The Intelligent Fiber Knitted Fabrics Development and Function Test

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Received: 24 August 2013 / Accepted: 25 October 2013 / Published: 30 November 2013

Abstract: Introduction of a new type of intelligent Outlast textile fabric applied in top grade casual coat and children’s coat. We discuss designing, developing, weaving, dyeing and finishing, and production. Also, to perform test on this kind of intelligent fabric temperature adjustment function, we can adopt test method like “warm model test”, and “human being group test in laboratory. Copyright © 2013 IFSA.

Keywords: The intelligent outlast fiber, Knitted fabrics, Production technique, Test.

1. Introduction

Intelligent garment materials are the main focus of the global textile industry. What contribute to the smartness of these materials are the special substances added to the garment materials. These special substances can be specially-structured alloy or polymer, phase change material, liquid crystal material, electronic device, etc. Some of the smart garments made of these materials can help wearer overcome unfriendly environmental conditions and provide better protection, thus mostly being applied under special conditions. But some of smart garments are promoted in the mass consumer market due to their more practical functions, better performances and more convenience. Integrating the sensory device, the driver and the control system, this kind of smart garment material exerts distinct features of creature. Temperature adaptable material is a kind of intelligent garment materials which can automatically sense external temperature and further adjust temperature smartly. It can absorb, store, redistribute and release heat. Energy conservation technology is getting more and more important in the circumstance today of energy shortage. Outlast air-conditioning fiber is a kind of temperature adaptable material, because of the function of heat preservation and temperature adjusting. Outlast air-conditioning fiber can be produced by two kinds of methods, namely particles embedded method and fabric coating method. It has the function of automatic absorbing, storing, and emitting heat in the form of latent heat, when the temperature changes, this material can absorb or release heat through the mutual transformation between the solid and liquid. The phase change material will absorb and store heat in the process of ambient temperature rise, and such material will let out the stored heat when the temperature decreases. The main point of Outlast fiber technology is phase change material wrapped in microcapsule, performing heat absorption, storage and release in the form of latent heat. Mutual transformation can be done between solid and liquid phases during the process of temperature variation, and will result in heat absorption or release, with some fixed temperature range of phase change. Hydrocarbon wax is the phase change material in microcapsule of Outlast fiber, which can make reaction on the skin at the same time, as a buffer in response to the outside temperature variation [1, 2]. Clothes which is made of such material is quite comfortable, because when the external temperature...
is too low, the material can automatically elevate the temperature of the clothes; while when the external temperature is too high, it can automatically decrease the temperature of the clothes. Clothes of such material are always in a comfortable and fitting temperature [3].

2. Development of Outlast Fiber

Developed by NASA in 1988, Outlast fiber was mainly applied for space suit and cover cloth for space instruments. Outlast technology, with microcapsule PCM--Phase Change Material as its core, was a patent developed by NASA at late 70th or early 80th. Application was spread to daily wear, for business purpose in 1994 and for outdoors costume in 1997, before its wide use today in clothing and bedding. Others countries involved are Ciba Switzerland for phase change microcapsule production, De Pont USA for Outlast textile product, Fountain Set Europe for Outlast cotton knits, Plouequet Europe for European fabric Dyeing and finishing technology and Tiong Liong Japan for Asian fabric finishing technology. American Outlast Company have developed temperature-adaptable acrylic fiber textures like underclothes, jackets, socks, boots, running shoes, gloves, blankets, and mattresses and the sales volume of the textures have increased every year. Xiongya Textile Group in China cooperated with an American company in 2003 produced phase change garments firstly whose temperature is adaptable to outside environmental temperature. Intelligent phase change textiles are also applied to trade of medical health. They can be used to make bandage and therapeutic pads (Cao Lihui et al., 2010). Outlast fiber, known a functional new type intelligent fiber, is actually temperature regulation fiber developed by Outlast Company in US. Its function is realized by embedding phase change materials (PCMs) to acrylic fiber or viscose acetal fiber, in the form of microcapsule. Outlast technology continuously interact with the unique microclimate of the human body and the environment to moderate temperature from being too hot or too cold to being just right. It is reported that Outlast fiber has a bright future.

This Outlast fiber can be supplied as new fabric for top grade casual coat and children’s coat. In this kind of material, new is currently undeveloped. Research on this field will possibly result in a fashion among the consumers, especially when market segmentation is more popular these days. Additional function brings additional sales.

Outlast fiber in this paper adopted is produced by particles embedded method, which can ensure the stability and lasting of preference. The morphological structure of outlast air-conditioning fiber is shown in Fig. 1. Fig. 1 (a) is longitudinal section of outlast air-conditioning fiber (amplification 1500 times) and Fig. 1 (b) is cross selection of outlast air-conditioning fiber (amplification 2700 times).

Wearing a casual coat, and participating in outdoor games and activities, people are feeling hot during at one time, while feeling cold at another. However they do not change clothes as often as they want. Another case is, children in schools do not have the habit of changing clothes, and neither do the teachers remind them to. People find they need some kind of advanced clothes with high-tech to meet their needs, both for themselves and for their children. They are the casual coat and children coat we researched on. We propose use Outlast fiber as material in this development. The unique performance of Outlast fiber can help us to realize the idea of advanced coat for people and their children. Now these products have already been sold in China and overseas market.

3. Outlast Fabric Example

3.1. Weaving Technique

Machine parameters

Material
T/C40S (65/35), JC40S, 60 nm (outlast), 100D polyester.

Weaving technique
a) Winding length (50 winding length): double-knitted 1.49 cm, single knitted 12 cm;
b) Material: 46 % polyester, 20 % outlast, 34 % cotton;
c) Weave, cam, yarn intake setting (see Table 1).
Table 1. Weave, cam, yarn intake setting.

<table>
<thead>
<tr>
<th>Weave Setting</th>
<th>Serial number 1</th>
<th>Serial number 2</th>
<th>Serial number 3</th>
<th>Serial number 4</th>
<th>Serial number 5</th>
<th>Serial number 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cam setting</td>
<td>Up stitch</td>
<td>none</td>
<td>none</td>
<td>∨</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td></td>
<td>Down stitch</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td></td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Yarn intake</td>
<td>T/C40S</td>
<td>60 nm (outlast)</td>
<td>100D polyester</td>
<td>T/C40S</td>
<td>JC40S</td>
<td>100D polyester</td>
</tr>
</tbody>
</table>

Note: ∨, ∧ denote the circle triangle, and ∪, ∩ denote not quite needle triangle.

3.2. Dyeing & Finishing Technique

Process
Cloth preparing→ pretreatment→ dyeing→ dehydration→ slitting→ drying→ medium inspection→ color assessment→ finalizing→ part inspection→ enter warehouse

Pretreatment
HK-1031 Scouring agent: 1.5 g/L, 0.26 kg
NaOH: 2 g/L, 0.35 kg (50°C)
H2O2:6 g/L, 1.05 kg (80°C)
98°C ×45' fast cooling, 70°C drain
HAC (acetic acid): 0.75 g/L, 0.13 kg
60°C ×7' drain/inlet 3' PH value: 5.5
Liquor ratio: 1:10

Dyeing technique
Acrylic dyeing technique is shown in Fig. 2.

Cotton dyeing technique is shown in Fig. 3.

After treatment
HAC: 1 g/L, 0.18 kg (7' drain)
HK-2051 soaping: 1 g/L, 0.18 kg
95°C ×10' fast cooling 70°C drain
Boil 80°C×10' hot water °C ×7' drain

Color stabilizing, softener adding
AB: 2 g/L, 0.35 kg
HAC: 0.05 g/tenacity additive L, 9 g
CS cotton softener: 8 g/L, 1.4 kg °C ×10' taken out

Product specification
Weight: 195 g/m²
width: 205 cm
Fastness to washing: Min grade 4
Fastness to lith: Grade 4
Fastness to perspiration: Color fade grade 4
Color change grade 4
Fastness to rubbing: Dry rubbing grade 4
Wet rubbing grade 4
Fastness to dry-cleaning: Color fade grade 4
Color change grade 4
Pilling resistance: Grade 3
Bursting strength: 1.061 MPa

4. Discuss on Open Issues

4.1. Yarn Selection

During production, Outlast fabric is easier to produce defect point in the form of pure yarn than blended yarn, but produces less defect points than cotton. Outlast fiber’s main technology lay in implanting microcapsule inside the fiber. By the solid liquid phase mutually transforming, the thermal phase change materials hydrocarbon wax wrapped in microcapsule could absorb and then release heat to regulate the body temperature [5]. The structures of materials are shown in Figs. 4 – Fig. 7. Through the observation of pure yarn of Outlast fiber’s transverse morphology [6], we could see the Outlast fiber had porous structure. Comparing the two kinds of fibers’ longitudinal morphology photos, it can be seen the Outlast fiber’s longitudinal section was relative
coarse, because of the microcapsule implanted in spinning solution. So it can not only meet the need of temperature adjustment (when Outlast ≥ 20 %), but also reduce yarn channels used and reduce the cost.

Fig. 4. Pure yarn of Outlast fiber transverse section (2000 times).

Fig. 5. Pure yarn of Outlast fiber transverse section (4000 times).

Fig. 6. Pure yarn of Outlast fiber longitudinal section (1000 times).

4.2. Cloth Surface Design

Considering the cloth surface appearance and style, it’s better to adopt plain loop and interlock compound stitch. Adopt interweaved with Outlast and cotton yarn for cloth inner side (considering wearing), in order to be comfortable and temperature adjusting. Then adopt polyester/cotton yarn for cloth outer side, to make the fabric in good shape and easy to wash, and also to raise the cloth bursting strength from 0.3 MPa of ordinary cloth to 1.06 MPa, in order to increase resistance to wearing out.

Fig. 7. Ordinary viscose fiber longitudinal section (1000 times).

4.3. Dyeing and Finishing

Since this fabric use Outlast acrylic fiber, we’d better introduce cationic dyeing technique, raising Temperature Method, also avoid sodium chlorite bleaching. When Outlast is under 85 °C, it has exhaustion, so the temperature raised from 60 °C to 80 °C should be a fast process (see Acrylic dyeing technique broken line). When doing after treatment, we should add tenacity additive to avoid stitch holes.

4.4. Fabric Performance

This product uses Outlast fiber as the material for new intelligent fabric, which embed phase change materials (PCMs) to fiber being microcapsules. The function of temperature adjustment will not deteriorate after many times washing. Also the fabric does not shrink or elongate after washing. It seems a good material for casual coat and children coat.

4.5. Wearing Characteristic Test

There are seven kinds of Outlast fibers knitted fabrics for the wearability test. There are air permeability test, thermal insulation test, moisture permeability test, bursting strength test, wrinkle elasticity test, draping test, pilling property test [7]. Finally fuzzy comprehensive evaluation method is used to analyze the wearing characteristic of Outlast fiber [8]. A kind of stitch with the optimum wearing characteristic can be reached.
It can be seen from the wearing performance test results of Outlast fiber knitted fabric, the main factors affecting the fabric wearing performance is draping, thermal insulation, fold elasticity, permeability, drapability and flexible. So determine the weight factors A and comprehensive evaluation matrix B.

\[ A = (\text{Wrinkles} \ 0.2, \ \text{Permeability} \ 0.2, \ \text{Warmth retention property} \ 0.1, \ \text{Permeability} \ 0.1, \ \text{Drape} \ 0.2, \ \text{Flexible} \ 0.2) \]

\[ R = (\text{Crease-recovery angle}, \ \text{Crease-recovery}, \ \text{Permeating degree}, \ \text{Heat-insulating}, \ \text{Permeability}, \ \text{Drape coefficient}, \ \text{Stiffness}) \]

\[
\begin{bmatrix}
1 & 0.9771 & 0 & 0.4444 & 0.3862 & 0.4092 & 0.6155 \\
0 & 0.4458 & 1 & 0.3966 & 0.7373 & 0.2661 & 0.539 \\
0.75 & 0.7195 & 0.7056 & 0.573 & 0.25 & 0.6391 & 0.3646 \\
0 & 0.1028 & 0.3999 & 0.6447 & 1 & 0.5487 & 0.7447 \\
1 & 0.75 & 0 & 0.4167 & 0.25 & 0.8333 & 0.5833 \\
0.9122 & 0.8316 & 0 & 0.2957 & 0.7971 & 0.6442 & 0.7354
\end{bmatrix}
\]

\[ B = A \cdot R = (b_1, b_2, \ldots, b_m) \]

\[ B^* = A \cdot R^* \cdot T = (0.6574, 0.6831, 0.3106, 0.4325, 0.5591, 0.5493, 0.6056) \]

The results from above show that the \( B^* \), \( 1 + 1 \) rib performance of Outlast fiber knitting fabric is the best, the performance of full needle rib knitting fabric is the worst.

**4.6. Test Method for Temperature Adjustment**

1) Warm model test

Make sock, gloves, and coat with this new intelligent fabric and put them on to the model. Test the temperature of the key sensitive parts on the model, like front breast, front belly, back waist, body back, and the joints. The model is shown in Fig. 8. Mount thermal sensors on such mentioned parts to monitor temperature changing. To evaluate the function of temperature adjustment, we can put the model in high and low temperature room to simulate the environment temperature changing, and trigger the phase change materials. We can not only do test on temperature difference before adjustment and after adjustment, but also do test on temperature difference of new material and ordinary material put on the model.

2) Human being group test in laboratory

The human being group test is shown in Fig. 7. Volunteers for the test put on the clothes made of new intelligent material, and we put thermal sensors on the clothes with the parts related to sensitive in the human body, like left/right breast, left/right arm, left/right thigh, and left/right leg. We can simulate the temperature, moisture, and air flow as the test setting. After they walk into the climate simulation room, we can collect data of temperature change under environment change from every parts with sensor, and transmit the data to a computer for processing.

**5. Conclusions**

Outlast fabric can not only be pure yarn, but also be interweaved with cotton, polyester, fine wool, and other man made fiber, chemical fibers. Although it’s now widely used in underwear, warn clothes, home textile, and socks, for casual coat and children coat, it’s totally new application. Actively develop new product with new fiber and occupy the market ahead of others, may be a way of exceeding other competitors, not only in current economic crisis situation but also any time in the future.
References