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To cite this article: M N Pervez et al 2018 IOP Conf. Ser. Mater. Sci. Eng. 284 012010

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Effect of heat-setting on UV protection and antibacterial properties of cotton/spandex fabric

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Abstract. An unexampled approach for simultaneous heat setting process with optimized condition at C3 (140°C, 45 s) and functional finishing, i.e. UV protection and antibacterial properties of cotton/spandex fabric were studied in this research. Experimental results disclosed that, ameliorative antibacterial efficacy and perdurable UV protection of heat-treated cotton/spandex fabrics with best sample A3 among all samples was achieved and mechanical properties also improved as the temperature rose from 120 to 140°C. In addition, Ultraviolet (UV) radiation protection and antibacterial properties are becoming increasingly necessary for human health, and textiles play an important role and this report will be appurtenant to meet regular demand.

1. Introduction
Due to the semi-crystalline structures orientation of synthetic polymeric fibers, the macromolecules are not widely distributed in their equilibrium state. Further instabilities are imparted if the fibers are adapted to yarns and the yarns to fabrics. Heat setting is an important industrial method, since it rids them of their instabilities [1]. The accepted method for the heat setting of synthetic material is the continuously acclimated through stenter frame. The stenter frame heat sets by way of the usage of warm air and important parameters like temperature, dwell time, width and overfeed are considered. For natural fibers relaxation dryers, crimping and steaming units are used [2]. The heat-setting has two important functions—it imparts dimensional balance and it relaxes the inter-yarn forces at the crossover points in the fabric. The relaxation of inter-yarn forces profoundly modifies the mechanical behavior of the fabric in shear and in bending and, in allowing the conclusion of the whole high-recuperation capacity of the synthetic fibers from bending traces, makes feasible the brilliant smooth-care overall performance of cloth constituted of these materials [3-5]. Heat-setting procedure, seen as an essential issue, is undertaken during the initial phase of the textile industry, considering the fact that it proffers the appropriate product’s output to make it appropriate for additional steps and for the customer to utilize it. Under-setting after-effects in eventual loss of fabric dimensions; over heat-setting lowers
power and can discolor the spandex and companion fibers. Relaxation remedy is used to lessen capacity distortion or deformation of the material from residual uneven tension. It develops the power and recovery of the fabric. The fabric should be secure prior to heat-setting to avoid rope marks and puckering during dyeing to ensure good dimensional balance of the final garment [6]. Special interest has been focused these days at the ultraviolet (UV) transmission of textile due to the developing demand in the marketplace for lightweight apparel that offers to human’s protection from UV radiation (UVR). In addition, some antimicrobials may additionally motive allergic reactions amongst purchasers, and the practical corporations liable for these reactions aren't well set up in many cases. Degradation of antibiotics as a result of heat treatments may also result in a loss of the antibacterial potential of those antibiotics and also in a likely lack of their allergenic ability [7]. Therefore, we were interested to elucidate the effects of heat-treatment on the UV protection and antibacterial properties of cotton/spandex fabrics and no study has been found in literature about assessing functional properties of heat setting processed fabric.

2. Experimental

2.1. Materials and methods
For experimental work knitted single jersey fabrics with (1-5%) spandex and 95% cotton have been used. The fabric samples were knitted on Mayer and Cie (Germany) single knit machine by using 30/1 Ne cotton yarn and 24 denier spandex filament yarn and produced fabric had 74 course/inch, 38 wales/inch and fabric density of 276 g sq. m$^{-1}$.

The stenter machine (BRUCKNER, Germany) was used to carry out the heat setting process. At first, samples were placed between parallel bars at 10 cm length and stretched out to different degrees on an aluminum frame with pre-determined tension. There were six levels of temperature and time such as (120, 130, 140, 150, 160, 170°C) and (15, 30, 45, 60, 75, 90 s) respectively, while all other machine variables were held constant. Then, the process conditions were denoted as C1, C2, C3, C4, C5 and C6. After heat setting, the samples were cooled before being removed from the aluminum frame. Then the samples were conditioned under standard conditions of 65±2 % relative humidity and 21±1°C for 24 h.

2.2. Measurement
The tensile strength of samples was calculated according to our previous report [8]. Transmittance (%) of the fabric samples was measured at the wavelength changing from 200 to 1000 nm using a UV–Vis spectrophotometer. The antibacterial activity of samples was evaluated qualitatively according to the Australian/New Zealand AS/NZS 4399:1996 in presence of Staphylococcus aureus (gram-positive) and Escherichia coli (gram-negative) bacteria.

3. Results and discussion

3.1. Tensile strength
The study of physical properties of fabrics is important due to apparel usually undergoes small extension and relaxation during wear and tensile strength is one of them [9]. Figure 1 shows the tensile strength values of the samples before and after under different heat-setting conditions. It can be seen that the tensile strength is increased after heat setting except for the sample number A1, as while it is decreased after heat setting. The highest tensile strength is shown in case of sample A3 and process condition C3 about 5% improvement compared to untreated sample and also there is little improvement about 3% observed from sample A4 and A5. This result was attributed due to the fiber adhesion and fabric becomes stiffer during the heat setting and also may be affiliated to the rearrangement of fibers after heat treatment which improved the tensile strength of the blended fabric [10]. Finally from these results it can be conclude that: (1) heat treatment at 140°C results to increase tensile strength and (2) degradation in fabric starts at about 160°C which results to decrease in tensile strength. Sample A3 was chosen for further study.
3.2. UV protection
Clothing is in actuality one of the best means of attention humans adjoin solar UV radiation [11], but not all apparel is abundantly careful adjoin UV radiation. From the angle of textile chemicals, dyes and UV absorbers, UV-protective clothing has not yet become a breakthrough. As it is known, The UVR band consists of three regions: the UV-A band (320–400 nm), UV-B band (290–320 nm), and UV-C band (200–290 nm). The UV-C band is captivated by oxygen and ozone in the high atmosphere. Of the solar UVR extensive the Earth’s surface, 6% is in the UV-B region and 94% in the UV-A region. Light radiation of wavelengths 280-400 nm permits tanning of the epidermis. Rays of wavelength 290-320 nm (UVB) causes erythemas and skin burns, which can inhibit skin tanning. Radiation of wavelength 320-400 nm (UVA) is known to induce pores and skin tanning, but can also purpose skin damage, especially to touchy skin which is uncovered to sunlight for a long time frame. Examples of such harm include lack of pores and skin elasticity, the advent of wrinkles, advertising of the onset of erythemal response, and the inducement of phototoxic or image allergic reactions [12, 13].

The amount of UV protection supplied through the samples turned into evaluated in phrases of ultraviolet protection factor (UPF value) that is contrary feature of transmission and there's simply the other correlation between the transmission and coloration values of a smaller depth [14]. UPF is the ratio of the minimum erythemal dose of sun UV radiation for skin covered by fabric to that unprotected [15]. Therefore, the transmittance of UVR, including UV-A and UV-B, through the fabrics turned into evaluated in this experiment.

Figure 2 shows the UV transmission curve of untreated and different heat-setting conditions treated sample (A3). It was noticed that in case of untreated sample indicating that almost 45% of the UV-A and UV-B can penetrate into the fiber which is insufficient for providing UV protection. In comparison, different conditions like C1, C2, C3, C4, C5 and C6 noticeable UPF were increases with the transmittance values decreases but C4 condition provided less protection than C5 and C6. Figure 2 indicates that the best UPF results condition C3 was obtained with the heat setting temperature at 120°C for 45 s. This UPF behavior can be classified as excellent and very good UV protection, respectively, according to to the Australian/New Zealand AS/NZS 4399:1996 for ultraviolet radiation (UVR) protection categories of fabrics [16]. In UPF rating, fabric shade performs a crucial function. Dark shaded fabric gift a higher protection towards ultraviolet radiation than light colored fabrics. Black colored fabrics recommend not simplest suitable, but even amazing UV protection. Light colors transmit greater UVR than darkish ones and shade and color depth of the cloth may be related to UV transmittance [17]. In addition, figure 2 indicates that, the presence of different heat setting conditions inside the treated fabric sample increases the UPF values compared to the untreated fabric. Also, the degree of upgrading in the UV-protection properties is estimated and follows the order: C3 > C5 > C6 > C4 > C2 > C1 > untreated. These results show clearly that heat-setting treated fabric can greatly enhance the UV-protection properties with C3 heat setting condition.
3.3. Antibacterial property

Antimicrobial finishes prevent the growth of microorganisms on fabrics utilized in wide kind of apparel, home furnishing, business and business merchandise. Fabrics for tents, tarpaulins, and car fabric could have an extended life when dealt with a few type of antimicrobial finish that reduces or prevents damage from rot and mildew [18]. Worldwide efforts are continuing to develop antimicrobial substances and heat treatment is the normally practiced era to feature value to products and complements the resistance of materials to weathering and rot fungi [19]. In general, the most suitable heat-setting condition for antimicrobial activity is C3 (140°C for 45 s) among all treated conditions. When temperature is lower than 140°C, the antibacterial activity against E.coli increases with the increase of temperature plotted in figure 3. However, as heat-setting temperature is higher than 140°C, the antimicrobial activity decreases. It is because the melting point of cotton is around 149°C, it is easier for cotton getting detached from the fabric surface at high temperatures, which may result in poor fixation of cotton, meaning it may dissolve again in water during the subsequent finishing process. Finally, the content of cotton and spandex decreases with the increase of the heat-setting temperature and the antimicrobial activity decreases [20]. Therefore, the optimal heat setting temperature for the antibacterial activity was 140°C at 45 s in this research.

4. Conclusion

Based on a series of experimental studies in this work, an analytical probe was performed to research the heat-setting effect on UV protection, antibacterial and mechanical properties of cotton/spandex knitted fabric. Then samples were annealed at 120 to 170°C range and subjected to assorted tests at room temperature. The aforementioned properties of cotton/spandex were significantly improved by annealing treatment with best condition C3 (140°C, 45 s) on sample A3. We have developed the procedure where simultaneous heat-setting and functional finishing of cotton/spandex fabrics with prominent antibacterial and perdurable UV protective properties can be evaluated.
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Acknowledgement
This work was supported by the China National Textile and Apparel Council (2013 “Textile Vision” Applied Basic Research), a grant from the Hubei Province Science and Technology Support Program (Project 2013BAA043), and the Collaborative Innovation Plan of Hubei Province for Key Technology of Eco-Ramie Industry (E JIAO KE HAN 2014 No.8).