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Effect of UV-Absorber Treatment on the Mechanical Properties of Cotton Fabrics

자외선 차단 가공에 의한 면직물의 역학적 특성 변화

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Abstract

본 연구의 목적은 자외선 차단 가공 처리 및 자외선 조사 처리에 의해 면직물의 역학적 특성 변화를 조사하고 가공제 처리조건에 따른 차이점을 분석하는 것이다.

시료로는 100% 면직물을, 자외선 흡수제로 2,2'-dihydroxy-4,4'-dimethoxy benzophenone을, 첨가제로 Triton X -100, polyethylene glycol 400, $MgCl_2 \cdot 6H_2O$를 사용하였다. 자외선 흡수제 처리는 Atlas Launder-O-meter로 75℃에서 60 분간 흡진법으로 하였다. 미처리 시료 및 처리 시료는 모두 xenon 램프에 80 시간 동안 노출되었으며, 자외선 조사 전후 시료의 역학적 특성은 KES-F 시스템을 사용하여 측정하였다.

본 연구의 결과는 다음과 같이 요약할 수 있다.

자외선 흡수제 처리는 처리 농도에 상관없이 면직물의 선형인장성(LT), 인장레질리언스(RT), 굽힘강성(B), 굽힘이력(2HB), 전단강성(G), 전단이력 (2HG5), 표면마찰계수(MIU) 등을 증가시켰으며 표면거칠기(SMD)는 감소시켰다. 압축특성은 처리농도의 영향을 받아서 고농도의 자외선 흡수제 처리는 압축특성을 감소시켰으며, 저농도의 처리는 압축특성을 증가시켰다. 자외선 흡수제 처리는 처리농도에 상관없이 면직물의 fullness/softness를 유의하게 증가시키는 반면 stiffness, crispness 및 anti-drape stiffness를 감소시켜서 가공포의 종합태(THV)는 가공 전에 비하여 저하하였다.

자외선 조사는 가공 전 면직물의 경우 B, 2HB, G, 2HG, 2HG5, LC를 감소시켰다. 자외선 조사는 처리농도와 상관없이 가공포의 WT, 굽힘특성, 전단특성을 감소시켰으며, 저농도의 흡수제 처리 포의 경우 SMD를 증가시켰으며, 고농도의 흡수제 처리포의 경우 SMD를 감소시켰다. 자외선 조사는 처리농도와 상관없이 가공포의 fullness/softness, stiffness, anti-drape stiffness를 유의하게 감소시켜서 자외선 조사 전 보다 THV가 37% 저하하였고 미가공포의 THV를 저하율보다는 저하가 낮았다.

자외선 흡수제 처리에 의해 면직물의 태는 가공 전보다 감소하지만, 자외선 흡수제 처리는 자외선 조사에 의한 태 감소율을 낮추는 데 유의한 효과가 있다.

Key words: ultraviolet ray, tensile, shear, compression, surface friction;
자외선, 인장, 전단, 압축, 표면마찰

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I. Introduction

UV-cut finishes have been used for many years to improve UV absorption properties and the light fastness of fabrics[1]. Conventionally UV-absorbers such as benzophenons were applied with polymeric resin and adhered to the fiber.

A previous study[2] found that the use of Triton X-100 would result in a more uniform distribution of UV-absorber in aqueous solution and thus improve the UV-cut properties of cotton fabrics. In addition, the study found also that the treatment at a proper concentration of both UV-absorber and Triton X-100 tends to improve the UV-cut properties.

The process of UV-absorber finishing associates the action of exhausting in a hot bath, padding, and finally drying of the fabrics. This process could influence the mechanical characteristics and handles of fabric. Although this finishing improves UV-cut properties to the fabric, the consequent effect of the UV-absorber finishing has not been investigated yet. There is no research on the effect of both UV-absorber finishing and UV-exposure on the mechanical characteristics of fabrics.

KES-F has been used a lot as it measures fabric mechanical properties of low loads and provides information useful in the assessment of fabric handle in the apparel manufacturing process and in the development of new fabrics.

The objectives of this study were to investigate the effect of UV-absorber treatment on the mechanical properties of cotton fabrics by the use of KES-F system, and to analyze the change in the mechanical properties of fabrics through UV-exposure.

II. Experiment

1. Fabrics and Reagents

A cotton fabric (KS K 0905) having the following characteristics, as described in Table 1 was used:

Table 1. Characteristics of fabric

Weave structure	plain-weave
Mass/unit	102 g/m^2
Fabric density	72×75/inch

2,2′-Dihydroxy-4,4′ dimethoxybenzophenone (ACROS DRGANICS, USA) was used as UV-absorber. The following chemicals were included as additives: Triton X-100 (Fluka Chemie AG), polyethylene glycol 400 (Katayama chemical, Japan), $MgCl_2 \cdot 6H_2O$ (Junsei Chemical Co. Ltd, Japan). All chemicals were used as supplied.

2. Application

The fabric samples were applied to the fabric by exhaustion in an Atlas launder-O-meter at 75±2℃ for 60 min. (1:100 o.w.f.), and by padding on a lab mangle (Roll Machiner, Jin Young Co. Ltd) to remove excess solution, dried 48 hours, and reconditioned in a conditioned room (65% RH, 20℃) for 48 hours prior to being tested. Fabric samples applied by the same procedures using distilled water were used as control samples.

Table 2 shows the symbols used to describe the concentrations of UV-absorber and Triton X-100. The concentration of PEG 400 and $MgCl_2 \cdot 6H_2O$ were fixed to 0.002 mol/l. The levels of concentrations were selected according to the pretest that indicated these concentration ranges resulted in the optimizing of both UV-cut properties and whiteness retention. The high concentration of UV-absorber was selected to optimize the UV-cut properties, while the low concentration of UV-absorber was selected to reduce the amount of the expensive UV-abosorber and to optimize whiteness retention.

Table 2. Various levels of UV-absorber and Triton X-100

Symbols	UV absorber ($\times 10^{-3}$mol/l)	Triton X-100 ($\times 10^{-3}$mol/l)
LL	5	1.64
LH	5	50
HL	10	1.64
HH	10	50

3. UV-exposure

Samples were exposed to ultraviolet light in the xenon-arc Fadeometer (Han-Won, Korea) for 80 hours, and analyzed before and after exposure to determine the effects of UV-exposure on the mechanical properties of each fabric.

4. Measurement of Mechanical Properties

The measurement of the mechanical properties of both the control and the treated fabrics was carried out on all fabrics by KES-FB (The Kawabata Evaluation System for fabric) system. Duplicate samples in both the warp and the weft directions were measured. Subsequently, the mechanical properties were compared with the fabric densities after treatment. The KES-FB consists of four instruments of measurement.

5. Hand Values

The measurement of the primary hand values and the total hand values was carried out on all fabrics before and after the experiment according to KN-202-DS(Men's thin dress shirt)[4].

III. Results and Discussion

1. Fabric Density after UV-absorber Treatment

The means of fabric density before and after finishing are presented in Table 3. After finishing the treatment process, it was found that there was a significant increase in the warp density (from 72 to 78 ends/inch) and a relatively small increase in the weft density (from 75 to 77 picks/inch).

Table 3. Characteristics of cotton fabrics before and after finishing

Fabrics	Thickness (mm)	Fabric Density (warp × weft/inch)
Control	0.33	72 × 75
Treated	0.36*	78 × 77*

*: mean values of the treated fabrics with four different UV-absorber treatment solutions.

2. The Effect of UV-absorber Treatment

The samples used in this study have been developed mainly to improve the UV-cut property. However, only mechanical properties and fabric handle are investigated in this paper. The mechanical parameters and the hand values of all the samples shown in Table 4 were obtained. The results are shown in Figure. 1. The horizontal axis of each parameter and hand values in this figure is normalized using the mean and the standard deviation of the data.

1) Tensile Properties

The effect of the UV-absorber applied by exhaustion on the tensile properties of the cotton fabric can be seen in Figure 1. The LT values increased after the UV-absorber treatment. This means that the fabric becomes slightly stretchable by UV-absorber finishing process. Table 4 shows

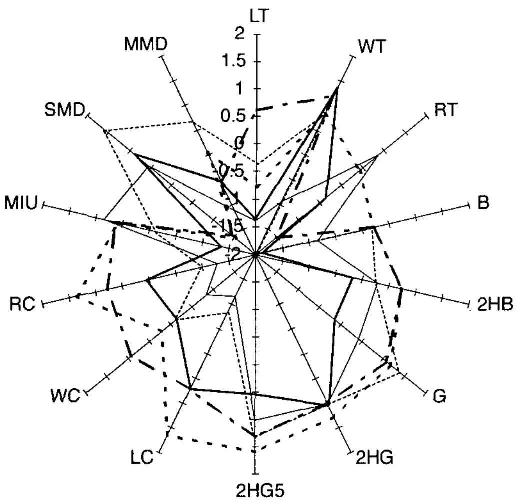

Fig. 1. The effect of UV-absorber finishing on the mechanical properties of cotton fabrics

that the tensile energy (WT) values in the warp direction were significantly lower than those in the weft direction. This result may be due to the pre-extension in the warp direction during processing. The mean tensile resilience (RT) values were not significantly changed by UV-absorber treatment. However, the RT values in the warp direction were greater than those in the weft direction. This means that the warp direction recover better than the weft direction after UV-absorber treatment.

Figure 1 demonstrates that significant increase in the LT value occurs only after LH treatment. This means that the fabrics treated with low concentration of UV-absorber and high concentration of Triton X-100(LH) are rather unstreachable.

The LT values of the warp direction are larger than those of the weft direction, it is also likely to be due to the pre-extension in the warp direction during processing.

Figure 1 also demonstrates that a significant decrease in WT values occurs only after HH treatment. The small tensile work energy means that the fabric becomes stretchable with high concentration of UV-absorber and Triton X-100. The weft direction had much higher WT values than the warp direction. It is likely that the tensile energy in the warp direction decreased with progress through extension and relaxation.

The effect of HH or LL treatments on RT values was insignificant, but HL or LH treatments reduced the RT values. This means that the fabrics treated with HL or LH recover better than those treated with HH or LL.

2) Bending Properties

The bending property of textile material and clothing is critical to their performances such as the fabric handle, the drape, the fabric formability, the shape retention, and the wrinkle recovery. Figure 1 shows that the bending rigidity (B) values were significantly increased by UV-absorber finishing as compared with those of the control. This means that fabrics becomes stiffer by UV-absorber finishing.

Table 4 demonstrates that the warp direction had much higher B values and bending hysteresis (2HB) values than the weft direction. This difference is likely to be due to the increased inter-fiber and inter-yarn pressures in the warp direction compared with those in the weft direction. The increase in fabric densities is thought to reduce the bending properties in the warp direction.

3) Shear Properties

The shear behavior of fabrics is one of the most important factors affecting their drape, handle, and dimensional stability. The shear rigidity (G) values were increased by the UV-absorber treatment. These increases are indicative of the increased

Table 4. Mechanical properties of the treated cotton fabrics

Treatment / Mechanical properties			Before UV- exposure						After UV- exposure					
			control	LL	LH	HL	HH	Treated mean	control	LL	LH	HL	HH	Treated mean
Tensile	LT	warp	0.86	0.88	0.96	0.91	0.86	0.90	0.95	1.00	0.90	0.84	0.90	0.91
		weft	0.67	0.68	0.68	0.67	0.66	0.67	0.67	0.67	0.66	0.66	0.65	0.66
	WT	warp	3.70	3.55	3.70	3.77	3.42	3.61	3.72	3.45	3.62	3.42	3.50	3.49
		weft	28.3	26.7	27.8	26.57	21.10	25.54	28.67	27.05	27.00	25.77	23.02	25.71
	RT	warp	65.56	71.90	56.75	53.66	68.63	62.73	57.13	63.77	66.89	70.08	67.16	67.00
		weft	34.27	34.15	34.04	33.77	40.77	35.68	34.35	34.66	35.43	36.22	39.62	36.48
Bending	B	warp	0.10	0.11	0.11	0.11	0.10	0.11	0.10	0.11	0.10	0.10	0.10	0.10
		weft	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04
	2HB	warp	0.14	0.15	0.15	0.14	0.14	0.15	0.12	0.12	0.11	0.11	0.12	0.11
		weft	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Shear	G	warp	1.41	1.48	1.46	1.48	1.42	1.46	1.40	1.39	1.39	1.35	1.36	1.37
		weft	1.35	1.42	1.43	1.44	1.40	1.42	1.34	1.27	1.32	1.28	1.27	1.28
	2HG	warp	2.67	2.72	2.60	2.67	2.62	2.65	1.97	1.90	1.95	1.94	1.99	1.94
		weft	3.24	3.34	3.27	3.24	3.26	3.27	2.67	2.65	2.64	2.65	2.64	2.64
	2HG5	warp	5.14	5.31	5.26	5.24	5.17	5.24	4.91	4.98	4.88	4.87	4.95	4.92
		weft	6.28	6.55	6.49	6.50	6.45	6.49	6.08	5.93	6.06	5.97	5.86	5.95
Surface	MIU	warp	0.15	0.18	0.17	0.16	0.17	0.17	0.14	0.17	0.17	0.17	0.16	0.17
		weft	0.14	0.15	0.16	0.15	0.17	0.16	0.14	0.16	0.16	0.17	0.15	0.16
	SMD	warp	4.42	3.15	3.75	4.91	4.43	4.06	4.23	4.31	4.05	4.13	4.14	4.16
		weft	3.80	3.62	3.08	3.74	3.60	3.51	3.60	3.51	3.37	3.09	2.98	3.24
	MMD	warp	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		weft	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Compre-ssion	LC		0.43	0.46	0.43	0.38	0.37	0.14	0.41	0.42	0.43	0.39	0.35	0.39
	WC		0.31	0.32	0.34	0.31	0.29	0.32	0.35	0.34	0.34	0.26	0.28	0.31
	RC		51.73	57.80	55.18	46.99	45.48	51.36	54.05	55.40	54.88	48.43	43.94	50.91

inter-yarn pressures in fabric after UV-absorber treatment.

The shear hysteresis at 0.5 (2HG) was not significantly affected by the treatments. The shear hysteresis at the shear angle 5° (2HG5) was slightly increased after treatments. This result was due to the reduction of freedom between threads in fabrics. Table 4 shows that both 2HG and 2HG5 values in the weft direction were significantly larger than those in the warp direction. This means that the change in shear hysteresis of fabrics should be considered according to the fabric direction.

4) Compressional Properties

The linearity of compression (LC) of each fabric became small after treatment with the high concentration of UV-absorber and became large after treatment with the low concentration of UV-absorber. This means that fabrics are rather harder with a lower concentration of UV-absorber. The WC and RC values were also increased by the low concentration of UV-absorber, while these values were reduced by the high concentration of UV-absorber. This means that fabric becomes harder with a low concentration of UV-absorber and that fabric becomes softer with a high concentration of UV-absorber.

These results suggest that the treatment with the low concentration decreased fabric specific volume, which mainly affected the compressional properties, while the treatment with the high concentration of UV-absorber increased fabric volumes. The increase in fabric thickness is indicative of the increase in the surface roughness by the UV-absorber adhered on the fabric surface. However, the influence of the specific volume on the compression properties is beyond the scope of this study.

5) Surface Properties

The effect of UV-absorber treatment on the mean coefficient of the fabric friction (MIU) is depicted in Figure 1. The MIU values significantly increased as compared with those of the control and this is another indicative of the increase in the surface roughness by the UV-absorber adhered on the fabric surface.

The SMD values increased after the treatment with the high concentration of UV-absorber and decreased with the treatment with the low concentration of UV-absorber. So, the amount of UV-absorber dispersed in the finishing bath affected the SMD values.

3. The Effect of UV-exposure

The effect of UV-exposure on the physical properties of both untreated and treated fabrics is depicted in Figure 2.

1) Tensile Properties

Figure 2 shows that the effect of UV-exposure had a significant effect on the LT values of each fabric. The LT values of the HL or LH fabrics were decreased, while those of the LL fabrics increased. The WT values of the fabrics were decreased after UV-exposure.

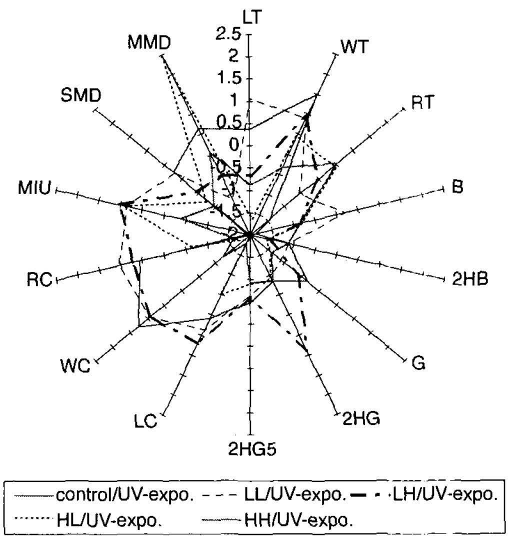

Fig. 2. The effect of UV-exposure on the mechanical properties of cotton fabrics.

The effect of UV-exposure on RT values was significant for each fabric. After UV-exposure, the RT values of each fabric were increased as compared with those of the control. The increase in tensile resilience by UV-exposure is indicative of the increased inter-yarn pressures in the fabrics.

2) Bending Properties

The effect of UV-exposure on B values was significant. After UV-exposure, the B values of the fabrics were increased, while UV-exposure generally reduced the 2HB values. The increase in inter-fiber friction effect and the reduction of the weakest point effect by UV-exposure could cause the increase in B values.

3) Shear Properties

The G values of the finished fabrics were remarkably reduced by UV-exposure. This means that the finished fabrics became softer in bending after UV-exposure. This could be explained by the reduction in the amount of UV-absorber on the surface of the fiber as the UV-absorber moved into the inside of fibers or inter-yarn structure. The G values were reduced as the yarns of the finished fabrics became softer and smoother.

The mean values of 2HG were unchanged by UV-exposure. However, Figure 3 shows that the 2HG values of the LH fabric were significantly increased as compared with those of the control. This means that the finished fabrics with LH became stiffer and less recoverable in bending after UV-exposure.

The shear hysteresis at the shear angle 5° (2HG5) was slightly reduced by UV-exposure. However, the reduction of the values was insignificant.

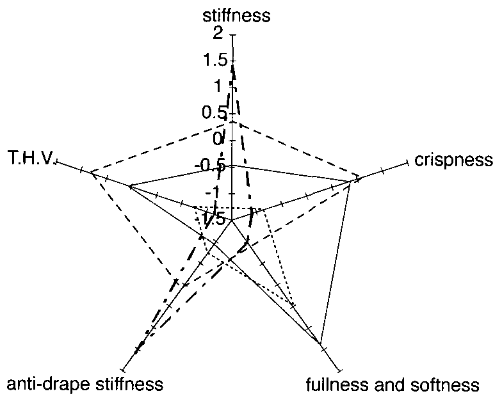

Fig. 3. Hand Values of the fabrics before and after UV-exposure

4) Compressional Properties

The overall compressional properties of the finished fabrics decreased after UV-exposure. After UV exposure the compressibility of the HL and HH fabrics decreased, while that of LL and LH fabrics slightly increased. The WC values of the fabrics treated with a high concentration of UV-absorber significantly decreased after UV exposure. This means that after UV-exposure, fabrics treated with a low concentration of UV-absorber become much harder and that fabrics treated with a high concentration of UV-absorber become much softer.

5) Surface Properties

After UV-exposure, the MIU values significantly increased, while the SMD values decreased. This result indicates that by UV-exposure the surface of fibers was uniformly coated with UV-absorber that was deposited on the surface of fibers, so that the surface became more uniform.

4. Hand Values

The primary hand values and the Total Hand Values (THV) are depicted in Figure 3. Fullness and softness (FUKURAMI) significantly increased, while stiffness and crispness (KOSHI), and anti-drape stiffness (HARI) decreased after UV-cut finishing. This means that fabric becomes softer and deformable. However, the difference in THV measured between the finished fabric and the control fabric is 0.5, this is not possible to discriminate between the two fabrics[9]. With regard to the final THV, the fabrics turn out to be identical.

After UV-exposure, stiffness and anti-drape stiffness of control fabrics increased, while crispness significantly decreased. Therefore, THV of control cotton fabrics were significantly reduced by UV-exposure. There was significant decrease in crispness of finished fabrics after UV-exposure. However, the difference between before and after UV-exposure was small in the THV of the finished fabrics compared to those of the control fabrics.

The effects of the concentration variations of UV-absorber on primary hand values and THV are summarized in Table 5. As shown, LH, a low level of UV-absorber and high level of Triton X-100, gave the best THV. When the concentration of Triton X-

Table 5. Effect of concentration of UV-absorber on the hand values of fabrics

Hand values	Fabrics					
	control	LL	LH	HL	HH	Finished mean
Stiffness	8.15	7.84	8.18	8.14	8.12	8.07
Crispness	6.28	5.62	6.55	6.53	5.24	5.98
Fullness & Softness	3.33	4.42	2.86	3.21	4.82	3.82
Anti-drape	10.25	9.29	10.45	10.82	9.55	10.02
T.H.V.	2.66	2.44	2.8	2.65	2.15	2.51

100 was high, the THV decreased with increasing concentration of UV-absorber. This was due to the significant increase in the fullness and softness of the fabric as the fabric formed a thick layer on the surface of the fabric.

In order to improve the THV with a limited sacrifice to the other properties of cotton, LH or HL was found to be the most suitable concentration. The low concentration of Triton X-100, when the concentration of UV-absorber was high, was helpful for the decrease in the fullness and softness, and for the improvement of THV of the fabrics. The high concentration of Triton X-100, when the concentration of UV-absorber was low, was helpful for the decrease in the fullness and softness, and for the improvement of THV of the fabrics.

IV. Conclusion

This study is concerned with the effect of UV-absorber treatment and the effect of UV-exposure on the mechanical properties of cotton fabrics. The following results were obtained:

1. The UV-absorber treatment had an effect on the mechanical properties of control fabrics. As a whole, the load-extension values became large, while the tensile energy values became small. The bending properties and the shear properties of the treated fabrics were increased as compared with those of the control fabrics. The compression properties were influenced by the concentration of UV-absorber.

2. The UV-absorber treatment generally increased fullness/softness, but reduce stiffness, crispness, and anti-drape stiffness of the unfinished fabrics.

3. After UV-exposure, the bending and the shear values of the finished fabrics were reduced. After UV-exposure, the SMD values of the fabrics treated with low concentration of UV-abosrber increased, while those values of the fabrics treated with high concentration of UV-abosrber decreased.

4. After UV-exposure, the primary hand values, fullness/softness, stiffness, and anti-drape stiffness, of the finished fabrics increased.

5. The THV of fabrics were reduced after both UV-absorber treatment and UV-exposure. However, the THV of the finished fabrics were less reduced by UV-exposure compared to those of the unfinished fabrics.

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