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〈研究論文(學術)〉

染·加工 공정에서의 열처리 온도 변화에 따른 폴리에스테르 絲 및 직물의 물성 변화

조대현 · 김승진* · 장동호*

(주) 코오롱 기술연구소
*영남대학교 공과대학 섬유학부
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Physical Properties of Polyester Yarns and Fabrics Treated with Various Heat Temperatures in Dyeing & Finishing Processes

D. H. Cho, S. J. Kim*, and D. H. Chang*

Textile Research Center of Kolon Ltd. Inc., Kumi, Korea
**Regional Research Center, School of Textile, Yeungnam Univ., Kyeongsan, Korea*
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요 약－본 연구에서는 sizing을 포함하여 염색·가공 공정에서 습·건열 처리 온도를 변화시켜 처리한 폴리에스테르 필라멘트 사와 직물의 물성 변화에 관한 상관성을 연구하였다. 경사는 50d/24f(spark) 그리고 위사는 75d/72f(semi-dull)사를 사용하여 평직물을 셔틀직기에서 제직하였다. 사이징 공정에서의 건조온도를 90℃, 125℃, 150℃로 변화 시켰으며 수세공정에서 습열 처리온도는 90℃, 110℃ 그리고 120℃로 변화시켰다. 그리고 프리세트 공정에서의 건열 처리온도는 180℃, 200℃ 그리고 220℃로 변화시켰다. 마지막으로 최종열처리 공정에서는 170℃, 180℃ 그리고 200℃로 각각 변화시켜 이들 직물의 인장, 굽힘, 전단 특성과 이들 직물에서 채취한 실의 탄성계수, 절단강도, 변형률 등을 측정하여 각 공정에서의 열처리 온도 변화에 따라 이들 물성치의 상관성을 검토 비교하였다.

1. Introduction

Process control in manufacturing of the polyester yarns[1)] and fabrics[2)~5)] is governed by 3T, i.e. time, temperature and tension. Many researches related to the 3T of the fibre spinning and yarn finishing have been performed until now. But, there was a few research related to the physical properties of yarns and fabrics treated with various wet and dry heat temperatures in dyeing and finishing processes. The most important processes in dyeing and finishing of polyester fabrics are scouring, pre-set and final set processes and the dry temperatrues of the chamber and cylinder in sizing process play an important role in the various physical properties of the yarns and fabrics.

This paper surveys relationship between mechanical properties of polyester filaments and fabrics treated with various wet and dry heat temperatures in dyeing and finishing processes including sizing.

Background

Polyester fabrics are made by processing from fibre spinning, yarn finishing, weaving preparation, weaving to dyeing and finishing.

We call fibre spinning manufacturer composed of large company, up stream, in Korea, and yarn finishing, weaving preparation and weaving factories which are small or medium factories, we call those middle stream, dyeing and finishing factory which are also small or medium factories, we call it down stream. But, they have all mass production systems, and they are facing to situation to have to change to the high quality and low cost systems by process automation and improvement. And they want small quantity and various kind systems for producing high added value textile products. But they have three issue points as follows :

1. Fragility of research and development in the middle and down streams.
2. No exchange of technical information between up, middle and down streams.
3. High cost due to import of textile machinery.

Therefore, our research center focuses the above issues in cooperation with the regional government and textile industries around Taegu region in Korea. This study is one result of research projects6) related to solve a problem such as streaky and color difference of the polyester fabrics after dyeing and finishing.

Experimental

Yarn and Fabric Preparation

Structural parameters of yarns and fabrics prepared in this study are shown in Table 1.

Processing in Dyeing and Finishing

Process conditions in dyeing and finishing including sizing are shown in Table 2.

Changed heat temperature conditions in this study were discussed with technical man in the

Table 1. Structural parameters of specimen

Structural parameters	Yarns		Structural parameters	Fabric	
	Warp	Filling		Warp	Filling
Denier of filament (denier/fil)	50/24(SPK)	75/72(SD)	Density of fabrics (ends or picks/inch)	160	82
			Width of grey fabric (inch)	53	
Twist of filament (t.p.m.)	100	2240	Density of dent (no./inch×ends)	40×4	
			Total warp ends	8400	

note : SPK ; Trilobal, SD ; Semidull

Table 2. Process conditions in dyeing and finishing processes

Process	Sizing	Scouring & Relaxation	Pre-set	Final-set	Remark
Heat temp.	90℃	90℃	180℃	170℃	Caustic Reduction : 18%
treated to	125℃	110℃×20min.	200℃×60min.	180℃×50mpm	Dyeing : 130℃×40min.
the fabric	150℃	120℃	220℃	200℃	Net dry : 150℃×40mpm
Machine	2 chamber & 5 cylinder (Ilshin m/c) Korea	Rotary type (Sam-il m/c) Korea	Sun super (Ilshin m/c) Korea	Ichikin(Japan) 6 chamber Victex	C/D : CDR Onomori Co.(Japan) Dyeing : Rapid, Onomori Co.(Japan) N/D : Non contact 2 chamber Onomori Co.(Japan)

note : mpm ; meter per minute

Kolon factory as the temperature range using now in Korean dyeing and finishing factories.

Measurement

Various physical and mechanical properties of yarns and fabrics were measured. Modulus and tenacity of yarns taken from fabrics after each process in dyeing and finishing processes were measured. Measured instrument was UIM(Universal Instrument Machine, Instron Model 4201). Crosshead speed is 300mm/min.. Chart speed is 300 mm/min.. And full scale of load was 5kg. Fabric warp shrinkage by weft density of fabrics after each process was measured.

Crystallinity was calculated using following eq. (1) and eq. (2).

$$(X^{w}_{cry.}) = (\rho_c/\rho)\{(\rho-\rho_a)/(\rho_c-\rho_a)\} \quad (1)$$

$$\rho_c = 1.457g/cm^3 \ [7]$$

$$\rho_a = 1.336g/cm^3 \ [7,8]$$

$$(X^{v}_{cry.}) = (\rho - r_a)/(\rho_c - \rho_a) \quad (2)$$

Equation (1) is weight fraction crystallinity($X^{w}_{cry.}$) and equation (2) is volume fraction crystallinity (X^{v}_{cry}). Densities of perfect crystalline and amorphous regions in equation (1) and (2) were used 1.457g/㎤(ρ_c) and 1.336g/㎤(ρ_a) respectively [7,8]. Density of filament(ρ) in equation (1) and (2) was measured by density gradient method using n-Heptane and CCl_4 solution under the temperature 23±2℃, relative humidity 55℃±5%. Orientations of crystalline (f_{cr}) and noncrystalline (f_a) were measured by X-ray diffraction device (Cu-Kα, Rigaku, Japan) using equation (3) and (4), respectively[9].

$$f_{cr} = \frac{3(\cos^2\phi) - 1}{2} \quad (3)$$

$$\text{Where, } \cos^2\phi = \frac{\int_0^{\pi/2} I(\phi)\sin\phi\, \cos^2\phi\, d\phi}{\int_0^{\pi/2} I(\phi)\sin\phi\, d\phi}$$

$$\Delta n = X^{v}_{cry.} \cdot \Delta^{o}_{c} \cdot f_{cr} + (1 - X^{v}_{cry.}) \cdot \Delta^{o}_{a} \cdot f_a \quad (4)$$

Where,

Δn : Birefringence

Δ^{o}_{c} : Birefringence of crystalline (0.29)[10]

Δ^{o}_{a} : Birefringence of noncrystalline(0.20)[10]

$X^{v}_{cry.}$: Volume fraction crystallinity

f_{cr} : Orientation of crystalline

f_a : Orientation of noncrystalline

In equation (3), orientation of crystalline (f_{cr}) was calculated about ($\bar{1}05$) face proposed by Hermans[9]. Birefringence (Δn) was measured by Polarized Microscope (Na-lamp, Nikon, Japan) using equation (5).

$$\Delta n = \frac{\lambda \cdot R}{t} \quad (5)$$

Where,

Δn : Birefringence

R : Retardation

λ : Wave length of ND radiation

t : Diameter of specimen

Thermal stress peak load of specimens was measured using KE-2 (Kanebo Eng., Japan).Extensibilities and shear rigidity of fabrics were measured using KES-FB1 and bending rigidities of fabrics after each process in dyeing and finishing processes were measured using KES-FB2. The fabric structure to the thickness treated with various pre-set temperatures was measured by SEM photograph.

Results & Discussion

Effects of Wet and Dry Heat Temperatures to The Yarn Mechanical Properties

Fig. 1 shows warp yarn modulus and tenacity after each process, i.e. untreated yarn, after sizing, weaving, scouring, pre-set, weight reduction, dyeing and net dry, and after final-set. After scouring, yarn modulus is evidently decreased, and after this process, warp and weft yarn modulus are almost same, but, yarn tenacity is decreased after weight reduction. This fact demonstrates that dyeing and finishing processes treated with wet and dry heats affect yarn modulus related to the fabric hand, and tenacity is affected by weight reduction process. And, it seems that yarn modulus of grey fabric is decreased by weave crimp, and yarn modulus after scouring is governed by fabric shrinkage in the dyeing and finishing processes.

Fig. 2 shows the evidence of this fact. It shows fabric warp shrinkage according to the each process step under the conditions of sizing dryer temp., 125℃, rotary washer 120℃×20min., pre-set 200℃, 18% caustic reduction, net dryer temperature, 150℃, final set 170℃×50mpm, which are normal conditions in Korean dyeing & finishing factories.

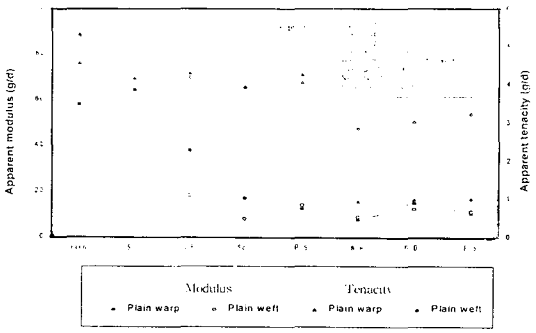


Fig. 1 Changes of the yarn modulus and tenacity in the dyeing and finishing processes.

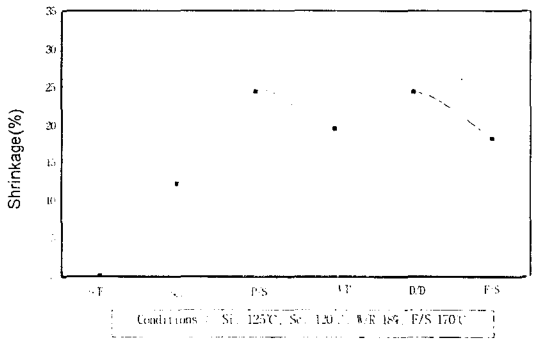


Fig. 2 Warp shrinkage of fabric on each process step.

It is shown that fabric warp shrinkage after rotary washer is about from 10% to 12%, after preset is also 12%, and fabric is relaxed by 5% after caustic reduction, and next, fabric is shrunk by 5% after dryer, and finally, fabric is also relaxed by 5% after final-set. But, these fabric shrinkages are largely changed with various wet and dry heat temperatures. Fig. 3 shows warp yarn modulus to the sizing temperatures with various scouring and pre-set temperatures.

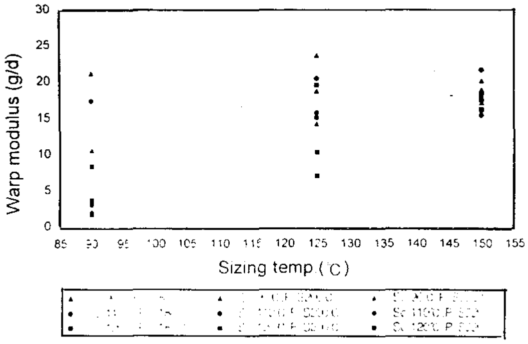


Fig. 3 Change of the yarn modulus to the various dry temperatures in the sizing process.

Warp yarn modulus is increased with sizing temperature irrespective of scouring and pre-set temperatures. These phenomena were investigated, and these are due to low shrinkage of fabrics treated with high sizing temperature. Fig. 4 shows fabric thermal shrinkage to the sizing temperature.

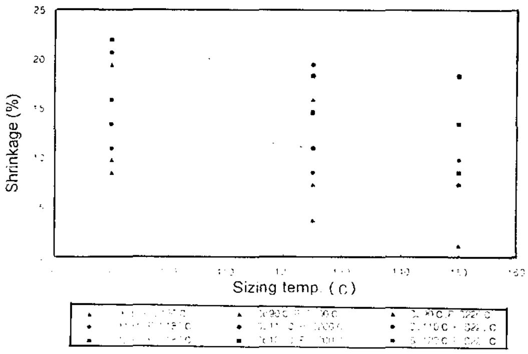


Fig. 4 Relationship between fabric shrinkage and sizing temperatures.

Fabric shrinkage is decreased with sizing temperature, and this low fabric shrinkage makes warp yarn modulus high. Yarn modulus taken from fabric treated with low sizing temperature of vicinity of Tg of polyester filament shows from low and high values according to the conditions of scouring and pre-set temperatures. On the other hand, yarn modulus treated with sizing temperature of 150℃ shows high value irrespective of scouring and pre-settemperatures. This phenomena demonstrate that high dry temperature in sizing makes yarn modulus high irrespective of scouring and pre-set temperatures. Fig. 5 shows warp yarn modulus according to the scouring temperature with various sizing and pre-set temperatures.

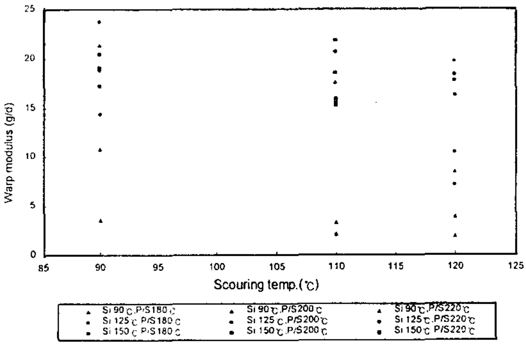


Fig. 5 Relationship between warp yarn modulus and scouring temperatures.

Warp yarn modulus is slightly decreased with increasing scouring temperature. This phenomena can be also explained by increase of fabric shrinkage with scouring temperature as shown in Fig. 6. It shows fabric shrinkage with various scouring temperatures.

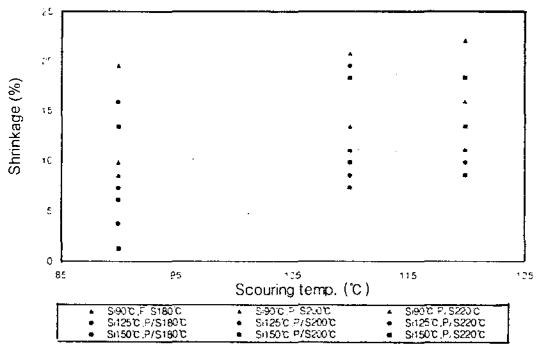


Fig. 6 Relationship between fabric shrinkage and scouring temperature.

It is shown that fabric shrinkage is increased with scouring temperature, therefore yarn extensibility is increased and modulus is decreased. And the variations of warp yarn modulus in relation with wet and dry heat temperatures were analysed for surveying about which is adominant factor between the wet heat in scouring and dry heat in sizing processes.

Especially, low warp yarn modulus which is triangular sign in Fig. 5 is shown in the case treated with low sizing temperature(90℃) and high scouring temperature(120℃) irrespective of pre-set temperatures. And yarn modulus treated with high sizing temperature(150℃) which is rectangular sign in Fig. 5 shows high value irrespective of scouring and pre-set temperatures. Fig. 7 shows the reason why high modulus is shown at the range of high sizing temperature. It shows crystallinity to the various sizing temperatures.

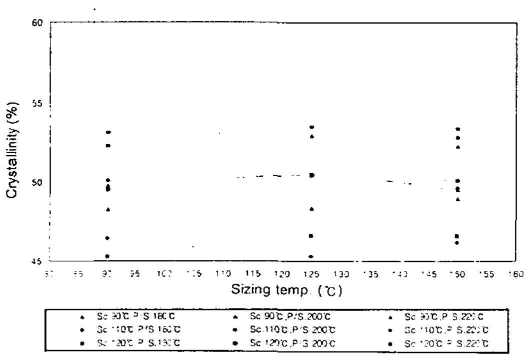


Fig. 7 Relationship between crystallinity and sizing temperature.

Crystallinity doesn't change according to the sizing temperatures. So, the orientations of crystalline and non crystalline of polyester filament treated with various heat temperatures were analysed. Fig. 8 shows orientations of crystalline and noncrystalline of filament to the various heat-set temperatures.

The orientation of amorphous region of the filament, f_a, is decreased with increasing heat temperature, from 90℃ to 150℃ and f_{cr}, which shows

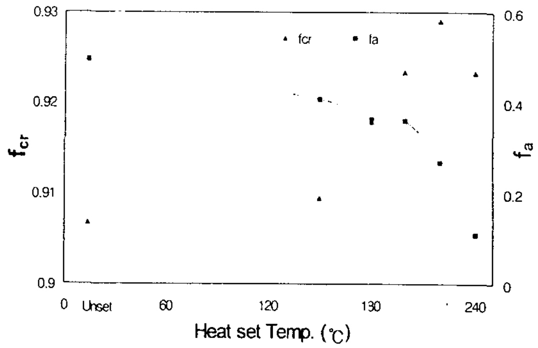


Fig. 8 Orientation factor of amorphous and crystalline to the heat set temperature.

the orientation of crystalline region of the filament is increased with increasing heat temperature, from 90℃ to 150℃. Therefore, yarn modulus is increased the with increase of f_{cr} and the decrease of f_a at the vicinity of the sizing temperature, 150℃. Fig. 9 shows warp yarn modulus according to the pre-set temperature with various sizing and scouring temperatures.

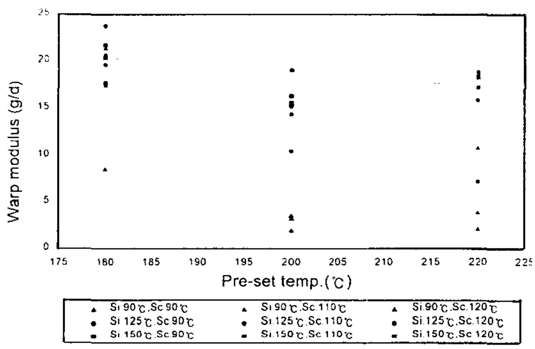


Fig. 9 Warp yarn modulus to the pre-set temperature.

A little differently to the sizing and scouring processes, minimum yarn modulus is shown at the 200℃ of pre-set temperature. Especially, minimum warp yarn modulus is shown under the conditions of sizing temperature, 90℃, and 200℃ of pre-set temperature with 120℃ of scouring temperature. These results coincide with those of fabric shrinkage as shown in Fig. 10 This figure shows fabric shrinkage according to the pre-set temperature with various sizing and scouring temperatures.

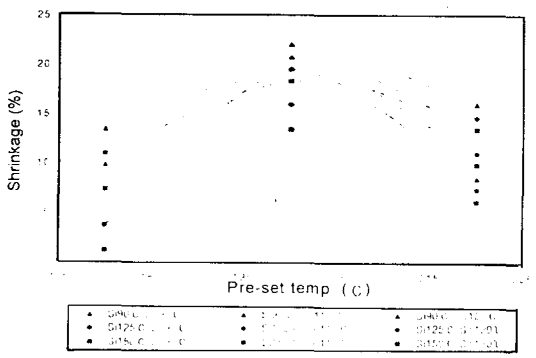


Fig. 10 Fabric shrinkage to the pre-set temperature.

Maximum shrinkage value is shown at the 200℃ of pre-set temperature. For surveying the reason why these phenomena were come out, crystallinity according to the pre-set temperature is analysed and discussed in Fig. 11 in relation with Fig. 8. Fig. 11 shows crystallinity according to the pre-set temperature, crystallinity is increased with increasing pre-set temperature, but as shown in Fig. 8, f_{cr} is increased with increasing heat temperature from 180℃ to 220℃. And f_a is decreased with increasing heat temperature from 180℃ to 220℃. But, it couldn't extinctly explain the phenomena of maximum fabric shrinkage which is shown at the 200℃ of pre-set temperature in Fig. 10.

So, results of thermal stress analyser were analysed and discussed. Fig. 12 shows maximum peak load according to heat set temperature.

Maximum thermal peak is shown at the 200℃, and it seems to be the reason why maximum shrinkage is shown at the point 200℃ of pre-set temperature. This point is well known temperature due to partial melting and recrystallization of polyester fibre inner structure.

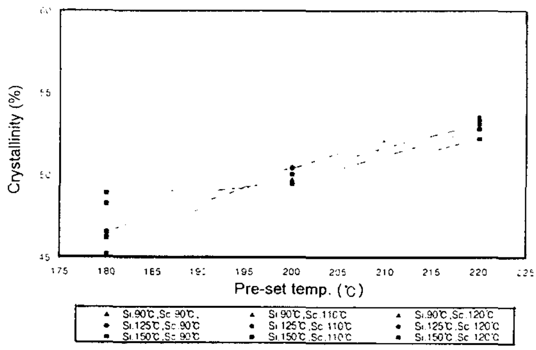


Fig. 11 Diagram between crystallinity and pre-set temperature.

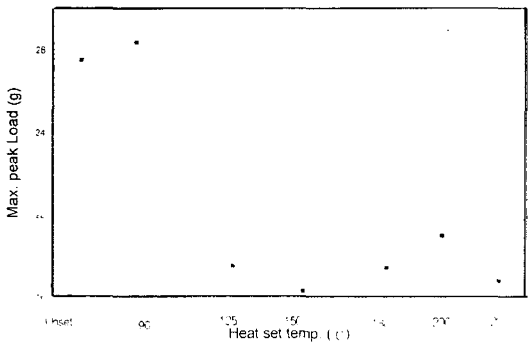


Fig. 12 Maximum peak load to the heat set temperature.

Effect of Wet and Dry Heat Temperatures to The Fabric Mechanical Properties

We surveyed fabric mechanical properties for analysing relation between yarn and fabric properties. Fig. 13 shows fabric extensibility of the warp direction according to the various sizing temperatures as yarn modulus in Fig. 3, and fabric extensibility is decreased with increasing sizing temperature.

This fact demonstrates that yarn mechanical properties with various heat temperatures in sizing process affect the mechanical properties of fabrics. Fig. 14 shows fabric extensibility of the warp direction according to the various scouring temperatures as yarn modulus in Fig. 5, and fabric extensibility is increased with increasing scouring temperature.

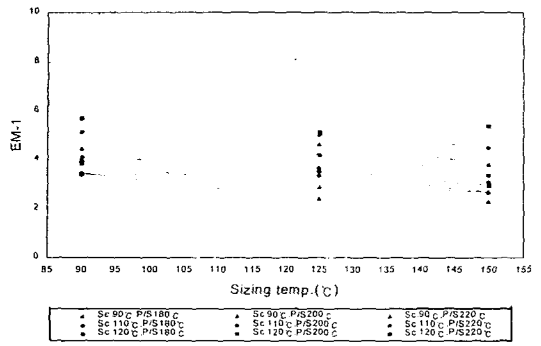


Fig. 13 Tensile strain of the warp direction of the fabric to the various sizing temperatures.

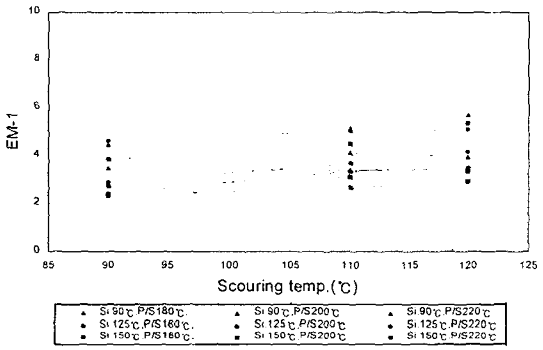


Fig. 14 Tensile strain of the warp direction of the fabric to the various scouring temperatures.

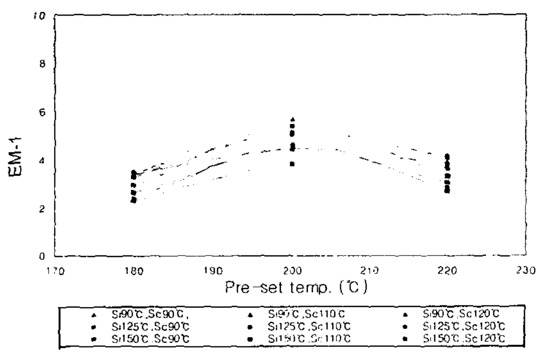
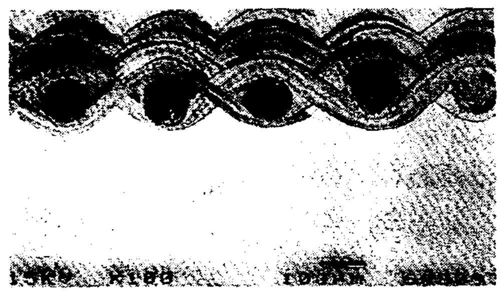


Fig. 15 Tensile strain of the warp direction of the fabric to the various pre-set temperatures.

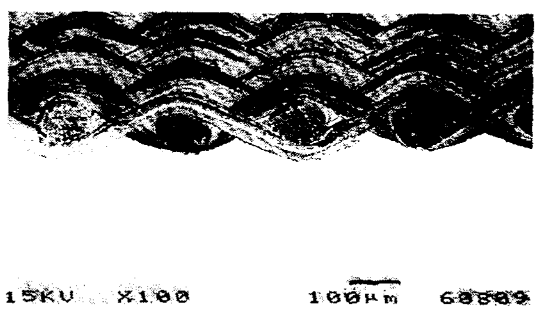
Fig. 15 shows fabric extensibility of the warp direction according to the various pre-set temperatures as yarn modulus in Fig. 9, and maximum extensibility is shown at the 200℃ of pre-set temperature.

These phenomena also show that yarn tensile properties with various wet and dry heat temperatures in scouring and pre-set in dyeing and finishing processes affect the fabric tensile properties. Fig. 16 shows SEM photographs of fabric

(a)



(b)



(c)

Fig. 16 SEM. photograph of fabric with various pre-set temperatures.
(a) 180℃, (b) 200℃, (c) 220℃

treated with 180℃, 200℃, and 220℃of pre-set temperatures. It seems that the fabrics treated with 220℃ of pre-set temperature is the most flat compared to the others.

Fig. 17 shows fabric bending(B) and shear rigidity(G) according to the process step, and bending and shear rigidity of fabric are evidently decreased after scouring process as yarn modulus in Fig. 1. Therefore, it is concluded that the results of fabric mechanical properties coincide well with those of yarn mechanical properties with variation of wet and dry heat temperatures.

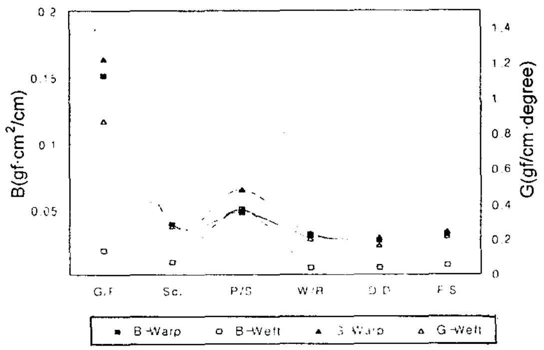


Fig. 17 Change of the fabric bending and shear rigidities in the dyeing and finishing processes.

Conclusions

Relationships between mechanical properties of polyester filaments and fabrics treated with various wet and dry heat temperatures in dyeing and finishing processes including sizing are summarized as follows.

- Warp yarn modulus is decreased with decreasing of the sizing temperature and increasing of the scouring temperature.
- Dry heat temperature in sizing to the yarn modulus is dominant factor compared to the wet heat temperature in scouring process.
- Minimum warp modulus is shown at the temperature of 200℃ in the pre-set process, which is due to thermal shrinkage and thermal stress in the range of dry heat temperature from 180℃ to 220℃.
- Fabric mechanical properties are signigicantly affected by yarn mechanical properties with various wet and dry heat temperatures in dyeing and finishing processes.

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