Fibers and Polymers 2006, Vol.7, No.2, 186-190

Mercerization in Degassed Sodium Hydroxide Solution

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(Received April 13, 2005; Revised January 23, 2006; Accepted January 25, 2006)

Abstract: The application of a degassing system to mercerization process was investigated. It was found that the physical properties of cotton fabrics mercerized in the degassed NaOH solution were superior to those mercerized in NaOH solution. The degree of penetration of the degassed water was examined by measuring wicking height. The wicking height in the degassed water without the wetting agent is higher than that of the saturated water with 0.1 % of wetting agent.

Keywords: Mercerization, Degassing system, Wicking, Degree of penetration, Membrane

Introduction

Mercerization is a finishing process for cotton fabrics to give various effects such as increased moisture regain, luster and dyeability in 20-30 % of NaOH solution with or without tension [1-5]. This process is also called a silket finishing because of the touch and luster similar to silk after the finishing process. Most of cotton products for garments are treated with the concentrated NaOH solution to give various effects as mentioned above [6-9].

When cotton fibers are immersed in the alkali solution (sodium hydroxide or liquid ammonia) at a specified concentration for a specified time, and then rinsed with stretching. The cross section of cotton fibers is converted from ribbon shape to circle and the natural twist of cotton fibers disappear. Also, a portion of the crystal region of cotton fibers is converted to the amorphous region so that the dyeability and chemical reactivity are enhanced. When the cotton fibers are immersed in an alkali solution, the alkali is adsorbed by fibers forming cellulosates. The cellulosates are very unstable so that the cellulose can be regenerated when rinsed in water [10-13]. Regenerated cellulose dose not have chemical changes compared to the original cellulose, but the crystal structure is converted from cellulose I to cellulose II.

The degree of mercerization of cotton fibers is affected by various factors such as the alkali concentration, treating temperature, time and tension. But in the most widely used mercerization process, the cotton is immersed in the NaOH solution at room temperature [14-19]. The mercerization at room temperature has some disadvantages such as a skin-core effect due to jamming effects [20].

In mercerization process, the penetrating ability of alkali into the inside of cotton fibers is very important factor. The sufficient and uniform penetration of the alkali solution can be achieved if the dissolved gases in the NaOH solution are removed effectively.

In the food industry, the degassed water is used for immersing soybean or rice to reduce immersing time and to acquire more complete swelling. When soybean or rice is immersed in the degassed water, the gases in the soybean or rice are extracted to the water because its partial pressure of gases is higher than that of water. So rapid sorption and complete swelling can be acquired. This principle can be adopted to the textile wet process such as mercerization and dyeing process because the wettability of liquid largely affects the dyeing and finishing properties of fabrics.

Therefore, this research was conducted to verify the possibility of application of the membrane based degassing technique to the textile industry, especially in cotton mercerization process by comparing the mercerization effect immersed in degassed NaOH solutions with the one in saturated NaOH solutions.

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Experimental

Materials and Chemicals

Desized, scoured, bleached cotton fabric (84 × 66), weighing 118.9 g/m^2, was used for mercerization. A wetting agent for the wicking test was Protepon SDLF (Protex Korea Co. Ltd.). For a wicking test, a polyester warp knitted fabric was used.

Degassing System and Dissolved Oxygen Meter

The degassing system equipped with a membrane module was manufactured by Nanomemtech Co. Ltd. and the system was operated at a flow rate of 0.8 ton/hr with 30 torr of vacuum conditions. The schematic diagram of the degassing system used in this research is shown in Figure 1. To measure the dissolved oxygen concentration of water accurately, MOCA3600 (Orbisphere, Swiss) was used because it can measure the dissolved oxygen of water to 1 ppb in the pipe line, continuously.

Wicking Procedures

When the medium such as fibers or fabrics is immersed in degassed water, the gases in the medium are extracted to the water because its partial pressure of gases is higher than that of water. So rapid sorption and complete swelling can be acquired. To prove this effect experimentally, the wicking

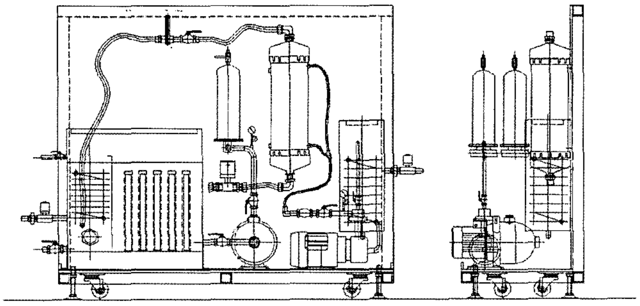

Figure 1. Schematic diagram of a degassing system for mercerization.

Table 1. Measurement procedures for the wicking ability of degassed water

Step	Procedure
1	Cut sample in the size of 20 × 200 mm
2	Prepare solution at specified concentration of wetting agent
3	Operate the supply and vacuum pump
4	Immerse sample to the solution (below 0.5 cm from the water surface)
5	Measure the absorbed height after 2 min.

test was performed. The experimental methods are listed in Table 1.

Mercerization and Dyeing Process

The saturated (concentration of dissolved oxygen, 6.5 ppm) and degassed (concentration of dissolved oxygen, 0.3 ppm) NaOH solution with the degassing system as shown in Figure 1 was prepared. The samples were immersed in the NaOH solution under slack or tension conditions and the rectangular pin frame was used to fix the sample. After immersing the samples at various concentrations and times, the sample was washed thoroughly with tap water, neutralized with 1 % acetic acid solutions, rinsed with cold water, then finally line-dried. The fabrics mercerized at various treating conditions were dyed in the IR dyeing machine at a liquor ratio of 40:1. The dyebath were prepared with Cibacron Navy F-G and Cibacron Red F-B (Reactive dye, 3 % owf) and the concentration of Na_2CO_3 and Na_2SO_4 were 20 *g/l*, respectively. Dyeing was commenced at 25 °C. The dyebath temperature was raised to 80 °C at a rate of 2 °C/min and maintained at this temperature for 30 min.

Measurements

The evaluation methods and standards of mercerized cotton fabrics were summraized in Table 2. The K/S value was determined by the Kubelka-Munk equation (1) using an X-Rite spectrophotometer under illuminant D_{65} using the 10 ° standard observer conditions. The crystallinity of cotton fibers was determined by the X-ray diffraction and calculated using the equation (2).

Table 2. Evaluation of mercerized cotton fabrics

Evaluations	Standards
Tensile strength	KS K 0520 (1" raveled strip method)
Barium activity number	AATCC test method 89-1998
Moisture regain	KS K 0221 (oven-balance method)
K/S value	X-Rite spectrophotometer
Crystallinity	X-Ray diffraction

$$K/S = \frac{(1-R)^2}{2R} \tag{1}$$

where;
K: absorption coefficient
S: scattering coefficient
R: reflectance

$$DC = \frac{\int_0^{\infty} s^2 I_c(s)ds}{\int_0^{\infty} s^2 I(s)ds} \times 100 = \frac{I_c}{I_c + I_a} \times 100 \tag{2}$$

where;
I: total scattered intensity
I_a: scattered intensity associated with amorphous region
I_c: scattered intensity associated with crystalline region
s: $(2\sin\theta)/\lambda$

Results and Discussion

Wicking

The results is shown in Figure 2. The wicking height in the degassed water without the wetting agent was higher than that of saturated water with 0.1 % of the wetting agent. From this result, it was found that the degassed water had an excellent penetrating ability.

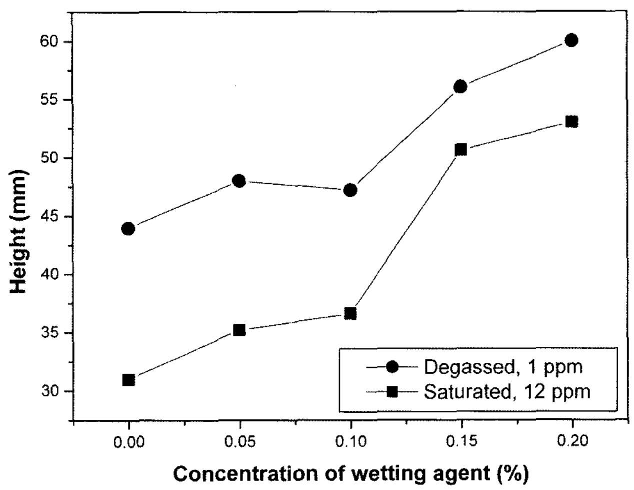

Figure 2. Effect of wetting agent concentration on wicking height of fabrics immersed in saturated and degassed water.

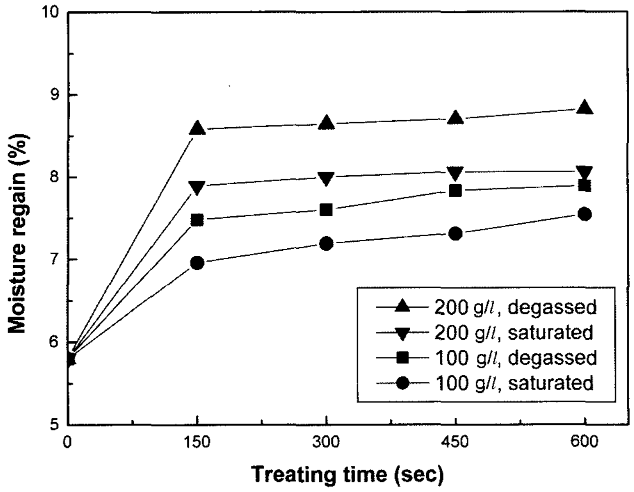

Figure 3. Effect of dissolved gases on moisture regain of NaOH mercerized cotton fabrics under tension.

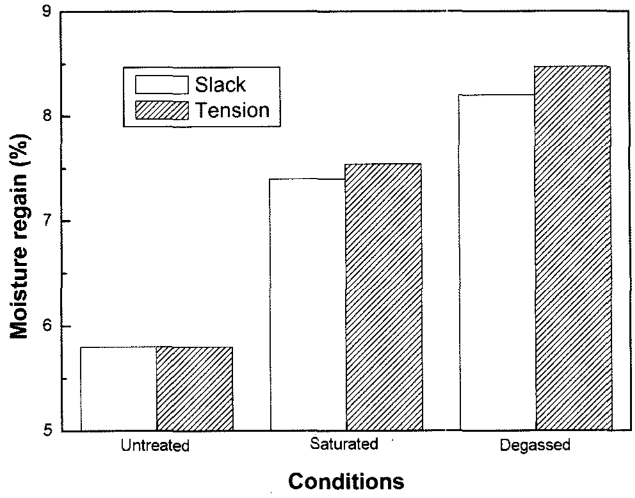

Figure 5. Effect of dissolved gases on moisture regain of NaOH mercerized cotton fabrics (NaOH conc. 200 g/*l*, 60 sec).

Moisture Regain

Generally, the crystalline region in the cotton fibers is decreased by mercerization so that the mercerized cotton fibers have higher moisture regain and water content compared to those of unmercerized cotton fibers. Figure 3 shows the changes in moisture regain of mercerized cotton fibers at the various immersing time. The concentration of NaOH solution was 200 g/*l*. The moisture regain increased as the immersing time increased and the moisture regain of cotton fabrics treated with the degassed NaOH solution was about 10 % higher than that of the saturated NaOH solution. This may be due to the increased amorphous region of cotton fibers treated in the degassed NaOH solution and consequently increased the wettability. However, since the immersing time in a practical mercerization process is shorter than the above mentioned experimental condition, the mercerization process having a short immersing time was conducted at the same NaOH concentration and the results are shown in Figures 4 and 5. The moisture regain of cotton fibers treated in the degassed NaOH solution was higher than that of the saturated NaOH solution. The increment of moisture regain was 7-8 % for the 30 sec immersion and 12 % for the 60 sec immersion, respectively.

Barium Activity Number

The barium activity number is widely used to express the degree of mercerization. Figure 6 shows the barium activity number according to the various sodium hydroxide concentrations and immersing time. Figure 7 shows the barium activity number of cotton fabrics immersed for 30 and 60 sec at the fixed NaOH concentration (200 g/*l*). The barium activity number increases as the NaOH concentration or the

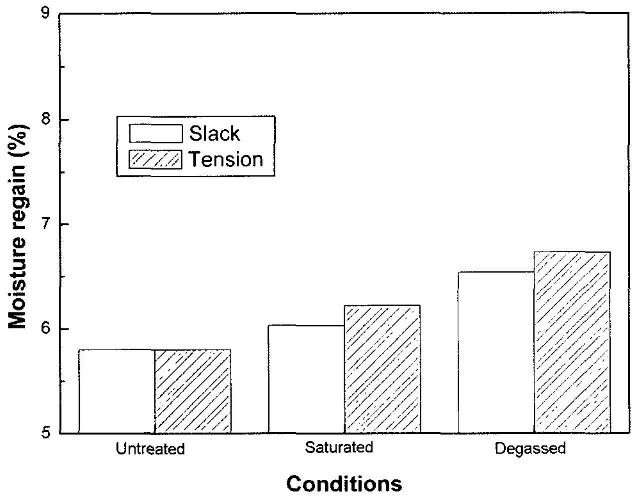

Figure 4. Effect of dissolved gases on moisture regain of NaOH mercerized cotton fabrics (NaOH conc. 200 g/*l*, 30 sec).

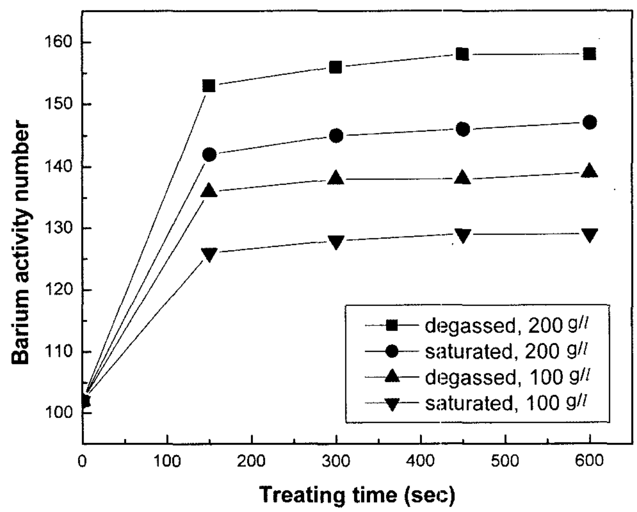

Figure 6. Effect of dissolved gases on barium activity number of NaOH mercerized cotton fabrics.

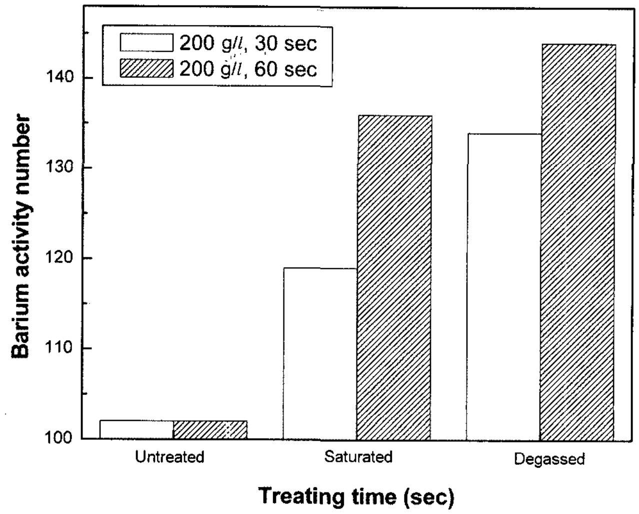

Figure 7. Effect of dissolved gases on barium activity number of NaOH mercerized cotton fabrics.

Table 3. Crystallinity of cotton fabrics mercerized in 200 g/*l* NaOH solution

Treating conditions	Crystallinity (%)
Untreated	69.7
Saturated, 30 sec	57.4
Degassed, 30 sec	53.3
Saturated, 60 sec	56.7
Degassed, 60 sec	52.1

immersing time increases. The barium activity number of cotton mercerized with the degassed solution is higher than that of cotton treated with the saturated solution. This may be due to the increased adsorption of chemicals by the reduced crystallinity as the NaOH concentration or immersing time increases as shown in the crystallinity data.

Changes of Crystallinity of Mercerized Cotton Fabrics

The crystallinity of mercerized cotton fibers was decreased because of the increased amorphous region. The crystallinity of samples used in this research is shown in Table 3. As shown in Table 3, the crystallinity of mercerized cotton fabrics was decreased abruptly and the crystallinity of cotton fibers treated with the degassed NaOH solution was decreased more than that of cotton fibers treated with the saturated NaOH solution. This may be due to the enhanced wettability of the fibers in the degassed NaOH solution and these facts are well consistent with the results of the moisture regain and barium activity number.

Dyeing Properties

Due to the decreased crystallinity of mercerized cotton fibers, the dyeability of them is expected to increase. The dyeability of the mercerized cotton fibers can be further

Table 4. K/S values of cotton fabrics mercerized in 200 g/*l* NaOH solution and dyed

Treating conditions	Cibacron Navy F-G	Cibacron Red F-B
Untreated	6.74	5.28
Saturated, 30 sec	8.49	7.12
Degassed, 30 sec	9.58	8.46
Saturated, 60 sec	9.25	8.64
Degassed, 60 sec	10.34	9.22

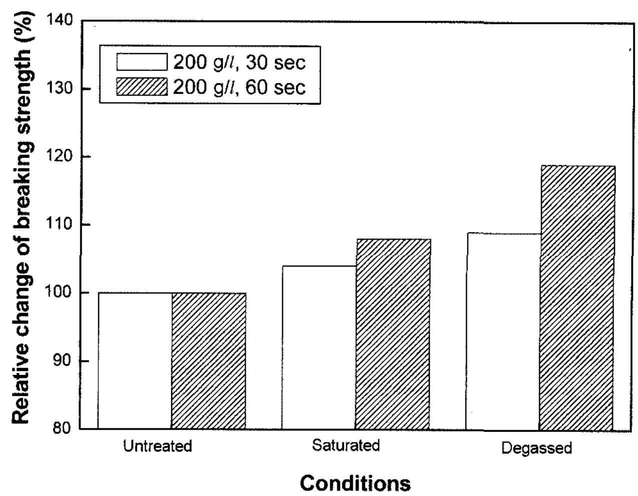

Figure 8. Effect of dissolved gases on breaking strength of NaOH mercerized cotton fabrics.

increased by removing the dissolved gases from the NaOH solution. The results are listed in Table 4.

K/S value of cotton fabrics dyed in the degassed solution was higher than that of the saturated solution. Also, as the immersing time increased the K/S value increased. Especially, the K/S value of cotton fabrics immersed for 30 sec in the degassed NaOH solution is similar to the value of those immersed for 60 sec in saturated solution. From this result, it was found that the dyeability can be increased by the simple removal of the dissolved gases from the NaOH solution.

Changes of Tensile Strength

The change of tensile strength during the tension mercerization process is closely related to the degree of swelling. As the swelling is increased, the orientation of chain is also increased, and the tensile strength [21] is increased. Since the cotton fabrics treated in the degassed NaOH solution have higher swelling compared to those of the saturated solution, it is also expected that the tensile strength can be increased. The results are shown in Figure 8. The tensile strength of cotton fabrics treated in the degassed NaOH solution is higher than that of the saturated NaOH solution. This may be due to the difference of the degree of swelling and the orientation.

Conclusions

The wetting ability of degassed water was examined by measuring the wicking height. The wicking height using the degassed water without a wetting agent was higher than that of the saturated water with 0.1 % of wetting agent. From these results, it was found that the degassed water has an excellent wetting ability.

From the results of mercerization in the degassed NaOH solution, it was found that the dissolved gases in the NaOH solution affected the physical properties of mercerized cotton fabrics such as moisture regain, barium activity number, crystallinity and tensile strength. All of the physical properties of cotton fabrics mercerized in the degassed NaOH solution were superior to those of the saturated NaOH solution.

Acknowledgement

This work was supported by Inha University Research Grant.

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