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Variations of Surface Properties of Corona Treated Wool

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Plasma and corona treatments as environmentally friendly processes modify the superficial properties of textile fibers without any damage to the bulk properties of the material. In this study, wool fabric was exposed to corona treatment in different powers and passages. The effect of corona treatment was investigated on the wettability, dye ability, mechanical and surface properties of wool fabric. Corona treatment leads to reduce acid dye exhaustion of wool fabric and increase the tensile strength and Young modulus. SEM micrographs show the etching effect of corona treatment and removing the edge of wool scales. FT-IR spectra indicate to surface functional groups variation of treated wool fabric.

Key Words: Corona, Wool, Surface Properties, Wettability.

INTRODUCTION

Plasma and corona treatments are environmentally friendly processes that represent an interesting alternative to conventional textile wet processes. These treatments modify the superficial properties of textile fibers without any damage to the bulk properties of the material[1]. Plasma treatments can be divided to cold plasma and hot plasma treatments according to their application temperature. Cold plasma techniques can be divided to low-pressure and atmospheric plasmas. Atmospheric plasma is generated at atmospheric pressure and it does not need any vacuum chambers or pumps. Atmospheric plasma is quite similar to the corona treatment. In corona treatment substrate surface is exposed to electrical discharges caused by electrical field of high frequency or voltage[2-4].

The presence of high amounts of oxygen and nitrogen ions in the plasma induce chemical and physical changes on the surface of wool fibers through oxidation and adhesion, by the formation of carbonyl, carboxylic, hydroxyl, peroxide, amino, nitro, *etc*. groups on the amino acid side-groups and at the end of the polypeptide chains.

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Corona/plasma treatment of textile fabric induces surface modification, such as smoothing the surface, enlarging positive charged functional groups, reducing hydrophobic character and therefore, improving hydrophylicity and sorption properties such as increasing the rate of dyeing and dyes exhaustion[5,6]. However, it has been shown that tetraflouromethane plasma treatment can reduce the rate of dyeing of acid and disperse dyes on polyamide-6 fabric, but there isn't any decreasing on the exhaustion of acid dyes[7].

In fact, some studies have shown that plasma treatments can improve the tensile strength of linen, cotton, wool, polyamide 6.6, polyethylene and aramid. However, chemical modifications and/or micro-cracks formation in the outer layers of the surface of fibers can also produce damage to the fibers and as a consequence, a loss of their tensile strength[8-13].

In this study, the effect of corona treatment on the wettability, dye ability, mechanical and surface properties of woven wool fabric have been investigated.

EXPERIMENTAL

The corona generator was made in Azad Electrical Industries, Iran. The reactor consist of 2 electrodes: silicon coated roller with parallel electrodes on it. The distance between two electrodes is 3 mm and velocity of roller and power are changeable. In this study, the velocity was set at 2 m/min. Woven wool fabric (weight 225.5 g^{-2}, 17 warps cm^{-1}, 15 wefts cm^{-1}) was used in this study.

Corona treatment: The washed wool fabric was exposed to corona discharge at two different power levels (500 and 1000 W) and different number of passages (3, 7, 11, 15 and 20 passages).

Dyeing: Untreated and corona treated fabrics were dyed with the acid Rubin F (Milling acid dye) along with acetic acid and sodium sulfate at boiling temperature for 0.5 h. The liquor ratio was 40:1. After dyeing, the samples were rinsed thoroughly in tap water and dried in the open air.

Colour measurement: The colour of dyed samples was determined using a reflectance spectrophotometer (datacolour V2.3), working with D65 at 10 visual angle, being used CIELab colour parameters (L*, a*, b*). The colour parameter were measured and calculated by computer.

Mechanical properties: The load (N), elongation at break (%) and Young's modulus of corona treated and untreated fabrics, average of five determinations, were determined using an Instron Testing Machine Micro 250 (SDL) according to method ASTM D-5035. Dimension of samples were 5 cm × 30 cm. A speed of 100 mm/min was used with an initial grip separation of 200 mm.

Shrinkage measurement: The variation of untreated and treated fabrics dimensions was measured before and after treating in milling bath (2 % detergent, 3 % sodium carbonate, L:R = 10:1) at room temperature for 40 min. Then the amount of shrinkage at two directions (warp and weft) was calculated according to eqn. 1.

$$\text{Shrinkage (\%)} = 100\ (L_2\text{-}L_1)/L_1 \qquad (1)$$

where L_1 and L_2 are the length of fabric (at warp or weft direction) before milling and after milling, respectively.

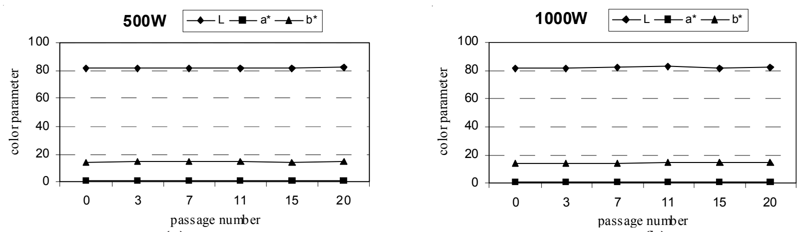
Wettability measurement: Wettability was evaluated by measuring the time it takes for a drop of distilled water dropped on the fabric to absorb according to method AATCC-39-1980. The time of water absorbance was expressed as average of five measurements.

The morphology of the wool fabrics were determined by observation of the samples on a scanning electron microscope (SEM) (PHILIPS XL30) with an acceleration voltage of 20 kV at magnification of × 2000. The wool fabrics were mounted on stubs using double side sticky tab and coated with a thin layer of gold to avoid charging in the microscope.

To estimate the functional groups on the surface of fabrics, FT-IR spectra were obtained from corona treated and untreated sample using FT-IR spectroscopy Bruker (Equinox55). All spectra were obtained using the spectrophotometer over a range of 3500-1000 cm^{-1} with a resolution of 4 cm^{-1}.

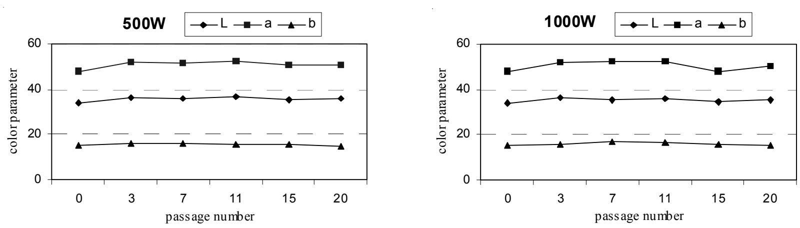
RESULTS AND DISCUSSION

Colour parameters results: The colour parameters of undyed and dyed corona treated wool fabric as a function of corona power and passages are shown in Figs. 1 and 2, respectively that L*, a* and b* display lightness, greenness-redness and blueness-yellowness of samples, respectively.



(a) (b)

Fig. 1. The colour parameter of undyed corona treated wool fabrics in different corona power a) 500 W b) 1000 W



(a) (b)

Fig. 2. The colour parameter of dyed corona treated wool fabrics in different corona power a) 500 W b) 1000 W

Fig. 1 shows that the corona treatment in different passages and power has not affected on the colour parameter of treated wool fabric as compared to untreated one (passage = 0). It means that corona treatment doesn't cause to change the colour of wool.

However, corona treatment leads to vary the exhaustion of acid dye in wool fabric in two corona power (Fig. 2). With increasing the number of passages, L* value of corona treated samples is increasing as compared to untreated sample. This indicates the reduction of dye exhaustion of wool fabric. Regarding a* and b* values, there isn't any variation in yellowness of corona treated fabrics, but redness value increases after corona treatment. Spectrophotometer results show that 11 passages of corona treatment create minimum of dye exhaustion and maximum of colour changes.

Mechanical properties: Tensile strength, strain and Young modulus of untreated and corona treated wool fabric are shown in Fig. 3. Tensile strength of corona treated wool fabric increases as number of passages increases. It is because of etching effect of corona discharge treatment that edge of wool scales remove from the wool surface and increase the surface friction.

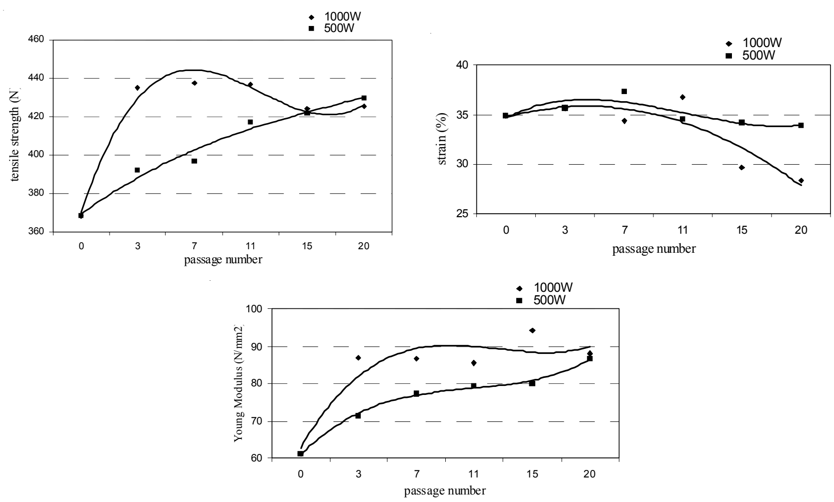


Fig. 3. Mechanical properties of corona treated wool fabric as a function of corona power and passage number

In 1000 W and 11 passages of treatment, tensile strength decreases. This is due to over degradation of wool surface. But in 500 W and 20 passages, tensile strength increases.

Corona treatment causes to increase the Young modulus of wool fabric, but the strain at break decreases resulting from surface degradation. So the fiber couldn't slide as a result of stretching.

Shrinkage and wettabilitty results: Shrinkage and hydrophilicity of untreated and treated wool fabrics are shown in Table-1. In general, shrinkage of treated wool fabrics decreases as compared with untreated sample. Felting behaviour of wool fabric is related to surface structure of wool fiber. Corona treatment causes to abrasion of surface scales of fiber and decreases shrinkage of fabric.

TABLE-1
SHRINKAGE (%) AND WETTING TIME OF UNTREATED AND CORONA TREATED WOOL FABRIC

Number of passage	500 W			1000 W		
	Warp shrinkage (%)	Weft shrinkage (%)	Wetting time (s)	Warp shrinkage (%)	Weft shrinkage (%)	Wetting time (s)
0	13	12	360.3	13	12	360.3
3	12	8	267.2	11	10	169.6
7	9	4	184.3	8	4	156.0
11	7	6	139.0	5	2	37.4
15	5	4	120.8	2	0	34.0
20	2	2	27.0	1	0	4.5

Shrinkage of fabric reduces by increasing the number of passages and power. This is due to the etching effect of corona treatment that can change the surface of wool fiber. As shown in 1000 W, 15 and 20 passages of treatment, there is not any significant shrinkage. Hydrophilicity results show that increased power up to 1000W can decrease absorbance time and water drop rapidly absorbs in the fabric. With increasing the number of passages, absorbance time reduces. This is owing to etching effect of treatment.

SEM micrographs of corona treated and untreated wool fabric are shown in Fig. 4. In all corona treated fabrics, there are some particles on the surface of wool. Theses particles are related to edge of wool scales which can be removed from the scale surface by corona treatment. Etching effect increases when the number of passages increases, so that in 1000 W and 20 passages, wool scales completely disappear.

The FTIR shows that in 3500-3000 cm^{-1} region, there is a peak related to -OH groups, but in 1000 W and 20 passages the height of peak significantly reduces. This indicates that corona treatment at high level of power and number of passages leads to reduction of -OH groups in wool fiber.

The regions of 1630 and 1520 cm^{-1} are attributed to amide-I and amide-II groups of peptide chain of wool which in untreated wool, the intensity of amide-I (stretching C=O) is higher than amide-II and it reduces by corona treatment. It might be because of breaking C-N bands or hydrogen bonds. There is a peak at about 1230 cm^{-1} associated to stretching C-O bond for

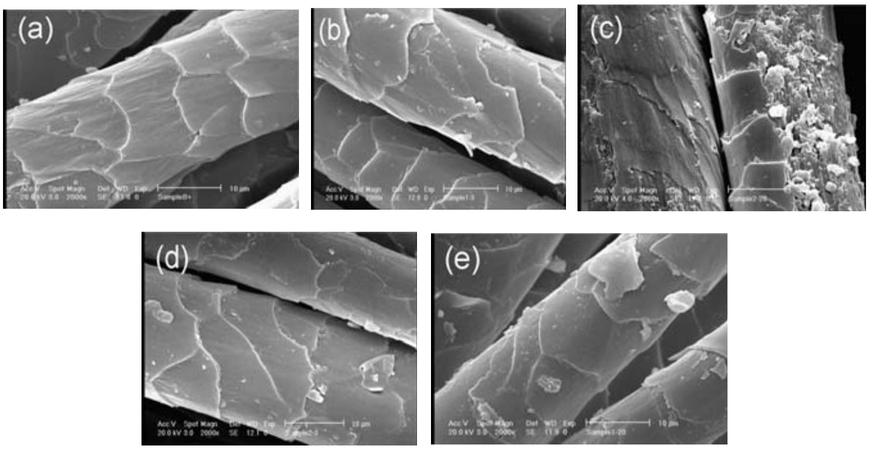


Fig. 4. SEM micrographs of untreated wool fabric (a) corona treated fabric in different condition: b) 3 passages, 1000 W c) 20 passages, 1000 W d) 3 passages, 500W e) 20 passages, 500 W

untreated sample, which its high increases for corona treated fabric. It is probably due to formation of carbon free radical on fiber surface and combination this free radical with oxygen of the air. In 1000W and 20 passages of treatment, the height of this peak decreases. It is seems that increasing the number of passages causes to decomposition of C-O bond.

Conclusion

Corona treatment is an environmentally friendly process without using water and chemicals that can be used for conventional textile wet processes such as chlorination. Shrinkage of corona treated wool fabrics decreases as compared to untreated sample. Corona treatment causes abrasion of surface scales of fiber and reduces felling of fabric. Hydrophilicity of corona treated wool fabric increases owing to etching effect of treatment. Corona treatment leads to vary the exhaustion of acid dye in wool fabric, increase the tensile strength and Young modulus and decrease strain at break of treated wool fabric. SEM micrographs confirm the etching effect of corona treatment and removing the edge of wool scales. FT-IR spectra indicate to variation and decomposition of surface functional groups and formation carbon free radical on the fiber surface as a result of corona treatment.

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