

The Study of Rapid Curing Crease-Resistant Processing on Cotton Fabrics. Part I. The Effect of Chitosan on the Physical Properties of Processed Fabrics

MING-SHIEN YEN, KUO-SHIEN HUANG

Department of Fiber Engineering, Kung Shan Institute of Technology, Yung Kang, Tainan, Taiwan, 71016, Republic of China

Received 19 July 1999; accepted 3 January 2000

ABSTRACT: The principal aim of this study is to explore the effect of chitosan on the physical properties of cotton fabrics in rapid curing crease-resistant processing. It was determined that compared with the traditional three-stage processing, the addition of chitosan is beneficial to the absorbency of processed fabrics, dry-wet wrinkle recovery angle, and tensile strength retention. In addition, the dry-wet wrinkle recovery angle of processed fabrics increases with the increase of curing temperature and curing treatment time, but absorbency and tensile strength retention both decrease. Also, the dry-wet wrinkle recovery angle and tensile strength retention of processed fabrics increase with higher chitosan concentrations, but the fabric's absorbency is reduced. In general, use of 0.5%–0.75% chitosan with DMEU curing treatment conditions of 8%, 200°C for 30 s will provide optimum physical property balance for processed fabrics. © 2000 John Wiley & Sons, Inc. *J Appl Polym Sci* 78: 35–40, 2000

Key words: cotton fabric; chitosan; crease-resistant processing; curing treatment

INTRODUCTION

Because cotton fiber contains a large amount of hydroxyl radical, it is classified as highly hydrophilic fiber. Also, fiber crystallization is not high, therefore when cotton fiber absorbs water the bonding force among cellulose molecules will be greatly reduced and cause swelling. Therefore, when cotton fabrics are twisted or rubbed when being washed or worn macromolecules in cellulose will shift and have plastic deformation. As a result, the fabric shrinks and wrinkles. The primary method of minimizing creases in cotton fabrics when washed or worn is to use appropriate cross-linking agents to link cellulose molecules in the fiber. This prevents relative displacement of cellulose molecules in cotton fiber when washed

or worn, thus increasing the elasticity of fibers in order to develop crease resistance.¹ Although cotton fiber itself is very absorbent, after resin processing its absorbency and tenacity deteriorates. Also, traditional processing generally uses the pad-dry-curing processing method. With this complicated processing process, reaction time is long and operation cost is accordingly high.^{2,3}

Because the molecular structure of chitosan is similar to cellulose, both have a similar bonding force. Therefore, chitosan can be applied in cotton finishing to give fabrics a function similar to cellulose.² Therefore, we used chitosan in this experiment as additive in conducting DMEU resin processing on cotton fabrics, using pad-curing treatment processing, omitting the pre-dry process, and using variations in chitosan concentrations, curing temperatures, and curing times to investigate their effect on the physical properties of processed fabric.

Correspondence to: M.-S. Yen.

Journal of Applied Polymer Science, Vol. 78, 35–40 (2000)
© 2000 John Wiley & Sons, Inc.

EXPERIMENT

Materials and Reagents

The specifications of cotton fabrics before processing were 32^s*32^s ends (100) and picks (56) (supplied by Yi Hwa Textile Company). The nonionic surfactant used was penetrating AC (supplied by Tai Chieh Co.) as the detergent agent. Chitosan [M.W.:200,000; Degree of acetylation; > 70.0%; supplied by T.C.I. Co.] Paraformaldehyde, vinyl urea, sodium hydroxide, methyl alcohol, magnesium chloride, and paratoluene sulphonic acid (PTSA) that we used were reagent grade.

Instruments and Equipment

For our experiment we used the following instruments: (1) oil bath reaction tank, (2) Monsanto wrinkle recovery angle measuring instrument, (3) universal strength testing machine, (4) padding machine, and (5) differential scanning calorimetry (DSC).

Methods

Processing Flow

First, we prepared 8% DMEU resin processing liquid containing chitosan (0.25%, 0.5%, 0.75%, 1%) that has been first dissolved in acetic acid water, together with proper quantity of catalyst (PTSA: 0.8% ows, MgCl₂: 2% ows).

Then we dipped 25 cm × 20 cm pieces of testing fabrics in the processing liquid using the "2-dips, 2-nips" method and control pick up at 80%. Then without pre-drying, we proceeded with curing treatment at different temperatures (180°C ~ 200°C) and different times (10 s ~ 30 s), then we washed with soap, dried, weighed, and packed.

We conducted another test using the traditional processing method and compared the results.

Measuring the Physical-Chemical Property of Processed Fabrics

1. Dry-wet wrinkle recovery angle measurement: in accordance with ASTM D1295~67, Monsanto Method.
2. Warp tensile strength measurement: in accordance with ASTM D1682~64 (1975).
3. Absorbency measurement: in accordance with CNS 12915 L3233 B.

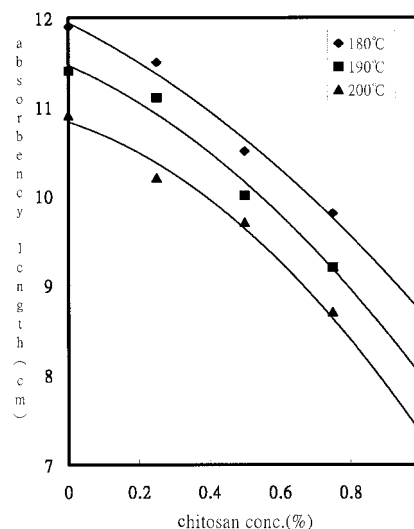


Figure 1 Effect of chitosan concentration on absorbency length of the treated fabrics at different curing temperatures. Catalyst (PTSA), 0.8% o.w.s.; penetrating AC, 1% o.w.s; curing time, 10 s; pick up, 80%; resin, 8% o.w.s.; conventional fabrics, absorbency length = 5.1cm.

RESULT AND DISCUSSION

Effect of Chitosan Concentration on Processed Fabrics

As shown in Figure 1, adding chitosan to cotton fabrics decreases the absorbency of the fabrics, and the higher the concentration of chitosan the poorer the absorbency the processed fabrics. This was because chitosan itself is water resistant and it can fill up gaps on cotton fabric surface so that it is more difficult for moisture to enter. Chitosan also bonds with the hydroxyl radical of cotton fabrics, causing the hydrophilic radical of the fiber to become smaller with a larger link, thus reducing absorbency. However, compared with traditional processing, its absorbency is still better. This is because chitosan is not naturally hydrophilic, however a small amount of acetic acid was added, producing partial moisture hydrolysis, and as a result the chitosan became more hydrophilic.

The effect of chitosan concentration on the dry wrinkle recovery angle of processing fabrics, as shown in Figure 2, is very high. This was because chitosan solution is cohesive, and can also reinforce the tensile strength of fabrics, so that the natural elasticity of the fabrics improves and their wrinkle recovery angle also improves. Chitosan also generates an ether reaction with the

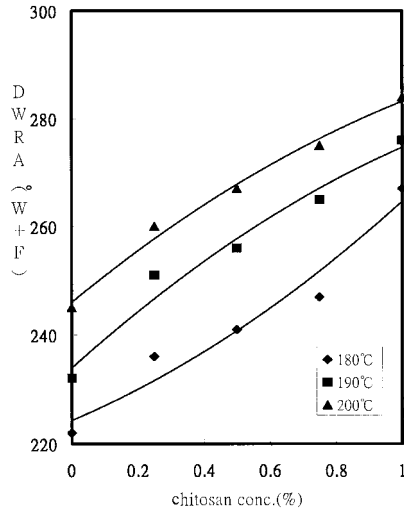


Figure 2 Effect of chitosan concentration on DWRA of the treated fabrics at different curing temperatures. Catalyst (PTSA), 0.8% o.w.s.; penetrating AC, 1% o.w.s.; curing time, 10 s; pick up, 80%; resin, 8% o.w.s.; conventional fabrics, DWAR = 268°.

hydroxyl radical of fiber, and the two formed a two-dimensional structure, so the crease-resistance of the fabrics is improved.⁶⁻⁸

The effect of chitosan on the tensile strength of processed fabrics is as shown in Figure 3, indicating that the higher the concentration of chitosan, the higher the tensile strength of the fabrics. Some causes previously mentioned are that chi-

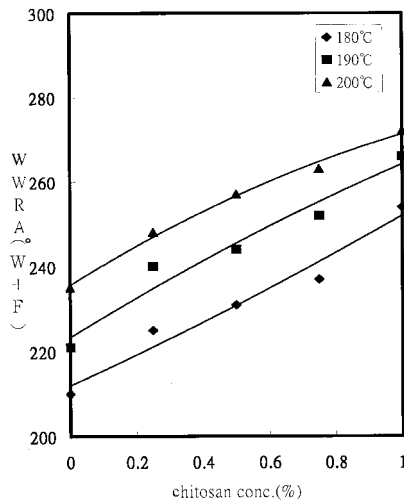


Figure 3 Effect of chitosan concentration on WWRA of the treated fabrics at different curing temperatures. Catalyst (PTSA), 0.8% o.w.s.; penetrating AC, 1% o.w.s.; curing time, 10 s; pick up, 80%; resin, 8% o.w.s.; conventional fabrics, WWAR = 256°.

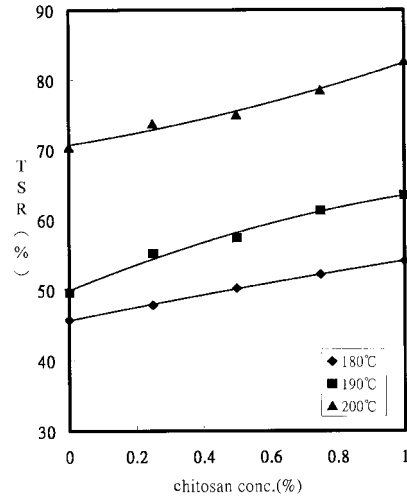


Figure 4 Effect of chitosan concentration on tensile strength retention of the treated fabrics at different curing temperatures. Catalyst (PTSA), 0.8% o.w.s.; penetrating AC, 1% o.w.s.; curing time, 10 s, pick up, 80%; resin, 8% o.w.s.; conventional fabrics, tensile strength retention = 64.1%.

tosan could fill in gaps of cotton fabrics, thus reinforcing the tensile strength; that chitosan bonds with fabrics, producing longer links and better elasticity, so there is less loss of tensile strength; chitosan itself is very cohesive, easily adhering to the fabric surface and contributing to the reinforcement of the fabrics.

Effect of Curing Treatment on Processed Fabrics

As shown in Figure 1 the absorbency of processing fabrics decreases with the increase of curing temperature. This is because when PTSA catalyst is between 170°C~190°C it will generate and decompose H_2SO_4 ,³ easily destroying cellulose. As a result, yarn becomes finer and the gap between yarns increases, so it improves the absorbency of processed fabrics. Also, the greater the concentration of H_2SO_4 , the better the absorbency, although its quantity also decreases as curing temperature rises. When curing temperature reaches 200°C, catalyst activity increases, accelerating the reaction between fiber and resin. As a result, the fiber loses more hydroxyl radicals and its absorbency become poorer.⁴⁻⁵ Also, as the curing temperature increases, the dry wrinkle recovery angle of processed fabrics is larger. This is because the hydroxyl radical in fiber has more opportunity to bond with chitosan, improving the crease-resistant, as shown in Figures 2 and 3. It is shown in Figure 4 that curing

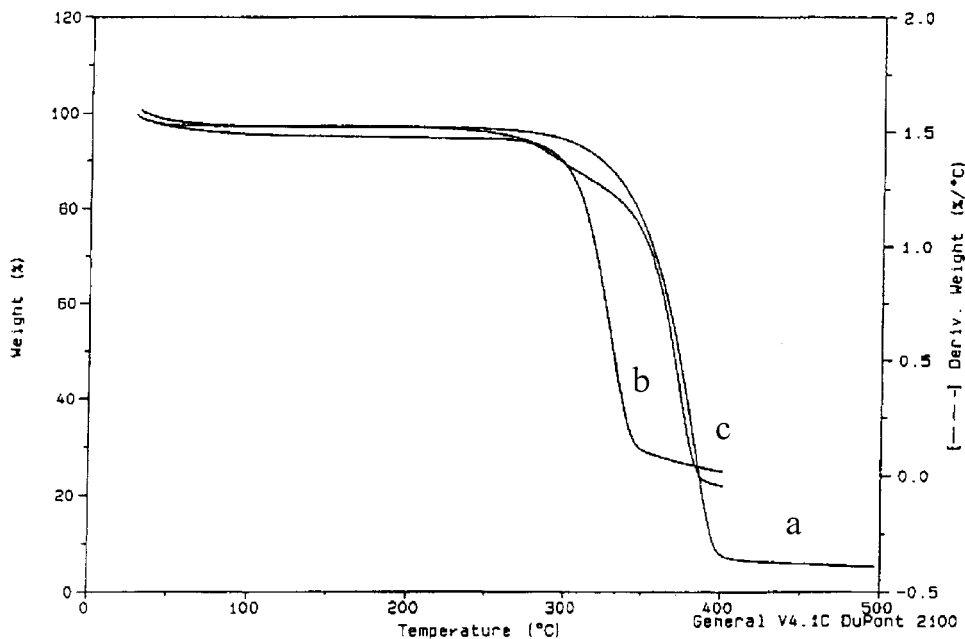


Figure 5 TGA diagram of the treated fabrics by different catalysts. a, gray fabrics; b, treated with PTSA; c, treated with $MgCl_2$.

temperature is related to strength of the fabric. The higher the temperature the better the tensile strength. This was because when PTSA catalyst is between $170^{\circ}C \sim 190^{\circ}C$ it generates H_2SO_4 , which oxidizes cellulose, so the tensile strength was severely reduced in proportion to the concentration of H_2SO_4 . However, when the temperature exceeds $190^{\circ}C$, PTSA catalyst activity increases, accelerating the quick reaction between the fiber and chitosan. This is an improvement to the reaction between two-dimensional chitosan and fiber, increasing the cross-linking bond length and reducing tensile strength loss of fabrics. However, generally speaking, the tensile strength of processed fabrics will still be damaged by the use of chitosan, although to a lesser extent than traditional processing.

It can be seen in Figure 5 that gray fabrics (a) begin heat degradation at $300^{\circ}C$ until the processing temperature reaches $350^{\circ}C$, at which point the weight drops rapidly. But for processing fabrics treated with PTSA (b) the heat degradation begins at around $270^{\circ}C$ and its weight also drops rapidly. This shows that using PTSA as catalyst for treating processing fabrics may seriously affect the fiber during curing treatment, because at temperatures between $170^{\circ}C \sim 190^{\circ}C$ PTSA will generate a catalytic reaction, producing H_2SO_4 , so that there is no buffering period before weight loss begins. Using $MgCl_2$ as a catalyst for processing fabrics, the fabric starts to

seriously lose weight at around $270^{\circ}C$ until $325^{\circ}C$, at which point the weight drops even more rapidly. This indicates that when processed fabrics undergo curing treatment, the fiber damage is less than the damage that results from using PTSA as a catalyst, but there is still damage.

It was also shown in Table I that curing time affects processed fabrics. With longer curing times, absorbency and tensile strength of processing fabrics deteriorate but the dry-wet wrinkle recovery angle improves. This was because with longer curing periods, the reaction between fiber, resin, and chitosan was more complete. Also shown in Table I is that when chitosan was added to fabrics during processing, the above-mentioned physical properties are better than with traditionally processed fabrics.

Effect of Processing Conditions on Physical Property Balance of Processed Fabrics

As can be seen in Figure 6, when moisture absorption is higher the dry wrinkle recovery angle is lower. This was because chitosan itself is hydrophobic. Similarly, when chitosan concentration is high, the dry wrinkle recovery angle of processing fabrics increases. Also, because hydroxyl radical of cellulose more or less bonds with chitosan, its moisture absorbing length reduces. Therefore, the improvement of dry wrinkle recovery

Table I Effect of Processed Condition on Physical Property for the Treated Fabrics

Curing Temp. (°C)	Curing Time (s)	Absorbency Length (cm)	DWRA ^a (W+F) ^o	WWRA ^b (W+F) ^o	TSR ^c (%)
Conventional ^d		5.1	268	256	64.1
180	10	9.8	247	237	52.2
	15	9.1	263	251	51.1
	20	8.5	273	260	50.5
	30	7.7	279	265	48.8
190	10	9.2	265	253	61.3
	15	8.7	275	264	58.4
	20	8.0	280	267	56.3
	30	7.4	285	274	53.3
200	10	8.7	275	263	78.5
	15	8.4	282	272	76.5
	20	7.7	287	276	74.3
	30	6.5	293	281	70.9

^aDry wrinkle recovery angle.

^bWet wrinkle recovery angle.

^cTensile strength retention.

^dPad → Dry → Cure (dry: 80°C × 5 min, cure: 150°C × 3 min).

^eDMEU: 8%, PTSA: 0.8%, penetrating AC: 1%, pick up: 80%, Pad → Cure (No Dry), chitason conc.: 0.75%.

ery angle does not benefit absorbency. And, because chitosan and resin can fill up the fiber pores, absorbency thus becomes poorer. On the contrary, if absorbency is higher, the dry wrinkle recovery angle drops.

Figure 6 also shows that when the processing temperature is higher, wrinkle recovery angle

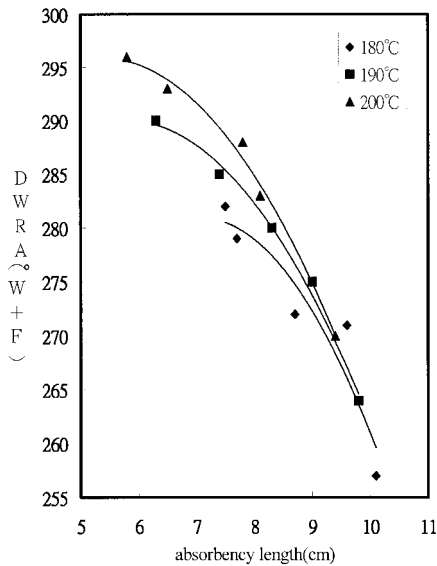


Figure 6 Physical property balance of absorbency length and DWRA for the treated fabrics. Resin, 8%; catalyst (PTSA), 0.8%; pick up, 80%; penetrating AC, 1%; curing time, 30 s.

and absorbency of processing fabrics are better. This was because with higher treatment temperatures cotton fiber molecules will swell more and moisture can enter more easily, thus improving absorbency. Also chitosan and resin will react more with the fabric fibers and adhere to the fiber molecules, improving the dry wrinkle recovery angle of the fabric.

From Figure 7 it can be seen that as the dry wrinkle recovery angle improves, the tensile strength also increases. This was because chitosan and resin can fill in gaps and bond with hydrophilic radicals to form a radical group, increasing the tensile strength. In addition, at the same dry wrinkle recovery angle, the tensile strength retention of processed fabric treated at 200°C is better than processed fabrics treated at 180°C or 190°C. This was mainly due to the processing reaction that occurred under the different temperatures mentioned above. In all reactions PTSA generated H₂SO₄, damaging the fibers, and reducing the tensile strength of the fabric. But with the higher temperature the reaction between chitosan and fiber was more thorough, thus improving its tensile strength.

CONCLUSION

The following can be concluded obtained from this experiment:

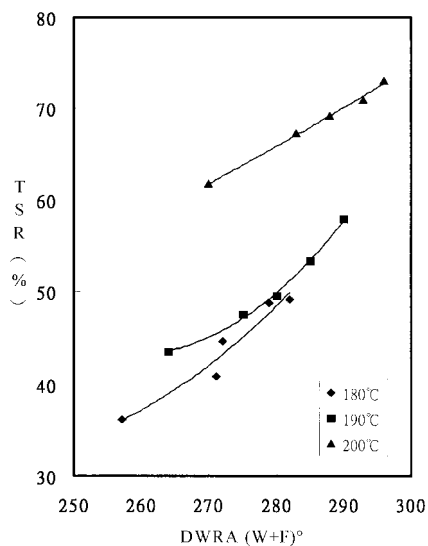


Figure 7 Physical property balance of tensile strength retention and DWRA for the treated fabrics. Resin, 8%; catalyst (PTSA), 0.8%; pick up, 80%; penetrating AC, 1%; curing time, 30 s.

1. In comparison with the traditional three-stage processing, use of chitosan is beneficial to the absorbency, dry wrinkle recovery angle, and tensile strength retention of processed fabrics.
2. Dry-wet wrinkle recovery angle of processed fabric that was treated with this method increases with higher curing temperature and longer curing time, but absor-

bency and tensile strength retention decreases.

3. Dry-wet wrinkle recovery angle and tensile strength retention of processed fabrics treated with this method both increase with greater of chitosan concentration, but absorbency decreases.
4. In general, for optimum balance of physical properties, the concentration of chitosan in curing of processing fabrics should be 0.5% ~ 0.75% with DMEU at 8%, 200°C for 20 s.

REFERENCES

1. Mark, H.; Wooding, N. S.; Atlas, S. M. *Chemical After-treatment of Textiles*. Wiley: New York, 1971; pp 184–216.
2. Yu-Li, H. Effect of Chitosan to the Physical Property of Cotton Fabrics. *Dyeing Magazine* 1997, 23(3), pp 22–24.
3. Hsiao-Kuang, M.; Yung-Chien, H.; Chen-Hsia, Y. Exploration of PEG Rapid Curing and Finishing of Cotton and Scoured Cotton Fabrics. *Dyeing Magazine* 1997, 23(9), pp 5–7.
4. Pierce, Jr., A.G.; Reihardt, R. M.; Kullman, R. M. H. *Text Res J* 1976, 46, 420–428.
5. Nai-Chieh, T. *Dyeing Work*. Vol. 4. Chinese Textile Publication: Peking, 1994; pp 121–125.
6. Pigman, W.; Horton, D., Eds. *The Carbohydrates*. Vol. IIA. Academic Press: New York, 1970.
7. Keith, R. B.; Dilip, M. P. *Text Res J* 1983, 53, 524.
8. Hsiao-Kuang, M.; Chen-Ya, Y. Polyethylene glycol Finishing on Textile. *Dyeing Magazine* 1996, 22(1), pp 9–13.