Effects of the modification of fiber surface on the mechanical properties of cotton fabric

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Abstract: Recently, the modification of the fiber surface is becoming an essential factor for comfortable clothing life. Therefore, understanding the relationship between the fiber surface characteristics and comfort of the garment is very important. However, studies on the effect of modification of the fiber surface on wear comfort of the garment has been done little. In this study, the effect of balance between hydrophilic and hydrophobic property of the fiber surface on the mechanical and frictional properties of the cotton fabric is investigated. In order to change the hydrophilic/hydrophobic balance of the fiber surface, we adopted a method of fixing the hydrocarbon chains directly to the surface of the cotton fiber. The resulted fabrics demonstrated a good water repellency and the degree of water repellency can be controlled by the hydrocarbon agent (stearylamine) concentration in the non-aqueous media. Mechanical and friction properties of cotton fibers that are immobilized by stearylamine are assessed by KES-FB1~4, and 16 properties are measured [1]. In addition, based on these values, the primary hand value is computed. Consequently, it is found that hysteresis of shear force, 2HG, and hysteresis of bending moment, 2HB, of stearylamine-treated cotton fabrics tend to be lower, and tensile resilience, RT, tends to be higher. On the other hand, it is found that KOSHI (stiffness), HARI (anti-drape spread) tend to be lower, and SHINAYAKASA (flexibility with soft feeling) tends to be higher. These results suggest that the cotton fabric used in this study becomes softer by immobilizing the hydrocarbon chains.

Keywords: modification of cotton fiber, KES, water-repellent

1. INTRODUCTION

Functionalization of fabrics has been studied for a long time for comfortable clothing life. Many of them are carried out by modification of the fiber surface. In many cases, some resin, which are play a role of fixation of the functional agent, are used for the fiber surface treatment. Unfortunately, this process harden the texture (hand feeling) of the fabric. In other words, mechanical and frictional properties of fabric surface are changed. These properties are involved in comfort of the garment. Therefore, understanding the relationship between the fabric surface properties and comfort of the garment is very important. It is necessary to clarify the change in the fabric mechanical and frictional properties caused by the modification of the surface of fabrics

So far, the effect of the treatment by natural indigo dyeing [2] and softener [3] on the mechanical and surface properties of fabrics have been reported. However, some changes in these properties caused by hydrophobizing of the fiber surface has not been studied. In this study, we tried the application of the water repellent on hydrophobizing of the fiber surface. A general method of water-repellent has been using the resin for fixation of water-repellent agents. Mechanical and frictional properties of the treated fabric by these methods are affected by the properties as caused by resin. Consequently, it is not possible to evaluate the change in some mechanical and frictional properties caused by hydrophobizing of the fiber surface. Therefore, to clarify the change in their properties caused by hydrophobizing of the fiber surface, we have adopted the method of immobilizing a hydrocarbon chains directly to the surface of the cotton fibers which gave reactive by treatment with cyanuric chloride [4].

2. EXPERIMENT

2.1 Materials

Sample fabrics were cotton fabric (broad) as shown in Table 1. Reagents were used cyanuric chloride, stearylamine and benzene of special grade.

Table 1: The specimens used in this study

Sample	Weave	Weight (mg/cm^2)	Thickness (mm)	Bulk Density (g/cm^3)	Volume Fraction(%)
Broad	Plain	11.4	0.20	0.568	36.88

2.2 Methods of cyanuric chloride treatment

First, the cotton fabric was swollen by distilled water (100℃) for 3 min, and then returned to normal temperature. The preswollen fabric was treated with 5%v/v aqueous sodium hydroxide solution at 20°C for 30min. After that, an excess alkaline solution remaining in cotton fabrics was removed. Then, Cotton fibers that has been converted to cellulose anion cellulose-anion fabric was treated with 5%v/v cyanuric chloride solution in benzene at 20°C for 5min, and washed with running water and dried.

2.3 Methods of stearylamine treatment

The cotton fabric modified by cyanuric chloride was immersion treatment with 5×10^{-2}mol/L stearylamine solution in benzene at 30°C for 30min. After that, washed with running water and dried.

2.4 Evaluation of the hydrophobizing the fiber surface

The hydrophobizing the fiber surface was evaluated by the shape of water droplet that was dropped on the cotton fabrics. Water droplets photographs were taken with digital microscope.

2.4 Measurement of mechanical and frictional properties

Mechanical and frictional properties were measured by KES (Kawabata Evaluation System). Measurements were carried out under standard conditions [1]. Measured values are the average of the three points. In addition, the primary hand value of each sample is computed with KN-201-LDY that based on measured value by KES.

3. RESULTS AND DISSCUTION

3.1 Reaction with water repellent

Fig.1 shows the water droplet on the cotton fabric which was treated by some commercial ready-made water-repellent. The photograph of the water droplet on the cotton fabric treated with 5×10^{-2}mol/L stearylamine benzene solution was exhibited in Fig.2. Both water droplets has a shape close to spherical, indicating that the fiber surface is covered with the water-repellent agents.

Fig.3 shows the water droplet on the cotton fabric that was immersed in 5×10^{-4}mol/L stearylamine benzene solution. The shape of a water droplet became a semi-spherical shape. This suggests that stearylamine are immobilized on the fiber surface, but the reaction of stearylamine is insufficient. Consequently, it was found that the degree of hydrophobizing the fiber surface could be controlled by the hydrocarbon agent (alkylamine) concentration in the non-aqueous media.

1

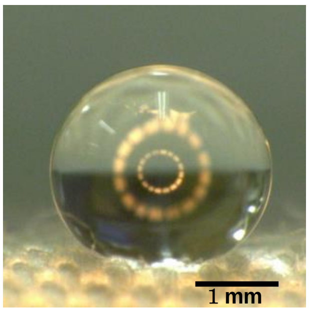

Fig.1 Photograph of the water droplet on the cotton fabric treated with a commercial ready-made water-repellent.

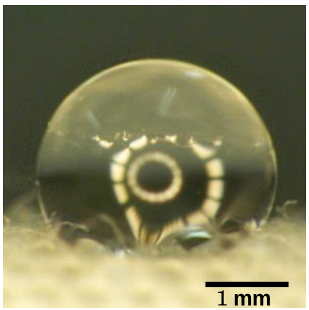

Fig.2 Photograph of the water droplet on the cotton fabric treated with with 5×10^{-2}mol/L stearylamine benzene solution

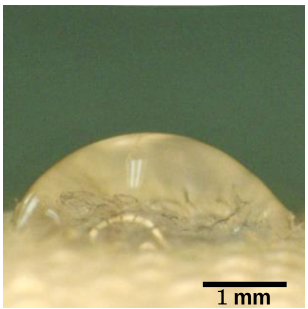

Fig.3 Photograph of the water droplet on the cotton fabric that was immersed in 5×10^{-4}mol/L stearylamine benzene solution.

3.2 Mechanical and frictional properties

Table 2 shows the measured values of untreated, alkali-treated and stearylamine-treated sample that was evaluated using KES system. Stearylamine treatment cotton fabrics have been subjected to alkali treatment in the initial process. This alkali treatment is expected to be affecting the physical properties of the fabric. Therefore, the changes in the mechanical and frictional properties caused by hydrophobizing the fiber surface can become obvious by comparing the stearylamine-treated samples and the alkali-treated samples. Alkali-treated sample was prepared by treated with the blank solution in benzene after treatment with the alkaline solution.

When comparing the untreated and the alkali-treated sample, the changes were indicated at following properties. Strain of maximum load, *EM*, and tensile energy, *WT*, increased. Shear rigidity, *G*, and hysteresis of shear force, *2HG*, decreased. Bending rigidity, *B*, and hysteresis of bending moment, *2HB*, decreased. Compression resilience, *RC*, decreased clearly. Mean of friction coefficient, *MIU*, did not change. Mean deviation of *MIU*, *MMD*, increased slightly.

Table 2 The measured value of the different samples that was evaluated using KES system.

	Symbols	Units	Untreated	Alkali-treated	Stearylamin-treated
Tensile	LT	–	0.938	0.873	0.775
	WT	gf・cm/cm^2	8.00	11.6	10.8
	RT	%	48.5	49.1	56.5
	EM	%	3.26	5.32	5.58
Shear	G	gf/cm・deg	0.770	0.650	0.750
	2HG	gf/cm	1.05	0.850	0.990
	2HG5	gf/cm	3.64	3.19	2.33
Bending	B	gf･cm^2/cm	0.117	0.0855	0.0518
	2HB	gf･cm/cm	0.0719	0.0502	0.0337
Compression	LC	–	0.318	0.354	0.405
	WC	gf・cm/cm^2	0.210	0.180	0.260
	RC	%	41.8	36.3	36.5
Surface	MIU	–	0.143	0.143	0.152
	MMD	–	0.015	0.0204	0.0173
	SMD	μm	1.50	2.03	1.73
Thickness	T	mm	0.200	0.220	0.222
Weight	W	mg/cm^2	11.4	11.6	12.2

*Average of values

When comparing the properties of alkali-treatment sample with that of stearylamine-treated samples, changes were observed in the following items. Tensile linearity, *LT*, and *WT* decreased. Tensile resilience, *RT*, increased clearly. Therefore, stearylamine-treated sample becomes soft elongation and increase resilience is suggested. *G* increased. *2HG*, *B* and *2HB* further decreased. As well as changes in the alkali treatment, the decreased *2HG* and *2HB* suggest a reduction in the friction between the fibers coated with stearylamine. Compression linearity, *LC*, and compression energy, *WC*, increased, but *RC* did not change.

In the friction properties which was expected to change greatly, *MIU* increased slightly and *MMD* decreased slightly. This change means that hand feeling of the fiber surface coated with stearylamine is not substantially changed. However, feeling touched by the finger actually are considerably different, and it can be expressed as waxy feeling. This suggests that measurement of friction by KES is not possible to represent the feeling of reality.

3.3 Primary hand value

Figure 4 shows the values of the primary hand value of each sample that was computed with KN-201-LDY. When comparing the primary hand value of alkali-treatment sample with that of stearylamine-treated samples, it was found that *KOSHI* (stiffness), *HARI* (anti-drape spread) and *SHARI* (crispness) decreased, and *SHINAYAKASA* (flexibility with soft feeling) increased. *FUKURAMI* (fullness and softness) and *KISHIMI* (scooping feeling) hardly changed. *KOSHI*, *HARI* and *SHINAYAKASA* are affected by bending and shear properties.

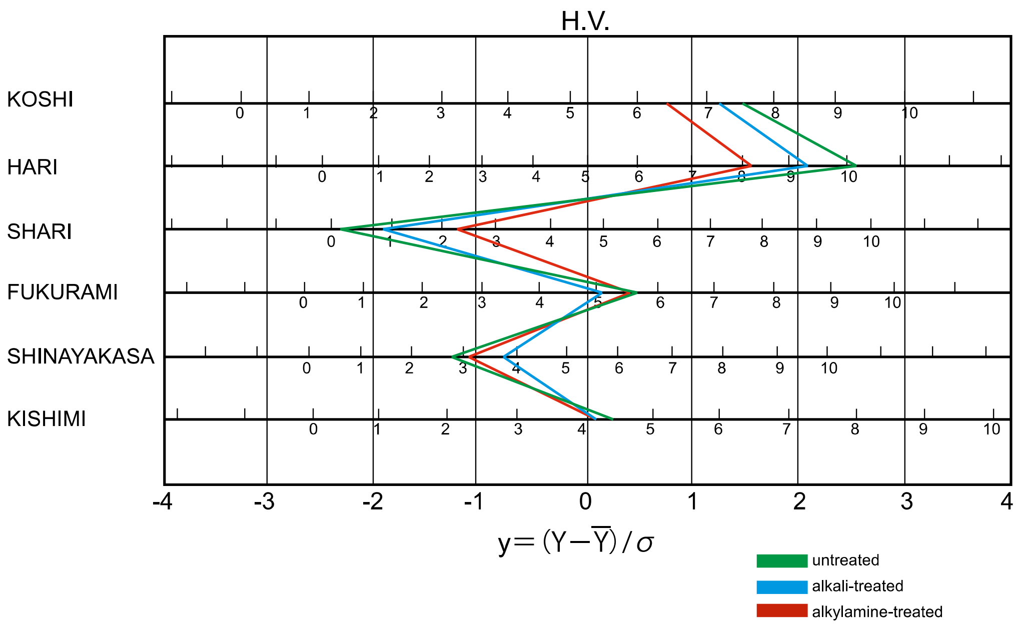

Figure 4: Primary hand value of samples

4. CONCLUSIONS

To hydrophobize the surface of cotton fibers, we adopted the method of immobilizing a hydrocarbon chains (stearylamine) directly to the surface of the cotton fiber. As a result, surface of cotton fabric showed a good water repellent. Mechanical and friction properties of cotton fabric that was treated with this method are *2HG*, *2HB* and *B* were decreased, and *RT* was increased clearly. These results suggest that friction between the fibers coated with stearylamine was decreased and elastic effect was increased. Hand feeling touched by the finger actually are considerably different, Indicating that friction properties change clearly by stearylamine treatment. Unfortunately, the value of friction properties measured by KES could not obtain the expected result of hand feeling. On the other hand, in primary hand value, *KOSHI* and *HARI* were decreased, and *SHINAYAKASA* was increased. Consequently, it was suggested that the cotton fabric used in this study became softer by immobilizing a hydrocarbon chains directly to the surface of the cotton fiber.

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