperature, and eluting time.

The following results were obtained:

1) The elution rate of hollow filaments is increased with

increasing the concentration of NaOH, bath temperature and elution time. Especially, the elution rates are largely affected by NaOH concentration and eluting temperature.

2) Concerning to mechanical properties of hollow fabric according to eluting conditions, Wincall® with higher eluting rates has higher EM value and lower B value than C types and EEP.

3) Hollow fabrics woven by C types were eluted by CPB, Wincall® was not eluted by CPB but was rapid-dyed and showed excessive elution rates.

4) The hollow fabrics woven by Wincall® with higher elution rates showed lower tenacity and higher breaking strain than C types and EEP.

On these results, elution type nylon sportswear fabrics with various functions such as light weight and warming properties were developed.

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