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Improving Wrinkle Resistance of Cotton Fabric by Montmorillonite

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Abstract: Cotton fabric was treated with montmorillonite (MMT) so as to evaluate its effectiveness on improving its wrinkle resistance. The MMT in emulsion form was applied to cotton fabric by padding and finally the wrinkle resistance of the MMT-treated cotton fabric was improved. Furthermore, instrumental methods were used for studying the presence of MMT particles on the cotton fabric surface. It was noted that nano-scale MMT particles adhered on the fiber surface and the particle size played an important role in influencing the wrinkle resistance of the cotton fabric. The experimental results are discussed thoroughly in this paper.

Keywords: Montmorillonite (MMT), Cotton fabric, Wrinkle resistance, Recovery angle, Nano-particle

Introduction

Montmorillonite (MMT) is a type of inorganic natural clay minerals typically which has silicate (SiO_4) tetrahedral sheets arranged into a two-dimensional network structure [1]. MMT can provide thermal resistance, wrinkle resistance and anti-bacterial properties on textiles [1-7]. The aim of this paper was to investigate the effect of MMT on the wrinkle resistance of cotton fabric. Throughout the paper, the particle sizes of the MMT were reduced by an ultrasonic crashing machine. The reduced particles in an emulsion form were padded onto the cotton fabrics. Although the physical testing had been carried out to evaluate the effect of the MMT treatment on the wrinkle resistance of the treated fabrics, the instrumental methods were also be conducted to measure the particle sizes of the reduced MMT particles in order to characterize the surface morphology and chemical composition of the treated fabrics.

Experimental

Fabric

100 % twill cotton fabrics, each of size 20 cm × 30 cm, with yarn density of 50 picks/cm and 24 ends/cm were used. The fabrics had been desized, scoured and bleached.

Determination of the Concentration of Dispersing Agent for Preparing the MMT Emulsion

In order to prepare a good MMT emulsion such that the tiny particles of MMT should be well dispersed and will not be aggregated again to form large molecules, a nonionic dispersing agent, Matexil DN-VL, with different concentrations were used for dispersing the MMT clay to form an emulsion. The emulsion was prepared by adding 1.0 g of MMT into 50 m*l* of dispersing agent with four different concentrations, i.e. 10 %, 50 %, 70 % and 100 % respectively. Each emulsion was then crashed by an ultrasonic crashing machine (Ningbo Scientz Biotechnology Co. Ltd.) for 15 minutes. After crashing, the behavior of the emulsions with different concentration of dispersing agent was observed carefully at different time intervals, i.e. 5, 10, 15, 30 minutes.

Preparation of MMT Emulsion and Its Application on Cotton Fabric

MMT emulsions were prepared with 1.0 g montmorillonite and 50 m*l* of 70 % dispersing agent. The MMT emulsions were then subjected to an ultrasonic crashing machine to reduce the particle sizes. The emulsions were crashed with different numbers of cycle, i.e. 8, 14, 20 numbers of cycles with duration of 1 hour, 2 hours and 3 hours respectively. Each crashing cycle represented that the emulsion was crashed for 99 times by the ultrasonic wave.

In addition, two MMT emulsions were also prepared by (i) 2 m*l* of the binder mixed with 48 m*l* of the dispersing agent; and (ii) 8 m*l* of the binder mixed with 42 m*l* of the dispersing agent. Each MMT emulsion was then subjected to crashing by the ultrasonic crashing machine to reduce the particle sizes. The emulsion was crashed up to 20 numbers of cycles for 3 hours.

After preparing the MMT emulsions, the MMT emulsion of reduced particle size was padded onto the cotton fabric by a padding machine (Labortex Co. Ltd.). Due to the poor dispersing properties of the MMT particles, this padding process should be carried out as soon as possible, i.e. not longer than 30 minutes after finishing the crashing process, in order to prevent the reduced particles from aggregating again to form larger molecules. The emulsion was padded onto the cotton fabrics by the padder with the pressure of 3 kg/cm^2 and the speed of 5 rpm. Two padding times were investigated including 3 padding times and 6 padding times, and subsequently the wet pick-up was 55 % and 65 % respectively. Finally, the treated fabrics were dried at 90 °C for 10 minutes in the oven; and cured at 16 °C for 3 minutes. Table 1 below summarized the experimental procedures for preparing the MMT emulsion and its application on cotton fabric.

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Table 1. The experimental procedure for preparing the MMT emulsion and its application on cotton fabric

Runs	1	2	3	4	5	6	7	8	9	10
MMT	1.0 g									
70 % Matexil DN-VL (dispersing agent)	50 m*l*						48 m*l*		42 m*l*	
Acramin SL (Binder)	–						2 m*l*		8m*l*	
Number of crashing cycle	8		14		20					
Time duration	1 hour		2 hours		3 hours					
Padding times	3	6	3	6	3	6	3	6	3	6
Wet pick-up	55 %	65 %	55 %	65 %	55 %	65 %	55 %	65 %	55 %	65 %
Padder pressure	3 kg/cm^2									
Speed of padder	5 rpm									
Drying condition	90 °C for 10 minutes									
Curing condition	160 °C for 3 minutes									

Evaluation of the Wrinkle Resistance of the Fabrics

The wrinkle resistances of the treated fabrics were evaluated by the AATCC Test Method 66-1998.

Surface Morphology

The surface morphology of the MMT-treated was investigated by a scanning electron microscope (SEM) (JEOL, Model No: JSM-6335F) with magnification of 1,000X and 30,000X.

Chemical Composition Measurement

The chemical compositions of the treated fabrics were studied by using a Perkin Elmer System 2000 of Fourier Transform Infrared spectrophotometer (FTIR) with the scanning range between 4000 and 650 cm^{-1}. The characteristic infrared bands of silicon compounds to be studied were summarized in Table 2.

Table 2. Characteristic infrared bands of silicon compounds [8,9]

Frequency (cm^{-1})	Assignment
3700-3200	Si-OH stretching
2250-2100	Si-H stretching
1280-1255	Si-CH_3 symmetric deformation
1250-1200	Si-CH_2-R stretching
1150	Si-C_6H_5
1130-1000	Si-O-Si asymmetric stretching
1110-1000	Si-O-R asymmetric stretching
970-920	Si-O-C_6H_5
950-800	Si-H stretching
860-760	Si-C stretching

Results and Discussion

Dispersing Properties of MMT

Since MMT clay was poorly dispersed in water, thus dispersing agent was required to form an emulsion with these particles. The dispersing properties of MMT with four different concentrations of dispersing agent were shown in Table 3.

The results in Table 3 showed that the MMT clay could be well dispersed and stayed for a longer time in the presence of 70 %-100 % dispersing agent. However, the 100 % dispersing agent was very viscous. Therefore, the concentration of 70 %

Table 3. The dispersing properties of MMT with four different concentrations of dispersing agent at different time duration

Concentration of dispersing agent / Time	10 %	50 %	70 %	100 %
5 minutes	The particles started to sediment within 1 minute and the emulsion started to separate into two layers after 4 minutes.	The particles started to sediment after 5 minutes.	The particles were well dispersed within 5 minutes.	The particles were well dispersed within 5 minutes.
10 minutes		The emulsion started to separate into two layers after 10 minutes.	The particles were well dispersed within 10 minutes.	The particles were well dispersed within 10 minutes.
15 minutes		After 15 minutes, the emulsion was separated into two clear layers.	The particles were well dispersed within 10 minutes.	The particles were well dispersed within 10 minutes.
30 minutes			The emulsion started to separate into two layers after 30 minutes.	The emulsion started to separate into two layers after 30 minutes.

Table 4. Wrinkle resistance of MMT-treated fabrics

Run	Times of padding	Recovery angle (W+F), degree	% Improvement
Untreated	–	212	–
1	3	212	0
2	6	214	0.9
3	3	214.00	0.9
4	6	215.33	1.6
5	3	222.00	4.7
6	6	224.67	6.0
7	3	226.67	7.0
8	6	230.67	8.8
9	3	231.33	9.1
10	6	234.00	10.4

dispersing agent was selected and used.

Wrinkle Resistance of the Fabric

The wrinkle resistance of the MMT-treated fabrics have been evaluated and the results obtained were shown in Table 4.

From Table 4, it is obvious that wrinkle resistance of the MMT-treated fabrics in runs 1 to 4 have no significant improvement when compared with the untreated fabric. However, when increasing the number of crashing cycles to 20 for 3 hours in runs 5 and 6, the wrinkle resistance of the MMT-treated fabrics was improved. The recovery angle of the fabric treated with 3 times of padding increases 4.7 %, while that of the fabric treated with 6 times of padding increases 6.0 %. Therefore, it could conclude that a longer crashing time used, a better would be the wrinkle resistance of the cotton fabrics obtained.

2 m*l* of binder was added to runs 7 and 8, the recovery angle of the fabric treated with 3 times of padding increases 7.0 %, while that of the fabric treated with 6 times of padding increases 8.8 %. On the other hand, 8 m*l* of binder was added to runs 9 and 10, the recovery angle of the fabric treated with 3 times of padding increases 9.1 %, while that of the fabric treated with 6 times of padding increases 10.4 %. These results showed that the wrinkle resistance of the fabrics are improved by the treatment with binder. It also revealed that larger amount of binder used would impart slightly higher wrinkle resistance to the fabrics. The reason might be due to the binder could change the surface tension of the treated fabrics so that more MMT particles are attached on the fiber surfaces. Generally speaking, the MMT treatment could improve the wrinkle resistance of cotton fabric to certain extent depending on the application conditions.

Surface Morphology of MMT-treated Cotton Fabric

Figures 1 to 7 demonstrated a series of SEM images of (i) the untreated fabric, (ii) MMT-treated fabric without binder and (iii) MMT-treated fabric with 2 m*l* or 8 m*l* binder with magnification of 1,000. The SEM results of the fabrics treated

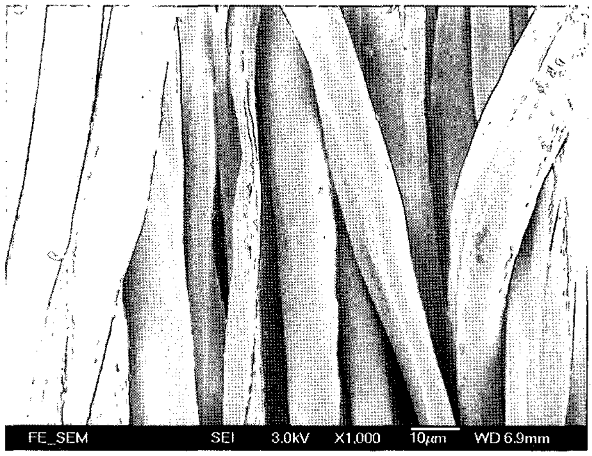

Figure 1. SEM image of untreated fabric (×1,000).

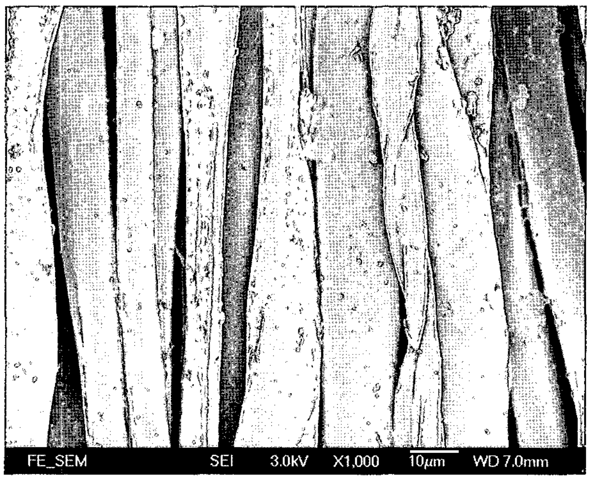

Figure 2. SEM image of MMT-treated fabric with no binder after 3 times of padding (×1,000).

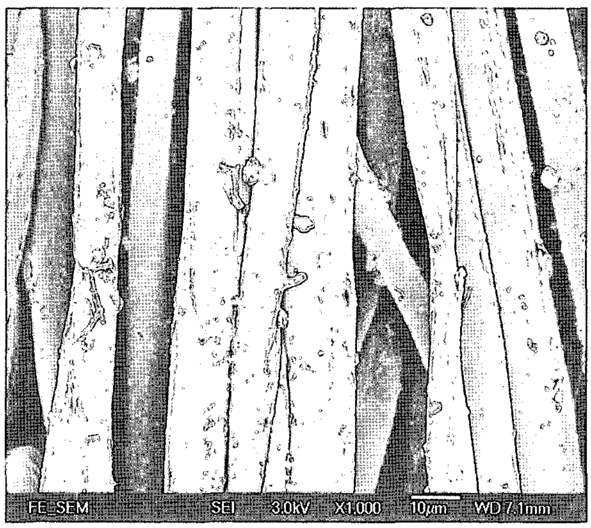

Figure 3. SEM image of MMT-treated fabric with no binder after 6 times of padding (×1,000).

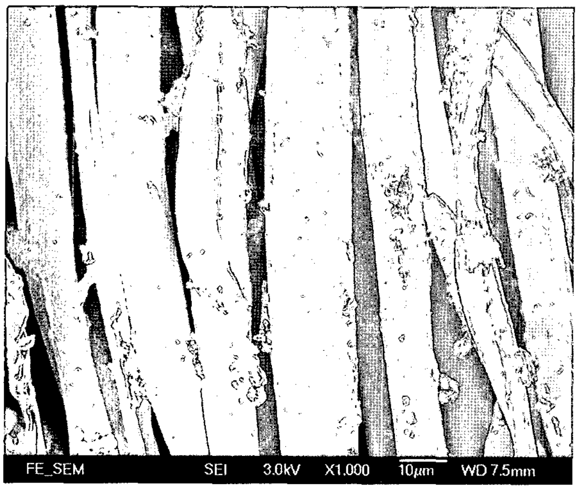

Figure 4. SEM image of MMT-treated fabric with 2 m*l* binder after 3 times of padding (×1,000).

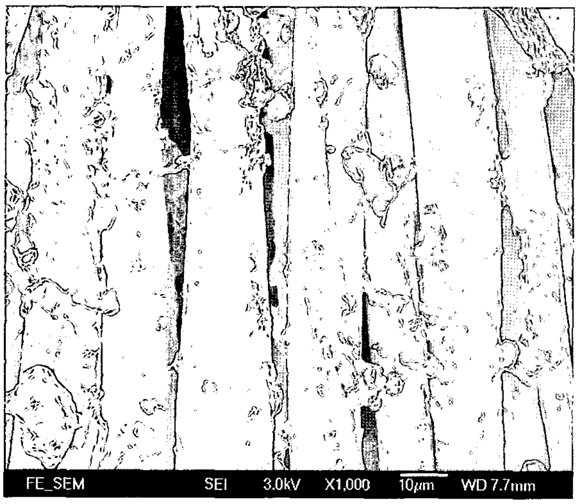

Figure 5. SEM image of MMT-treated fabric with 2 m*l* binder after 6 times of padding (×1,000).

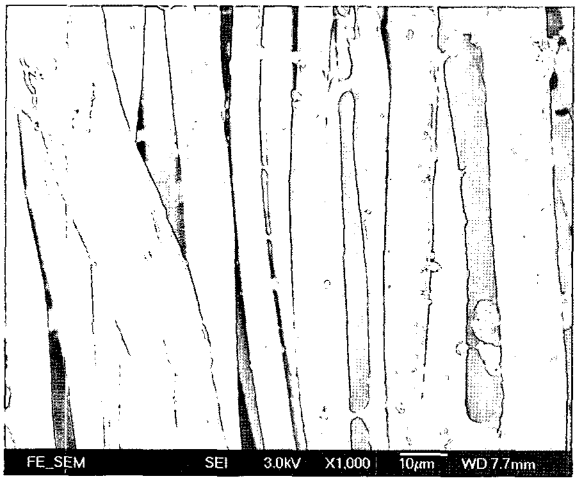

Figure 6. SEM image of MMT-treated fabric with 8 m*l* binder after 3 times of padding (×1,000).

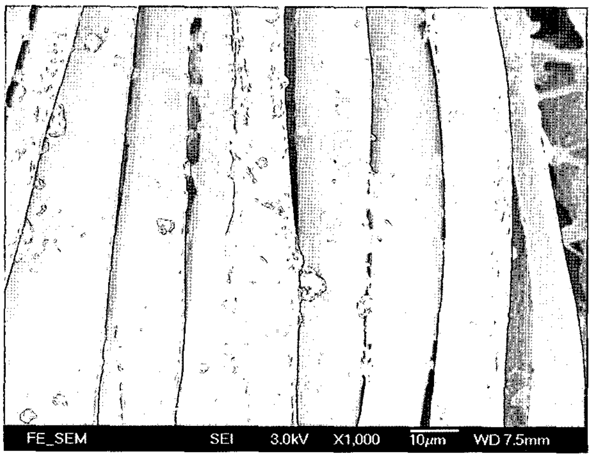

Figure 7. SEM image of MMT-treated fabric with 8 m*l* binder after 6 times of padding (×1,000).

with binder showed that the fibers are coated with large amount of substances forming crosslinkages between the adjacent fibers. This phenomenon does not exist in both the untreated fabric and the fabrics treated without binder. Hence, it was believed that binder could change the surface tension among the fibers, resulting in affecting the wrinkle resistance of the treated fabrics. In addition, when the padding times were increased from 3 to 6, it was obvious that more substances could be coated on the fiber surface.

Furthermore, Figures 8 to 14 demonstrated a set of SEM images of (i) the untreated fabric, (ii) MMT-treated fabric with no binder and (iii) MMT-treated fabric with 2 m*l* or 8 m*l* binder with a magnification of 30,000. All SEM images revealed that some tiny particles of around 100 nm, which are at nano-particle size [1,3,6], are attached on the fiber surfaces of the MMT-treated fabrics when compared with that of the untreated fabric. These tiny particles are regarded as nano-MMT particles. Figures 11 to 14 demonstrated that there are more MMT-particles present on the fiber surfaces

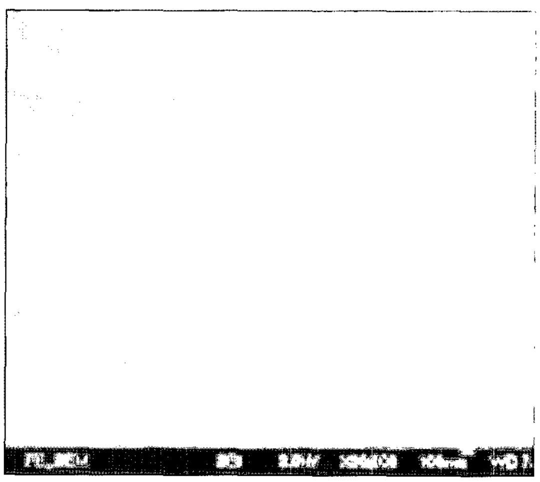

Figure 8. SEM image of untreated fabric (×30,000).

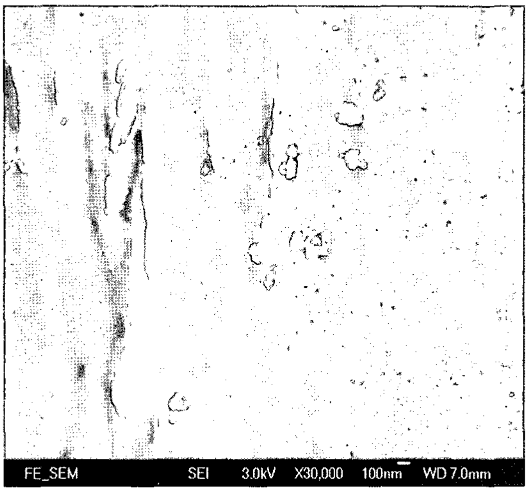

Figure 9. SEM image of MMT-treated fabric with no binder after 3 times of padding (×30,000).

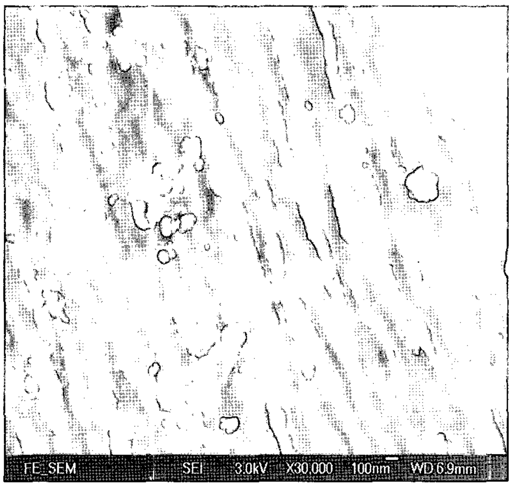

Figure 10. SEM image of MMT-treated fabric with no binder after 6 times of padding (×30,000).

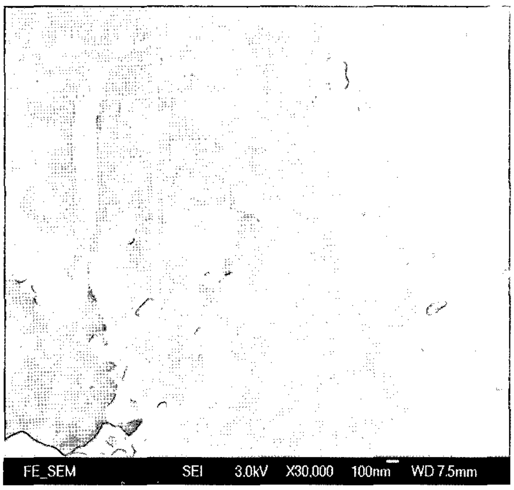

Figure 11. SEM image of MMT-treated fabric with 2 m*l* binder after 3 times of padding (×30,000).

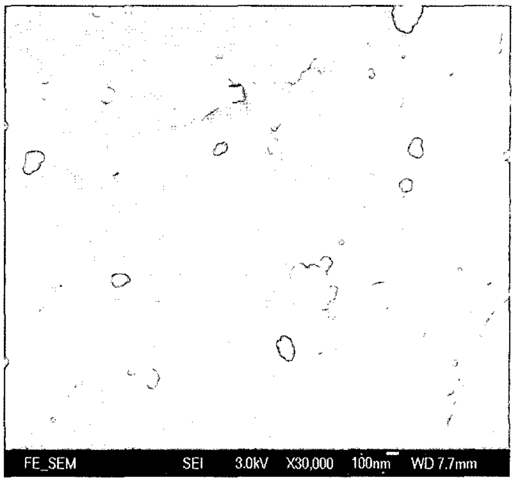

Figure 12. SEM image of MMT-treated fabric with 2 m*l* binder after 6 times of padding (×30,000).

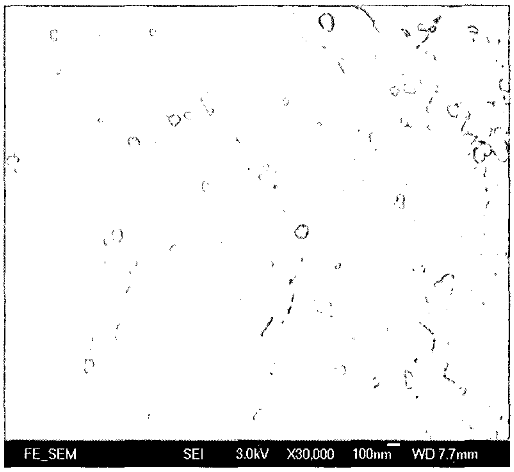

Figure 13. SEM image of MMT-treated fabric 8 m*l* binder after 3 times of padding (×30,000).

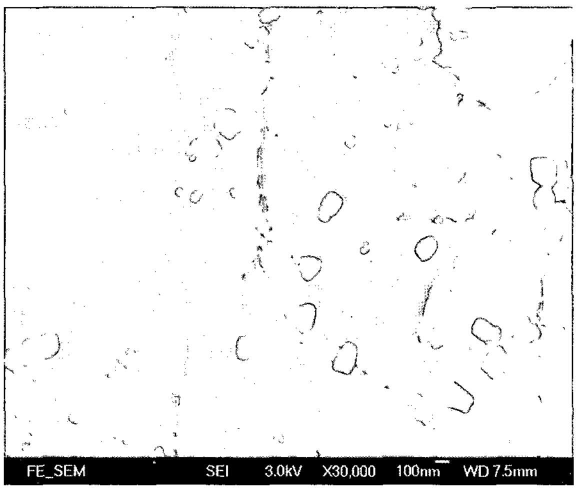

Figure 14. SEM image of MMT-treated fabric with 8 m*l* binder after 6 times of padding (×30,000).

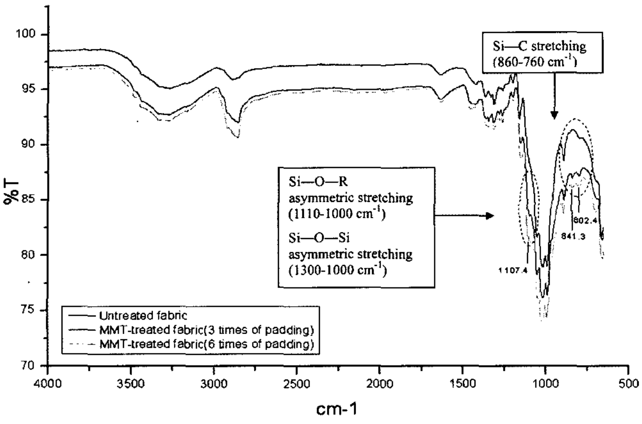

Figure 15. FTIR results of the MMT-treated fabrics without binder.

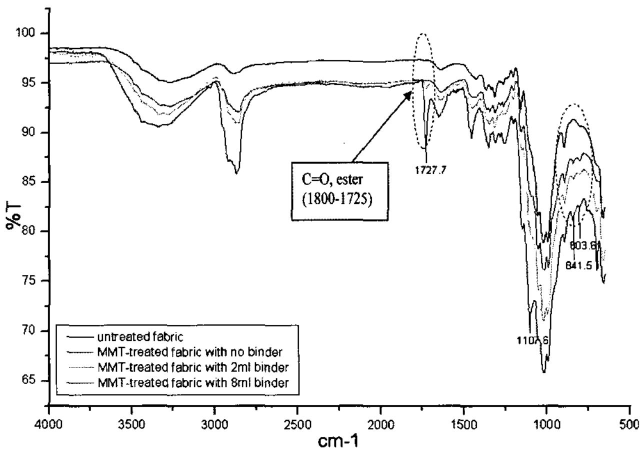

Figure 16. FTIR results of the MMT-treated fabrics (3 times of padding).

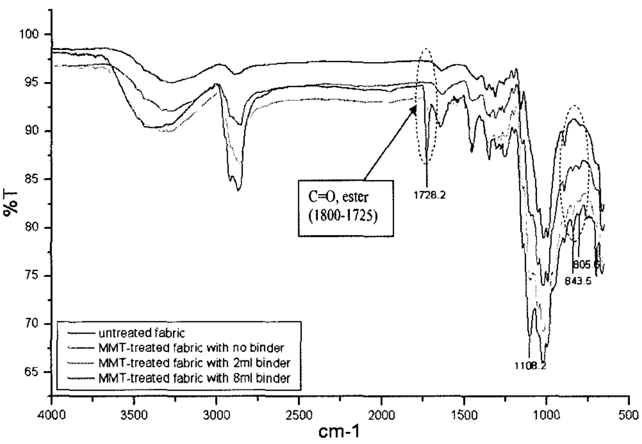

Figure 17. FTIR results of the MMT-treated fabrics (6 times of padding).

of the fabrics treated with binder. However, only a small amount of them is present on the fiber surfaces of those treated without binder as shown in Figures 9 and 10. Hence, the binder can be regarded as a medium enhancing the attachment of MMT particles in the cotton fiber surface.

Fourier Transform Infrared (FTIR) Spectroscopy Analysis

The FTIR spectra of both the untreated fabric and the MMT-treated fabrics without the use of binder were shown in Figure 15. The FTIR results obtained from the MMT-treated fabrics show that three absorption bands appear at 802.4 cm^{-1}, 841.3 cm^{-1} and 1107.4 cm^{-1} respectively, but none of them exist in the untreated fabric.

According to Table 2, the MMT-treated fabrics were characterized to have Si-C stretching at 802.4 cm^{-1} and 841.3 cm^{-1}, and Si-O-R asymmetric stretching and Si-O-Si asymmetric stretching at 1107.4 cm^{-1}. Since the major component of the MMT is silicon oxide, it is believed that such absorption bands are produced by the attachment of the MMT particles on the treated fabric. These interactions with cotton fibers could explain the improvement of the wrinkle resistance of the MMT-treated fabrics.

In addition, the absorption bands of Si-C stretching, Si-O-R asymmetric stretching and Si-O-Si asymmetric stretching are stronger as the times of padding were increased. This implies that the amount of MMT particles attached on the treated fabrics was increased by higher pick-up percentage.

Figure 16 showed the FTIR spectra of the MMT-treated fabric with or without binder after 3 times of padding, while Figure 17 showed those of the MMT-treated fabric with or without binder after 6 times of padding and both of them give the same results.

The FTIR results obtained from the fabrics treated with binder showed that an absorption bands appears at around 1727-1728 cm^{-1}, but none of them exist in the untreated fabric and the fabrics treated with no binder. This band is characterized to be C=O bond of ester compound. The absorption band becomes stronger as the amount of the binder used was increased. Therefore, it is believed that this band was produced by the addition of binder.

Furthermore, the absorption bands at 803.6-805.6 cm^{-1}, 841.5-843.5 cm^{-1} and 1107.6-1108.2 cm^{-1} have been characterized as Si-C stretching, Si-O-R asymmetric stretching and Si-O-Si asymmetric stretching respectively. These absorption bands of the fabrics treated with binder are stronger than those treated with no binder. In addition, the bands become stronger as the amount of binder used is increased. This can explain the increment of MMT particles attached on the fiber surfaces by using larger amount of binder. When combining these interactions with the high viscosity of the binder, the wrinkle resistance of the MMT-treated fabrics are slightly improved, which has been evaluated by the physical testing.

Conclusions

In this paper, study has been conducted to investigate the effect of the MMT on the wrinkle resistance of cotton fabrics. The sizes of the MMT particles were reduced by the ultrasonic crashing machine. The condition of 20 crashing cycles for 3 hours was applied in this paper. The effect of the binder on the MMT treatment has also been investigated.

Recovery angle test has been applied to evaluate the wrinkle resistance of the MMT-treated fabrics. The results showed that the wrinkle resistance of the MMT-treated fabric was slightly improved in the presence of binder.

SEM, particle size analysis method and FTIR Spectroscopy had been used for characterizing the MMT emulsion and the MMT-treated fabrics. The SEM results characterized that nano-particles attach mainly on the fiber surfaces of the MMT-treated fabrics.

The FTIR results demonstrated that the MMT particles could establish the interactions with the cotton fibers. These interactions were also intensified by the addition of binder and the increase in the pickup percentage. However, the particle size of the MMT was the major factor to affect the wrinkle resistant treatment for cotton fabric in this paper. Longer crashing cycles and time will impart better wrinkle resistant to the MMT-treated cotton fabric.

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