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Thermophysiological Comfort by PA6/TiO_2 Nanocomposite Yarns

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Thermophysiological comfort is one of the most important factors for people to choose desirable garments, which can be evaluated via measuring permeability of body heat and sweat. In this paper the water vapor permeability of nanocomposite nylon 6 fabrics produced from melt spun nanocomposite yarns with different TiO2 nanoparticle concentrations have been investigated. Results from measuring water vapor permeability at different environment temperatures for 4 h. indicated that sample with 0.4 wt% of TiO2 nanoparticle can provide fabric with maximum comfort properties. At low temperature 27.5% decline of permeability as compared to pure fabric causes this sample to protect body from cool weather through preventing loss of body heat. By increasing temperature from 12 to 35 oC water vapor permeability enhancement of nanocomposite improved about 99% as compared to pure one. Consequently nanocomposite with suitable nanoparticle content can provide more comfortable fabrics in different temperatures and applications.

Keywords: Comfort, Nanocomposite, Nanoparticle, Nylon 6, Smart Fabrics, Water Vapor Permeability.

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1. INTRODUCTION

Human beings are homoeothermic; therefore they need to keep their body temperature relatively constant. In fact, body comfort can be supplied when we are feeling neither too cold nor too warm, and when the humidity produced by the body (sweat) can be evacuated to the environment [1]. So far, different types of fabrics have been produced to regulate the body temperature. For instance, traditional fabrics made of fibers such as polyamide, cotton, silk, etc., can provide more comfortable condition in hot weather via keeping the body heat by presenting air pockets in their structures. As such, using hollow fibers, high-bulk fibers, etc. can improve their protective efficiency against cold weather. Textiles modified with phase change materials (PCM) loaded microcapsules or plastic crystals can improve thermal properties around a specific temperature [2].This material can absorb heat at high temperature, and release the heat in cold conditions. However, this effect can be done in sudden change of temperature and its duration is mainly limited dependant on the quantity and thermal capacity of phase change material. Their shelter should be resistance to heat and most types of chemicals as well as mechanical actions such as abrasion, shear and especially changing the pressure, resulting in the volume changes of material due to change their phases. Furthermore, their fastness on textile is not naturally satisfying. Hence their synthesis is difficult, time and energy consuming; they are also limited by their high cost and some technical problem in their production process to achieve practical products [3].

In fact, for desirable garment comfort, textiles should easily adapt body temperature in variable conditions. In this case, nanocomposite fabrics may be offered as a good alternative [4], because there have no usage limitations in different temperature ranges. Hence, in this paper the water vapor permeability of nanocomposite nylon 6 with different concentrations of TiO2 nanoparticles was investigated as a factor of body comfort and breathability of the textiles.

2. EXPERIMENTAL

2.1 Materials

Nylon 6 chips supplied by Aliaf Company, Iran, and TiO2 P25 nanoparticles produced by Evonic (Degussa) Co., Germany, were used to produce the masterbatch and nanocomposite yarns.

2.2 Methods

Masterbatch concentrated by 10 wt% TiO_2 nanoparticles were prepared from mixing of pre-dried nylon6 chips and TiO_2 nanoparticles by a co-rotating screw extruder (Brabender, Germany). PA6 chips and the produced masterbatch were dried for 24 h. in vacuum condition at 85°.

Pure PA6 fibers and the nanocomposite fibers containing 0.20, 0.40, and 0.60 wt% of TiO_2 were prepared, from mixing of virgin PA6 granule and concentrated masterbatch, during melt spinning by an Automatic pilot plant spinning machine (Germany), with the take up speed of 4000 m/min. The produced yarns were drawn by Zinser D5203 machine (Germany) at temperature of 170 ° and draw ratio of 1.2 [5]. A four-ply yarn, made of four bobbins of each drawn yarn samples, was used to produce weft knitted fabric of each sample.

Water vapor permeability (WVP) of prepared pure and nanocomposite fabrics were evaluated according to ASTM (E 96-80B) standard test method [6].

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3. RESULTS AND DISCUSSION

The water vapor permeability of pure and nanocomposite samples after 4 h. versus temperature has been plotted in Figure 1. As shown in this figure at low temperature (12 °C), the permeability recorded by sample containing 0.4 wt% of TiO_2 nanoparticles is 27.5% less than pure sample. Therefore, the lower permeability at low temperature can protect body from cool weather through preventing loss of body heat and air flow.

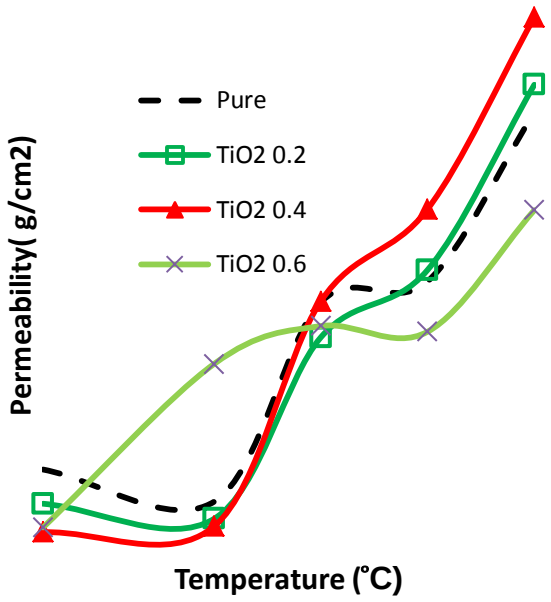

Fig. 1 – The water vapor permeability of pure and nanocomposite samples after 4 h. versus temperature

Increasing the temperature up to 35 °C causes all the samples permeability to be increased. The sample contains 0.4 wt% of TiO_2 nanoparticles has shown 311.5% permeability enhancement, while it has been only 156.7% for pure sample. Therefore, the improved water vapor permeability can simplify removing body heat and sweat, then offers more garment comfort at high temperatures. Consequently, nanocomposite yarn produced with suitable nano-filler content can provide more comfortable textile such as garment, tent etc. in the range of common environment temperature (12-35 °C) which is adaptable to the human body request. In this research, improved water vapor permeability of fabrics containing nanoparticles at warm weather has been proved. As the best result, sample contains 0.4 %wt of TiO_2 nanoparticles has the lowest permeability at temperatures below 25 °C. By increasing the temperature, the permeability of the nanocomposite fabric enhanced significantly more than pure fabric (about 99% improvement).

On the whole, nanoparticles can perform as impermeable material through the water vapor permeability. At low temperature, they act as a barrier and prevent permeability. Nanoparticles also can limit the movement of polymeric chain because of steric hindrance of particles against chain motion [4]. Increasing kinetic energy at high temperature causes the fiber permeability to be increased. In this case, decreasing crystallinity caused by nanoparticles can be effective as a key factor which leads to increasing the amorphous regions and thus permeability. While, gathering nanoparticles with decline of their special area causes this effect to be decreased. However changes in yarn such as linear density, crimp contraction, etc. and thus fabric structures such as cover factor can be also effective [4]. Overall, the associated effect of all factors led to appear the optimum point in fabric containing 0.4 wt% of TiO_2 nanoparticles.

4. CONCLUSIONS

This paper planned to evaluate water vapor permeability of nylon 6 nanocomposite as a criterion for fabric comfort. To reach this aim, polymer concentrated by 0.2, 0.4, and 0.6 wt% TiO_2 nanoparticles were prepared from mixing of nylon6 chips and prepared masterbatch during melt spinning at the take up speed of 4000 m/min. Spun yarns were drawn and finally weft knitted. The permeability of prepared fabrics has been appraised. Results indicate that sample containing 0.4 wt% of TiO2 nanoparticles provide the best comfort properties in comparison to other concentrations and pure samples. In fact, when the temperature increased from 12 to 35 °C the permeability increased 156.7% for pure sample while the composite sample showed 311.5% permeability enhancement. Consequently about 99% water vapor permeability enhancement can be achieved which can simplify removing body heat and sweat and offer more comfort for garment, tent, curtain etc. Also, protecting body heat at low temperature has been caused from 27.5% lower permeability of composite fabric in comparison to pure one.

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