

The Study of Rapid Curing Crease-Resistant Processing on Cotton Fabrics. II. Effect of Poly(ethylene glycol) on Physical Properties of Processed Fabrics

CHUNG-YANG SHIH, KUO-SHIEN HUANG

Department of Applied Fiber Style, Kun Shan University of Technology, Yung Kang, Tainan, Taiwan 71016, Republic of China

Received 21 May 2001; accepted 27 September 2001

ABSTRACT: This study aimed to examine the effects of the addition of poly(ethylene glycol) (PEG) on the physical properties of processed cotton fabrics in a rapid heat-curing crease-resistant process. Our results show that this addition influences the moisture absorbency, crease resistance in both dry and wet conditions, and tensile strength preservation rate of the processed fabrics. Moreover, with such addition, the use of higher temperature in the process would enhance the moisture absorbency and dry-wet crease resistance but reduce the tensile strength preservation rate. The optimum condition for processing cotton fabric is to use PEG with a molecular weight of 1000 at a concentration of 10%, heated at 200°C for 30 s. © 2002 Wiley Periodicals, Inc. *J Appl Polym Sci* 85: 1008–1012, 2002

Key words: additives; crosslinking; crease-resistant; poly(ethylene glycol); swelling

INTRODUCTION

The fact that there are lots of —OH groups in cotton fiber makes it very hydrophilic or water-loving. At the same time, the crystalloid property of such a fiber is rather low and different; thus, the binding strength between the cellulose molecules becomes much weaker after the fiber has absorbed moisture, which often appears swollen. Therefore, the fibers swell through absorbing moisture during washing or laundering and even rubbing and kneading when people wear them. Microscopically, there are shifts taking place between their cellulose molecules that result in changes in their relative plastic setting, making the fabric shrink unevenly and appear wrinkled. To avoid this, the most often used method is to let

it form bridge linkages between the cellulose molecules in the fiber with the so-called bridging agent. The fiber in fabrics so treated would become more flexible and crease-resistant. Although cotton fabrics are very absorbent by nature, their absorbency decreases after a refining process with resins and the treated fabric is also less stain-resistant than before. There have been quite a few studies reported in this regard. For example, it was found that the water affinity and stain-resisting quality of cotton fabrics deteriorate after treatment with a processing reagent of dimethylol dihydroxyl ethylene urea (DMDHEU) resin.^{1–3} Most of the published studies in this field either use some hydrophilic additives to go along^{4–5} with the resin process or treat the monomer with a certain grafting procedure.^{6–12} However, because of improper conditions of the chemical treatment selected, a good balance between moisture absorbency and crease resistance is very hard to come by. More often than not, after the

Correspondence to: C.-Y. Shih (scy-f@mail.ksut.edu.tw).

Journal of Applied Polymer Science, Vol. 85, 1008–1012 (2002)
© 2002 Wiley Periodicals, Inc.

traditional three-step (pad-dry-cure) process, not only does the tensile strength become much weakened, moisture absorbency is also reduced, while the treatment is time consuming and costly.

Water is the swelling agent and it allows the glycol to diffuse into the swollen structure, which is then held open after water is removed. Poly(ethylene glycol) (PEG) itself is also a good solvent and swelling agent,¹³ as well as a reagent. It can increase the swelling of the fiber during the process and thus make it easier for resin to penetrate into the fiber. At the same time, it reacts with both the resin and the fiber to form a netlike structure of polymer to settle on the fiber.^{14–16} As a result, the processed fabric displays good static resistance and water absorbency. In this study, we tried to use PEG as an additive in the cotton fabric resin processing with dimethylol ethylene urea (DMEU) and examined the effects of changes in molecular weight (MW) of PEG and its concentration in the reaction, as well as the temperature of curing step, on the physical properties of the processed fabric.

EXPERIMENTAL

Materials

A cotton fabric, 40 × 40 s ends (100) and picks (80), was desized, scoured, and bleached. Sodium hydroxide, magnesium chloride, PEG (MW = 400, 600, 1000, 1500), nonionic surfactant, and methanol were of reagent grade. DMEU was synthesized by the Hoover method.

METHODS

Process

The cotton fabric was first immersed in a solution containing a finishing agent (8% prepolymer), magnesium chloride (10% of the weight of prepolymer), PEG (5–30%), and 1% penetrating agent for 10 min at room temperature; then it was squeezed to a wetness pick-up of 80% and pinned on a frame with no tension applied for curing at different temperatures (180–210°C) or for different periods of time (10–30 s). After the curing was over, the sample was thoroughly washed in a solution containing 2 g/L soap and dried in ambient conditions.

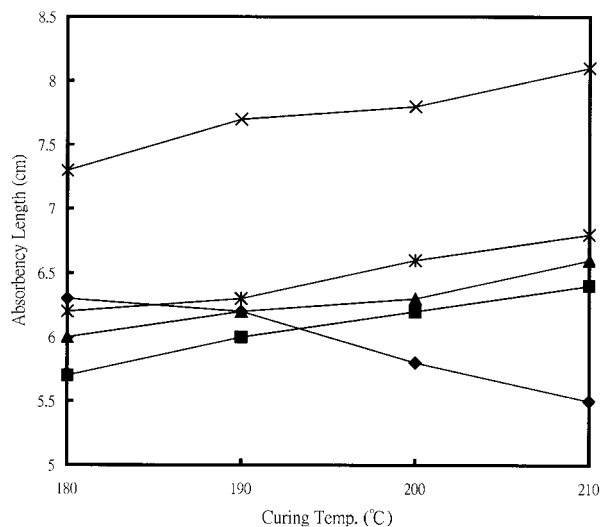


Figure 1 Effect of curing temperature on absorbency length of the treated fabric at different molecular weights of PEG. (—◆—) No added; (—■—) 400; (—▲—) 600; (—×—) 1000; (—*—) 1500. The absorbency length of treated fabric by conventional method is 5.1 cm.

Analysis

The tensile strength of warp yarns was measured by using an Instron tester according to ASTM standard D1682-64. Both dry and wet crease recovery angles (DCRA and WCRA) were determined according to ASTM standard D1295-67. The absorbency of the processed fabric was determined by an immersing method.¹⁷

RESULTS AND DISCUSSION

Effects of PEG MW and Curing Temperature

From Figure 1, we can see that the addition of PEG does help to maintain the water absorbency of the processed fabric. When the results are compared with those of the conventional process (i.e., the one with no PEG added at all), the increase in absorbency is higher than 20%. Moreover, absorbency is enhanced with the increase in MW of PEG added in the lower MW range. This might be because the hydrophilic PEG molecules can penetrate into the fiber, thus loosening it to expose more hydroxyl groups.¹³ However, when the PEG used became as much as MW = 1500, the absorbency turned out to be a little lower than the trend would indicate. It is presumably that the

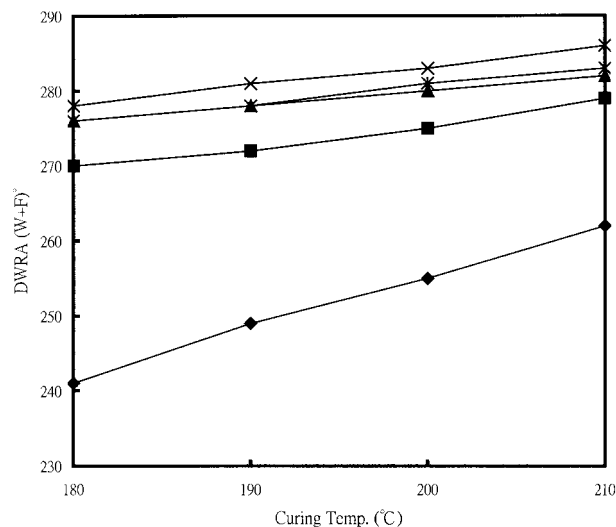


Figure 2 Effect of curing temperature on DWRA of the treated fabric at different molecular weights of PEG. (—◆—) No added; (—■—) 400; (—▲—) 600; (—×—) 1000; (—*—) 1500. The DWRA of treated fabric by conventional method is 279 (W + F)^o.

bulkier size of the larger molecule may hinder its own penetration into the fiber.

The water absorbency of the processed fabric is somewhat positively correlated to the curing temperature. That is, the absorbency becomes higher with the increase in curing temperature. We presume that at a higher temperature, the more ac-

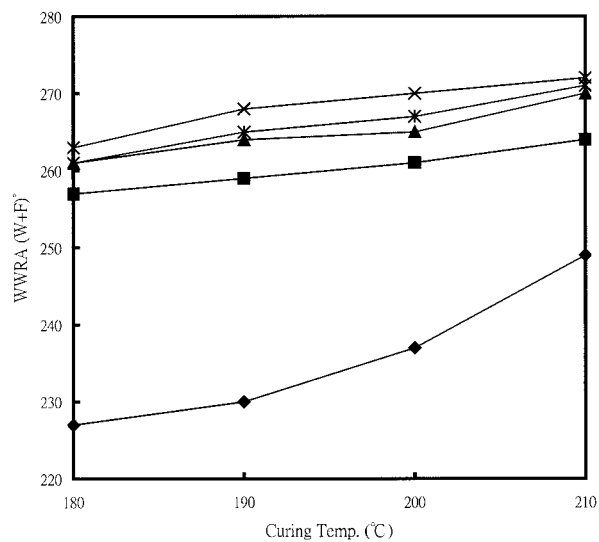


Figure 3 Effect of curing temperature on WWRA of the treated fabric at different molecular weights of PEG. (—◆—) No added; (—■—) 400; (—▲—) 600; (—×—) 1000; (—*—) 1500. The WWRA of treated fabric by conventional method is 262 (W + F)^o.

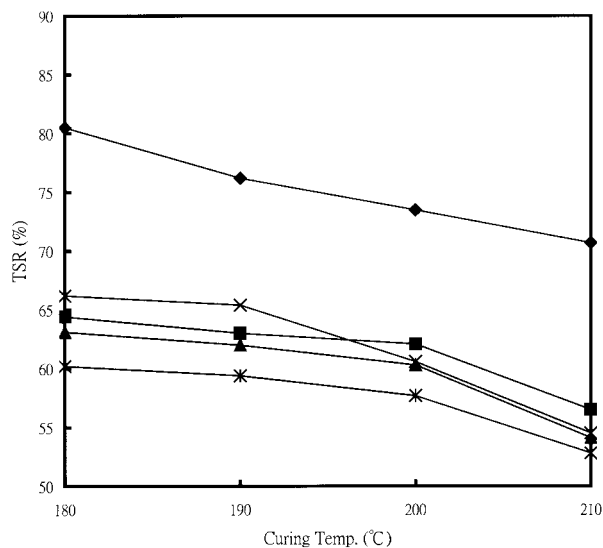


Figure 4 Effect of curing temperature on TSR of the treated fabric at different molecular weights of PEG. (—◆—) No added; (—■—) 400; (—▲—) 600; (—×—) 1000; (—*—) 1500. The TSR of treated fabric by conventional method is 60.1 (%).

tive and flexible PEG molecules would help the fiber reach a higher degree of swelling before the resin finally sets the structure.

As to the dry and wet crease resistance, it is just as Figures 2 and 3 demonstrate; the processed fabric becomes better crease resistant as long as PEG has been added to the fabric treatment solution. This is presumably because PEG can form crosslinkages with DMEU resin and the product of this reaction precipitates and deposits inside the fiber, whereas the fiber itself may also take part in the crosslinking reaction. The final result is the combination of the three of them together establishing a solid net structure of fiber-polymer, which has fibers in the thread bound up in a more fixed manner.

Other than that, the participation of PEG facilitates reaction between the fiber and DMEU resin, and this accelerating effect of PEG appears to be more profound with more MW of the polymer. However, a slight downturn was also observed when PEG with MW of 1500 was used, similar to that in the moisture absorbency. It is because the overbulkiness of the molecule prevents it from getting into the fiber for one, plus a lower extent of crosslinkage formed owing to fewer reactive hydroxyl groups in the same weight of the bigger PEG. It may even be in contrast that too many crosslinks are formed and the fiber-resin complex may become too rigid and

Table I Effect of Concentration of PEG on Physical Property for the Treated Fabrics

Concentration of PEG (%)	Curing Temp. (°C)	Absorbency length (cm)	DWRA ^a (W + F) ^o	WWRA ^b (W + F) ^o	TSR ^c (%)
Conventional method ^d					
0	180	5.1	279	262	60.1
	190	6.3	241	227	80.5
	200	6.2	249	230	76.2
	210	5.8	255	237	73.5
5	180	5.5	262	249	70.7
	190	6.3	278	263	62.1
	200	6.5	281	268	61.4
	210	6.8	283	270	58.6
10	180	7.1	286	272	53.2
	190	7.3	280	266	66.2
	200	7.7	285	271	65.4
	210	7.8	290	274	60.6
20	180	8.1	293	276	54.5
	190	7.0	278	262	72.2
	200	7.3	280	265	68.7
	210	7.5	282	268	65.4
30	180	7.6	286	272	62.2
	190	4.8	272	259	73.8
	200	4.9	276	260	72.7
	210	5.2	279	264	70.1
	210	5.5	282	267	67.8

^a Dry wrinkle recovery angle.^b Wet wrinkle recovery angle.^c Tensile strength retention.^d Pad → Dry → Cure (dry: 80°C × 5 min; cure: 150°C × 3 min).

inflexible.¹⁸ The dry-wet crease resistance is also enhanced at a higher curing temperature because the higher temperature facilitates the binding reaction between the resin and the fiber.

As Figure 4 shows, processed fabrics without PEG added possess better tensile strength preservation rates. In the cases of processing with PEG, the preservation rate apparently decreases gradually along with the increase in PEG MW and/or temperature of curing. We believe that PEG causes the fiber molecule to become more hydrophilic and loosens up or swells to a greater degree to allow a greater effect of bridging among fibers. The bigger the PEG molecule is, the more surface crosslinkages would form to make the fiber more rigid. Another possible reason for the worst tensile strength preservation rate at higher curing temperature might be that there are more opportunities for the fibers to be oxidized.

Effect of PEG Concentration on the Processed Fabric

As seen in Figures 1–4, variations in PEG MW affect the physical properties of the processed fab-

ric and the best PEG we have tested in terms of the profoundness of its effect on our measurements is PEG 1000. Therefore, we continued our study by choosing its concentration in the reaction solution as our next variant.

From Table I, we can see that at the same curing temperature, both moisture absorbency and crease resistance increase along with the increase in PEG concentrations lower than 10%. However, when the PEG concentration is higher than 10%, the advantages gained by adding PEG become less prominent as the concentration increases. In particular, when the PEG concentration reaches 30%, the moisture absorbency of the processed product turns out to be even worse than that of the conventional one with no PEG added. It is probably due to too much PEG reacting with DMEU resin and the reaction product overly coats the fiber surface. It makes the fiber less absorbent on one hand and also limits the chances for bridging reaction to take place between the resin and fiber during the process and results in declined crease resistance on the other hand.

The preservation rate of tensile strength of the processed fabric becomes comparatively higher with higher PEG concentration. It is presumably because there is a netlike structure formed among PEG, DMEU, and the resin that would tightly bind the fiber and restrict the latter to loosen up during regular wear and tear. Furthermore, the presence of more PEG molecules facilitates the formation of longer crosslinkages (i.e., the chances of PEG reacting with DMEU before forming bridges with fibers become more). This higher proportion of longer bridges between fiber molecules allows less stress-focusing incidents to happen and that would result in better toughness or durability of the processed fabric.

CONCLUSIONS

From the experimental results, we can draw the following conclusions.

1. Both water absorbency and dry-wet crease resistance of the processed fabric increase with higher curing temperature, but the tensile strength preservation rate decreases with rising curing temperature.

2. Both water absorbency and dry-wet crease resistance of the processed fabric increase with higher MW and concentration of PEG used in the lower ranges. Both of them peak at a MW of PEG at 1000 or a concentration of around 10%.

3. The preservation rate of tensile strength of the processed fabric deteriorates along with the increase in MW of PEG, but improves better with higher concentration.

4. The best selected combination of conditions we have experimentally tested uses PEG 1000, with a final concentration of 10% in the reaction solution, at a temperature of around 200°C, and

30 s of curing period. This would produce the best desirable physical properties in the processed fabric.

REFERENCES

1. Bruce, M. L. *Text Res J* 1981, 51, 579–587.
2. Reeves, W. A. *Text Res J* 1980, 50, 711.
3. Obendorf, S. K. *Text Res J* 1983, 53, 375.
4. Emery, I. V.; Kunjvikari, M. L. *Text Res J* 1962, 32, 331.
5. Pierce, A. G.; Frick, J. G.; Reid, J. D. *Text Res J* 1964, 34, 522.
6. Hebeish, A.; El-Rafie, M. M.; El-Kashouti, M. A.; Fl-Sis, F. J. *Appl Polym Sci* 1981, 26, 3995.
7. Hebeish, A.; Wuly, A. *Am Dye Rep* 1983, 7, 15.
8. Hebeish, A.; Elkharadly, E.; Abdel, S. H.; Nasr, F. H. *Am Dye Rep* 1983, 9, 48.
9. Hebeish, A.; Abou-Zeid, N. Y.; Waly, A.; El-Alfy, E. A. *Am Dye Rep* 1983, 10, 25–32.
10. Hebeish, A.; Waly, A.; Abou-Zeid, N. Y.; El-Alfy, E.; Abou-Shousa, M. H. *Am Dye Rep* 1984, 4, 31–37.
11. Hebeish, A.; Elkharadly, E.; Abdel, S. H.; Haggag, F. K.; Abou-Shousha, M. H. *Am Dye Rep* 1984, 7, 32–38.
12. Hebeish, A.; Abou-Zeid, N. Y.; Waly, A.; El-Alfy, E.; Abou-Shousha, M. H. *Am Dye Rep* 1985, 4, 58–64.
13. Reinhard, R. M.; Blanchard, E. J.; Graves, E. E. *Am Dye Rep* 1992, 6, 26–27.
14. Pierce, A. G.; Reinhard, R. M.; Kullman, R. M. H. *Text Res J* 1976, 46, 420–428.
15. Tau, N. G. *Engineering of Dyeing and Finishing*; China Textile Press: Beijing, 1994; Vol. 4, pp 121–125.
16. Mar, S. K.; Kui, G. I. *The Finishing of Fabric with PEG*; Printing, 1996, 22 (1), 9–13.
17. Kin, S. S. *Experiment of Dyeing and Finishing*; China Textile Press: Beijing, 1987; pp 169–170.
18. Maa, S. G.; Yu, J. S.; Yu, Y. *J Dyeing Finish Technol* 1997, 9, 10–13.