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The role of quaternary ammonium compound and reducing agent in environmentally friendly alkali treatment of PET (cotton fabric)

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Key words: Polyester, weight reduction, cotton, sodium hydroxide, QAC.

Abstract

An environmentally friendly pad-steam process for treatment of polyester/cotton fabric with sodium hydroxide was developed. To enhance the process efficiency, a quaternary ammonium compound (QAC) besides a reducing agent was used. Using QAC, the rate and amount of weight reduction were increased. The yellowness and loss of strength of the treated samples were reduced using reducing agent. The pad-steam process had the advantage of less treatment time, less consumption of water and chemicals that make the process to be less hazardous to the environment.

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Introduction

Nowadays, Polyethylene terephthalate fiber is one of the most important and prevalent fibers in the textile industry. Aside from the desirable characteristics of polyester fabrics such as tensile strength, dimensional stability, wash ability and abrasion resistance certain drawbacks such as low water absorbency, pilling, and poor handle has also been reported. To overcome these drawbacks, Blending with cotton fiber is recommended, so better water absorbency, handle and comfort can be achieved (Golh and Vilensky, 1983). By treating polyester/cotton fabrics with alkali further improvement in the fabric properties can be obtained (Betschewa and Wangelov, 1989, Kallay, 1990, Shet *et al* 1982, Lee, 1995).

Alkali treatments of pure polyester or cotton fabrics are well-known and conventional processes in textile industry (Kallay, 1990).

Sodium Hydroxide can hydrolyze the ester groups in the polyester chains. Favorable properties such as silky handle, luster, soil repellency and anti static are imparted to polyester fabric by alkaline hydrolysis (Golh and Vilensky, 1983, Betschewa and Wangelov, 1989, Shet *et al*, 1982) and its stiffness, Tenacity and elongation are decreased (Shet *et al* 1982, Lee, 1995, Khosravi, 1994, Yang, and Tsai, 1997). Although this process decreases the diameter of the fibers, but the Density of the fibers is not affected (Needles *et al*, 1985, Needles *et al*, 1990, Kish and Nouri, 1999, Datye, 1991, Kish and Yousefi, 1992). The rate of polyester hydrolysis can be improved by using certain accelerants (Shukla and Mathur, 2000).

The use of microwave irradiation (Xu and Yang, 2002), alcoholic media rather than sodium hydroxide aqueous solution (Raslan and Bendak, 2005), magnetic activation of the water media (Konovalova, 2005) and high pressure conditions (over 100 Mpa) (Kimizu *et al*, 2005) have been reported by several researchers to increase the efficiency of alkaline hydrolysis of polyester fiber.

Furthermore, the mercerization process with a concentrated solution of NaOH is a well-known process for the improvement of some of the physical properties of cotton fabrics (Montazer and Sadighi, 2006).

A wide range of studies has been carried out to investigate the effect of alkali on polyester/cotton fabric (Montazer and Sadighi, 2006). However, no one has worked on continuous processes such as pad-steam in this subject.

In our previous work, we developed a pad-steam process for alkali treatment of polyester/cotton fabric (Haji *et al*, 2011). Due to its lower costs, less required time, fewer chemicals consumption, minimum environmental pollution and higher production (Kazakeviciute *et al* 2004), continuous processes can be a solution as stated in that work. However, the previously mentioned process had the disadvantage of yellowing of the fabric due to oxidation of the polymeric chains of the fibers. In this study, a reducing agent is used as an oxygen scavenger to reduce the yellowing of the fabric besides lowering the loss in tensile strength of the alkali treated samples.

Materials and methods

Materials

Plain weave polyester/cotton (67/33) fabric (123 gram/m^2, yarn count Nm= 40, 50 warp/cm, 30 weft/cm) was obtained from Brujerd Textile Co. Iran. Tinegal PAC (quaternary ammonium compound), Ultravon CN (non-ionic surfactant) and Invadine VB (a weakly anionic wetting agent) were kindly supplied by Ex-Ciba, Iran. Thiourea dioxide ($HN=C(NH_2)SO_2H$) and acetic acid were laboratory grade reagents obtained from Merck.

Alkali Treatment

To remove any natural or synthetic impurities, all samples were scoured as mentioned in our previous work (Haji *et al*, 2011).

The alkali treatment was done by the following method:

The samples were padded in a bath containing sodium hydroxide (5-30 g/l), Tinegal PAC (0-5 g/l), Invadine VB (10 g/l) and Thiourea dioxide (0-0.5 g/l), at 100% pick up. Steaming process at 120°C was practiced. Then washing, neutralization with 1% V/V acetic acid solution and final rinse of the samples were followed.

The weight loss (WL) is expressed as relative WL according to the equation:

$WL\ \% = (W_1 - W_2 / W_1) \times 100$

Where, W_1 and W_2 are the weights of the samples before and after alkaline treatment, respectively.

Hydrolysis of PET can be controlled to affect fabrics at varying levels, i.e. from surface hydrolysis to extensive removal of the constituent polymer. In this study, to avoid from imposing significant changes in the bulk of PET fiber, and restrict the hydrolysis to the surface of the fiber, a weight loss between 15 to 20 % has been considered as optimum weight reduction value.

Tensile strength measurement

The tensile strength of treated sample fabric was determined on an Instron tester model TM-SM 1026 according to ASTM D5034 - 95(2001) and wicking test was measured according to BS 3424: Part 18, Method 21A.

Color measurement

CIE Whiteness Index (WI) was measured according to AATCC test method 110-1989 using a Color eye 7000A spectrophotometer and the standard illuminant D65. Whiteness values were measured at four different places in the samples, and their average was used for the analysis of results.

Results and discussion

Effect of QAC on weight loss

Fig. 1 shows the effect of Tinegal PAC concentration on weight loss percentage of polyester/cotton fabric and Fig. 2 shows the effect of sodium hydroxide concentration on weight loss percentage, without and with 2 g/l Tinegal PAC.

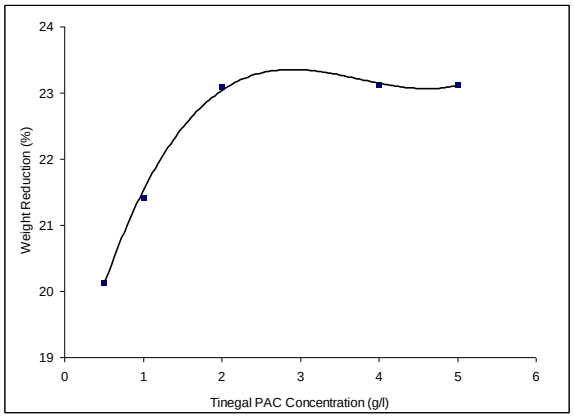

Fig. 1. Effect of Tinegal PAC concentration on weight reduction of samples (20 g/l NaOH, 5 min steaming time).

According to Fig.s 1 and 2, the presence of Tinegal PAC has an important role in weight loss of the samples and accelerates the process of alkali treatment. Tinegal PAC is a quaternary ammonium salt with cationic charge, so it seems to be able to cover the negative group indicated in Fig. 3, caused by the attack of alkali on the polyester chain, which provide further alkaline attack so increasing the hydrolysis and weight loss of polyester fibers.

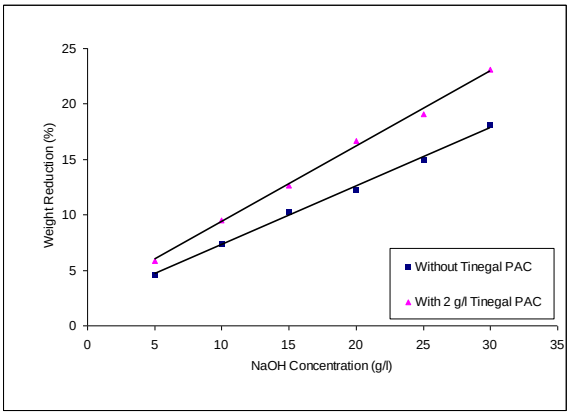

Fig. 2. Effect of sodium hydroxide concentration on weight loss percentage (5 min steaming time).

The weight reduction of samples increased with the increase in concentration of both NaOH and Tinegal PAC, but in the case of QAC, there was a critical concentration (about 2 g/l) which above it, there was no significant increase in the weight loss.

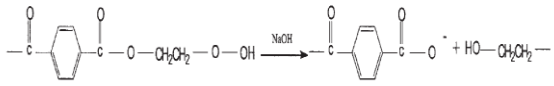

Fig. 3. Mechanism of the polyester chain alkaline hydrolysis (Montazer and Sadighi, 2006)

It should be mentioned that according to experiments, the use of 0.5 g/l Thiourea Dioxide showed no significant effect on weight loss of the samples.

Tensile properties of treated fabric

Fig. 4 and 5 show the effect of steaming time and Tinegal PAC concentration on the tensile strength of treated fabric, respectively. It seems that the higher the steaming time the lower would be the tensile strength. Five minutes steaming time at 120°C resulted in the lowest loss of tensile strength and was considered as the optimized steaming time.

Increase in Tinegal PAC concentration over 2 g/l in the pad-liquor caused an increase in loss of fabric tensile strength.

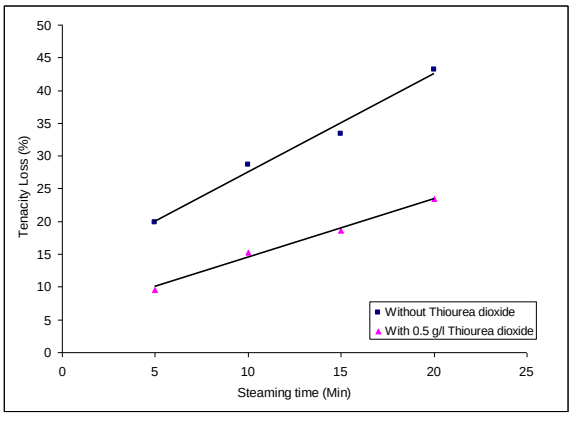

Fig. 4. effect of steaming time on tenacity loss percentage of fabric (20 g/l NaOH, 2 g/l Tinegal PAC, with and without 0.5 g/l Thiourea Dioxide).

From fig. 4, it seems that Thiourea dioxide as an oxygen scavenger has lowered the effect of oxygen in the treatment media on the fibers and reduced the oxidation, so led to less damage to fiber strength.

In addition to reducing the strength loss of the samples, Thiourea dioxide had another important effect. As shown in table 1, the whiteness of alkali treated samples in the presence of 0.5 g/l thiourea dioxide is significantly more than the sample treated without it. The high temperature applied in this process may cause yellowing of the fibers, specially the cotton portion, which is decreased using the reducing agent. It seems that Thiourea dioxide acts as an oxygen scavenger and reduces the yellowing effect caused by oxidation of cotton.

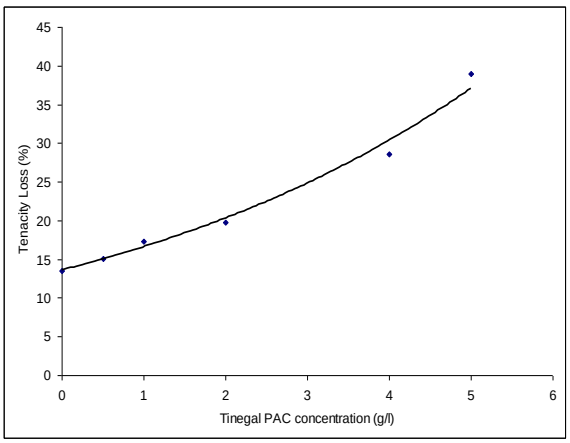

Fig. 5. Effect of Tinegal PAC concentration on the tensile strength (5 min steaming time, 20 g/l NaOH, 2 g/l Tinegal PAC).

Table 1. whiteness index of alkali treated samples (20 g/l NaOH, 2 g/l Tinegal PAC, with and without 0.5 g/l Thiourea Dioxide).

	Whiteness index
Without Thiourea Dioxide	47.2
With 0.5 g/l Thiourea Dioxide	64.6

Conclusion

Alkali treatment by Pad-Steam method at 120°C, for 5 minutes reduces the weight of polyester/cotton fabric resulting in minimum loss of tenacity, increase in hydrophilicity and better handle of the finished fabric.

Tinegal PAC increases the process efficiency and reduces the time needed. The use of 0.5 g/l Thiourea Dioxide reduces the strength loss and yellowing of the fabric. Considering the reduced amount of water, alkali consumption time, energy spending and environmental requirements, the proposed process seems to be a good suggestion for replacement of traditional exhaustion method for alkaline weight reduction process of polyester/cotton fabric.

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