Research Journal of Applied Sciences, Engineering and Technology 5(23): 5484-5488, 2013
DOI:10.19026/rjaset.5.4224
ISSN: 2040-7459; e-ISSN: 2040-7467
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Submitted: December 20, 2012 Accepted: January 25, 2013 Published: May 28, 2013

Research Article

Dynamic Moisture Comfort Property of Fine Denier Polypropylene Fabric in Different Wind Speed Conditions

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Abstract: In order to study the moisture comfort property of fine denier polypropylene fiber fabric in different wind speed conditions, dynamic experiments were performed using Textile-Microclimate Measuring Instrument in climate chamber. The relative humidity variation curves of inner and outer surfaces of test fabrics were tested and the comprehensive index was introduced to evaluate fabric's dynamic moisture comfort property. Results show that under four different environmental wind speed conditions, the dynamic moisture comfort property of fine denier polypropylene fiber fabric is much better than other fiber fabrics. In addition, grey mathematics theory was introduced to establish models to predict dynamic experiment's results using static descriptive parameters. Four prediction models of dynamic comprehensive index were established and the predictive precision is much higher.

Keywords: Dynamic moisture property, fine denier polypropylene, wind speed

INTRODUCTION

Moisture handling properties of clothing used fibers during transient conditions have been regarded as a major factor in the comfort performance of clothing in normal use (Kim, 1999; Onofrei *et al*., 2012). As the development of textile industry, many new functional fibers and new finishing technology have been developed to satisfy people's life (Obiazi, 2009). Fine denier polypropylene fiber as a new functional fiber is increasingly being used in the textile industry. The wide range of applications and rapid growth of this fiber can be attributed to its excellent physical and chemical properties compared to other fibers. Fine denier polypropylene fiber has good moisture transported and dry-fast properties (Lizak *et al*., 2012). Fabrics made by fine denier polypropylene fiber have characteristics of quick water absorption, ability to evaporate water and a dry touch, being capable of transporting perspiration from the skin to the outer surface and then quickly dispersing it. So they are widely used as sportswear fabric. Sportswear is usually worn in hot and humid conditions. Evaporation of perspiration from the skin's surface is substantially impeded by sportswear and this ineffective evaporation often causes the wearer to feel uncomfortable. So a major complaint about these garments is their uncomfortable sensations related to sweat management (Troynikov and Wardiningsih, 2011; Sampath and Senthilkumar, 2009). When people take part in sports and perspire, skin will experience dry, moist and dry again, which is a dynamic process (Wang and Li, 2005). So sportswear fabric's dynamic moisture comfort property is an essential factor deciding whether the sportswear is comfortable or not (Yang *et al*., 2008). Wind speed is an important environmental factor, which plays great effect on sportswear fabric's comfort property and human body's sensation of comfort (Huang and Chen, 2010). So it is necessary to study fine denier polypropylene fiber fabric's moisture comfort property in different wind speed conditions.

In this study, the contrast study of dynamic moisture comfort property between fine denier polypropylene fiber fabric and conventional fiber fabrics was performed in four different wind speed conditions. Results show that under different wind speed conditions, there has significant difference in fabric's dynamic moisture comfort property, but compared with other fiber fabrics, fine denier polypropylene fiber fabric's dynamic moisture comfort property of is always the best.

EXPERIMENTS

Apparatus and materials: The experiments were performed using Textile-Microclimate Measuring Instrument, which was a simulated sweating skin-microclimate-fabric system. This instrument was used to measure fabric's surface relative humidity in wearing conditions that produce continued sweat. The simulated sweating skin stabilized at 33°C, 90%RH, which is the skin situation of normal people with heavy sweat. This

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Table 1: Descriptive characteristics of test fabrics

No.	Component	Thickness (mm)	Weight (g/m^2)	Vertical wicking height (cm)	Moisture regain (%)	Air permeability (mm/s)
1	Cotton	0.32	132.05	7.82	7.96	302.81
2	Linen	0.33	145.08	6.51	10.92	329.23
3	Nylon	0.34	182.34	3.02	1.91	271.68
4	Polyester	0.35	201.53	1.85	0.41	256.87
5	Fine denier polypropylene	0.30	103.94	12.23	0.22	341.17

instrument was programmed by LabVIEW software (Odon and Krawiecki, 2011; Abuzalata *et al*., 2010), which is an energetic and functional virtual instrument software in industrial measuring and controlling field (Bok and Schauer, 2011). The instrument was used to record the real time changes of relative humidity in inner and outer surfaces of fabric on contact with simulated sweating skin and then to evaluate fabric's dynamic moisture comfort property.

To study fine denier polypropylene fiber fabric's property contrastively, another four different fiber fabrics were selected to be test fabrics. Five kinds of test fabrics had similar styles and were all used in summer and spring, so had a certain comparability in moisture comfort property. Their descriptive parameters are given in Table 1.

Experimental procedure: Experiments were completed using Textile-Microclimate Measuring Instrument in climate chamber. The environmental temperature was (28±1)^{o}C and the relative humidity was (70±5) %. Experiments were performed under four different wind speed conditions. One was less than 0.1 m/s, which is the natural convection state. The other three were 1, 2, 3 m/s, respectively. All test fabrics were conditioned in the test atmosphere for 24 h prior to testing. The experiments were designed to record the relative humidity variation curves in inner and outer surfaces of test fabrics. The instrument recorded the relative humidity data every 3 sec for about 50 min.

RESULTS AND DISCUSSION

After above experiments, five test fabrics' relative humidity curves varying with time in four different environmental wind speed conditions were obtained. The typical relative humidity variation curves are shown in Fig. 1. T_1 is the time of putting test fabric into instrument and test fabric touching simulated sweating skin. T_2 is the time of reaching dynamic moisture balance in inner surface of fabric. H_1 is fabric's average maximum relative humidity in outer surface of fabric when dynamic moisture balance is reached. H_2 is fabric's average maximum relative humidity in inner surface of fabric when dynamic moisture balance is reached.

From the dynamic relative humidity curves in Fig. 1 we can get such dynamic characteristic values as follows:

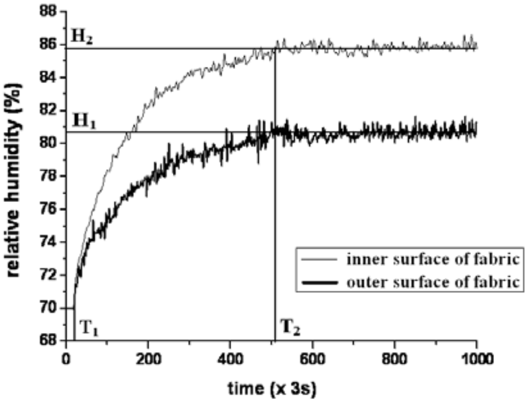

Fig. 1: Typical relative humidity variation curves

- Initial ascending slope of relative humidity variation curves in outer surface of fabric (S_1 (%/s)).
- Initial ascending slope of relative humidity variation curves in inner surface of fabric (S_2 (%/s)).
- The time of reaching dynamic balance in inner surface of fabric (T (s) = T_2-T_1).
- Difference of average maximum of humidity between inner and outer surfaces of fabric when dynamic balance is reached (Δmax (%) = H_2-H_1).
- In order to evaluate fabric's dynamic moisture comfort property comprehensively, we introduce a dynamic comprehensive index-CI:

$$CI = \frac{100}{S_1 \times S_2 \times T \times \Delta max} \quad (1)$$

From the above analysis, we can see that the bigger the CI is, the more comfortable moisture property the fabric will have. To differentiate fabric's dynamic moisture comfort property in four different environmental wind speed conditions, we define that $CI_{0.1}$, CI_1, CI_2, CI_3 means fabric's dynamic moisture comfort property under the environmental wind speed of 0.1m/s, 1m/s, 2m/s, 3m/s, respectively. After calculation, the dynamic comprehensive index of five different fiber fabrics in four environmental wind speed conditions is shown in Fig. 2.

From Fig. 2 we can see that in general, test fabrics' dynamic moisture comfort property becomes better as the rising of environmental wind speed. From Fig. 2a

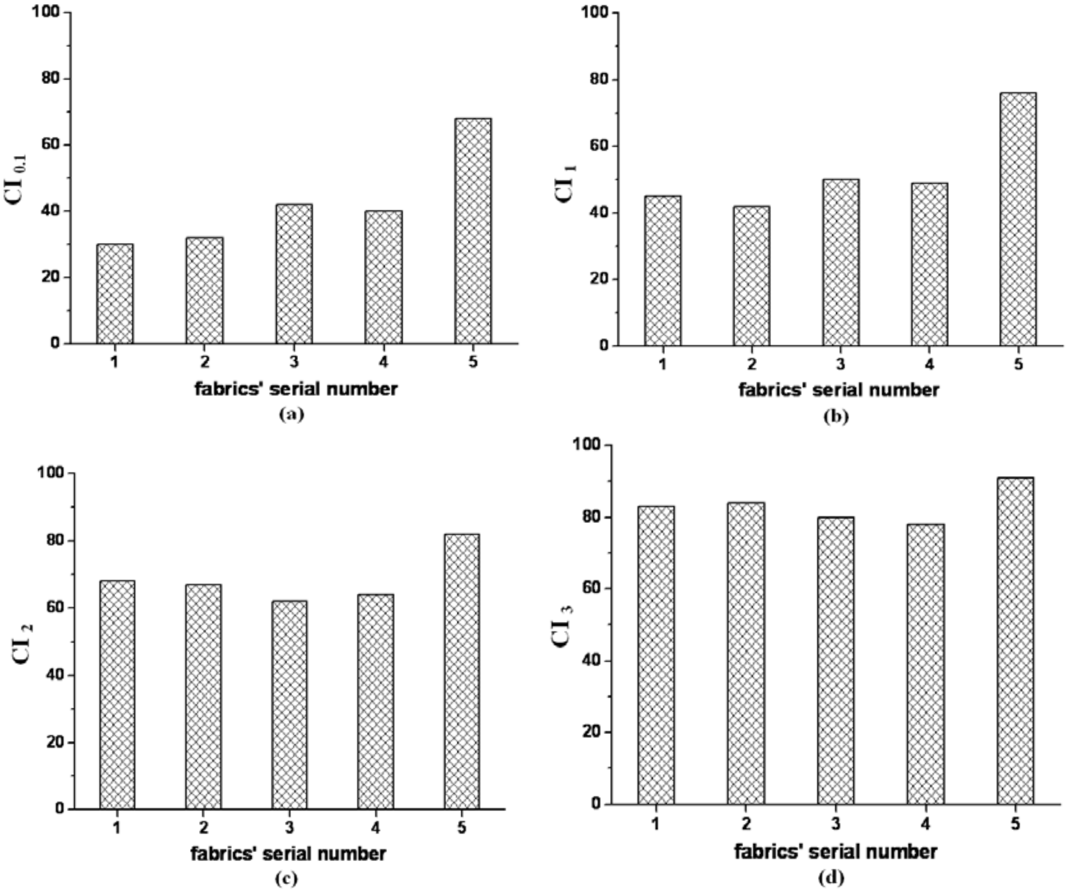

Fig. 2: Columnar diagrams of test fabrics' dynamic comprehensive index

and b, we can see that under the environmental wind speed of 0.1m/s and 1m/s, the dynamic comprehensive index has significant difference among different fabrics. The dynamic moisture comfort property of fine denier polypropylene fiber fabric (No. 5) is the best, in turn is chemical fiber fabric (No. 3 and No. 4) and nature fiber fabrics (No. 1 and No. 2). From Fig. 2c and d, we can see that under the environmental wind speed of 2m/s and 3m/s, different fabrics' dynamic comprehensive index becomes similar. The dynamic moisture comfort property of fine denier polypropylene fiber fabric (No. 5) is also the best, in turn is nature fiber fabrics (No. 1 and No. 2) and chemical fiber fabric (No. 3 and No. 4). Above analyses show that when environmental wind speed is lower (less than 1m/s), because of nature fiber's higher hydrophilicity, the moisture comfort property of nature fiber fabric is worse than that of chemical fiber fabric. While, when environmental wind speed is higher (higher than 2m/s), the moisture comfort property of nature fiber fabric is better than that of chemical fiber fabric.

From Fig. 2a, b, c and d, we can see that fewer than four different environmental wind speed conditions, the dynamic moisture comfort property of fine denier polypropylene fiber fabric (No. 5) is much better than the others. It approves fine denier polypropylene fiber's highly moisture comfort property and indicates that the comfortable sensation when people wear fine denier polypropylene fabric is the highest.

Above dynamic experiment can evaluate fabric's comfort property much better, but it is complicated and will cost more time and energy than the conventional static experiment. So it is necessary to establish models to predict dynamic experiment's results using static descriptive parameters. At first, the grey mathematics theory (Liu and Zhang, 2012) was performed to find out the static parameters that have high degree of association with dynamic comprehensive index. The degrees of grey incidence of dynamic comprehensive indexes and static indexes are given in Table 2. From Table 2 we can see that $CI_{0.1}$ and CI_1 have high grey correlation degree with fabric's thickness, weight, vertical wicking height and moisture regain. While CI_2 and CI_3 have high grey correlation degree with fabric's thickness, weight, vertical wicking height and air permeability. In order to find the relation among them, grey mathematics theory (Tian *et al*., 2009) was applied to establish models predicting the dynamic comprehensive index using static parameters. The models are shown in Table 3. By relative residual error

Table 2: Degree of grey incidence

	Thickness	Weight	Vertical wicking height	Moisture regain	Air permeability
$CI_{0.1}$	0.795	0.723	0.768	0.862	0.325
CI_1	0.872	0.754	0.821	0.819	0.402
CI_2	0.854	0.803	0.891	0.352	0.783
CI_3	0.877	0.869	0.918	0.403	0.772

Table 2 only indicates the value of degree of grey incidence, and it can not indicate the polarity of grey incidence, i.e. positive correlation or negative correlation

Table 3: Prediction models of dynamic comprehensive index

	Prediction models
$CI_{0.1}$	$dY^{(1)}_0/dt + 0.2103\, Y^{(1)}_0 = -2.6408\, X^{(1)}_1 - 0.8735\, X^{(1)}_2 + 2.0459^{(1)}_3 - 3.6176\, X^{(1)}_4$
CI_1	$dY^{(1)}_0/dt + 0.5120 Y^{(1)}_0 = -3.7528\, X^{(1)}_1 - 0.6925\, X^{(1)}_2 + 2.^{(1)}_3 - 3.6176\, X^{(1)}_4$
CI_2	$dY^{(1)}_0/dt + 0.3512 Y^{(1)}_0 = -4.2881\, X^{(1)}_1 - 4.3601\, X^{(1)}_2 + 5.2175\, X^{(1)}_3 - 1.9540\, X^{(1)}_5$
CI_3	$dY^{(1)}_0/dt + 0.3029\, Y^{(1)}_0 = -4.5416\, X^{(1)}_1 - 1.3601\, X^{(1)}_2 + 5.0469\, X^{(1)}_3 - 2.8438\, X^{(1)}_5$

$Y^{(1)}_0$ is $CI_{0.1}$, CI_1, CI_2 or CI_3; $X^{(1)}_1$ is thickness; $X^{(1)}_2$ is weight; $X^{(1)}_3$ is vertical wicking height; $X^{(1)}_4$ is moisture regain; $X^{(1)}_5$ is air permeability

test, the predictive precision of each model is above 93.5%. Models show that when environmental wind speed is lower (less than 1m/s), fabrics with lower thickness, lower weight, lower moisture regain and higher vertical wicking height will be more moisture-comfortable. While when environmental wind speed is higher (higher than 2m/s), fabrics with lower thickness, lower weight, higher vertical wicking height and higher air permeability will be more moisture-comfortable. From Table 3 we can also see that fabric's thickness, weight and vertical wicking height play great effect on fabric's dynamic moisture comfort property in different wind speed conditions. While moisture regain plays greater effect on fabric's dynamic moisture comfort property in lower wind speed conditions than in higher wind speed conditions. Air permeability plays greater effect on fabric's dynamic moisture comfort property in higher wind speed conditions than in lower wind speed conditions.

CONCLUSION

This study investigated moisture comfort property of fine denier polypropylene fiber fabric in four different environmental wind speed conditions. By dynamic experiments, the relative humidity changes of inner and outer surfaces of test fabrics were tested and the comprehensive index was introduced to evaluate fabric's dynamic moisture comfort property. Results show that under four different environmental wind speed conditions, the dynamic moisture comfort property of fine denier polypropylene fiber fabric is much better than the others. It approves fine denier polypropylene fiber's highly moisture comfort property. Results also show that when environmental wind speed is lower (less than 1m/s), because of nature fiber's higher hydrophilicity, the moisture comfort property of nature fiber fabric is worse than that of chemical fiber fabric. While, when environmental wind speed is higher (higher than 2m/s), the moisture comfort property of nature fiber fabric is better than that of chemical fiber fabric.

In addition, grey mathematics theory was introduced to establish models to predict dynamic experiment's results using static descriptive parameters. Models show that when environmental wind speed is lower (less than 1m/s), fabrics with lower thickness, lower weight, lower moisture regain and higher vertical wicking height will be more moisture-comfortable. While when environmental wind speed is higher (higher than 2m/s), fabrics with lower thickness, lower weight, higher vertical wicking height and higher air permeability will be more moisture-comfortable. Fabric's thickness, weight and vertical wicking height play great effect on fabric's dynamic moisture comfort property in different wind speed conditions. While moisture regain plays greater effect on fabric's dynamic moisture comfort property in lower wind speed conditions than in higher wind speed conditions. Air permeability plays greater effect on fabric's dynamic moisture comfort property in higher wind speed conditions than in lower wind speed conditions.

ACKNOWLEDGMENT

This study is supported by Natural Science Research Plan in Education Department of Henan Province of China (Program No. 2010A540009) and science and technology instructional project of China Textile Industry Institute (Program No. 2011076) and national natural science foundation training plan in Zhongyuan University of Technology.

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