STUDY ON TEMPERATURE ADAPTABILITY OF NEW COLD CLOTHING MATERIALS

by

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Original scientific paper
https://doi.org/10.2298/TSCI2203545C

Cold protective clothing directly affects outdoor workers' health and work efficiency in winter, and a good performance is particularly needed. This article studies a lightweight smart cold-proof clothing material. Its thermal insulation and heating performance are analyzed theoretically, and its temperature adaptability is obtained, which sheds new light on the design of cold protective clothing.

Key words: *cold protective clothing, functional fabric, thermal insulation, thermal insulation properties*

Introduction

When the human body is exposed to a low temperature environment for a long time, the heat generated in the body usually cannot compensate for its energy loss, and the thermal balance is broken, leading to a low body temperature, frostbite, and even death [1]. In order to resist the cold, cold protective clothing with different degrees of warmth is constantly being developed, especially for workers working in an extremely cold area, cold protection and warmth are particularly important. The cold protective clothing can be divided into life cold protective clothing and special-purpose cold protective clothing in terms of wearing purposes. The cold protective method can be divided into the passive insulation type cold clothing and the active heat-generating cold clothing. The passive thermal insulation cold protective clothing mainly increases the thickness or number of layers of the clothing and adjusts the air content inside the clothing to prevent the body's heat from radiating outward to achieve the purpose of keeping warm. However, the total thermal resistance of clothing has an upper limit, namely 4-5 layers, beyond which a higher thickness is not necessary, because it cannot increase further the warmth retention of clothing [2]. The thermal insulation performance of the cold-proof clothing is influenced by multiple factors, such as material, environment, relative humidity, skin temperature, air permeability of fabrics, and inter-fiber stacking structure [3-8].

At present, the emergence of some new heating fiber materials has further improved the warmth retention of cold protective clothing. Heating materials can be roughly divided into five types according to their heating methods: hygroscopic heating materials, electric heating materials, chemical energy heating materials, phase change heating materials, and light-

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absorbing heating materials. Due to the different heating principles of various heating fibers, their performance will also change under different usage conditions. How to use various materials reasonably is a prerequisite to ensure the best performance of winter clothes.

In this paper, two new thermal insulation materials and common thermal insulation materials on the market are selected for performance tests and comparative analysis. According to the performance characteristics of different materials, suggestions are put forward for their reasonable applications in the design process of cold protective clothing.

Principle of fabric performance technology

Light-absorbing heating fiber fabric

By absorbing light and heating fibers, the visible light and infrared rays emitted by the surrounding environment and the human body are converted into heat energy and absorbed by the body to achieve the effect of keeping warm. In the test of light absorption and heat preservation, the temperature of the thermal fiber fabric is significantly higher than that of the ordinary fabric. This fabric is mainly used for the inner layer of cold protective clothing.

The light-absorbing heating fiber studied in this paper uses a special process to add light-absorbing heating powders into the fiber, which can absorb sunlight and visible light and infrared rays in the surrounding environment, and convert the light energy into the heat energy to increase the temperature of the fabric. This heating method using natural energy is more energy-saving and environmentally friendly.

Capsule fiber fabric

Phase change materials can improve the thermal insulation effect of clothing, but the effective heating time is short, and continuous heating function cannot be guaranteed under the condition of long time outdoor work. Compared with other heat-generating materials, the phase change materials have much prominent advantage in slow temperature change and avoid the human discomfort caused by sudden and drastic changes in the external environment temperature.

The capsule fiber fabric studied in this paper uses the phase change material in the capsule fiber to make the fabric absorb heat or generate heat when the external temperature changes to avoid sudden rises and drops in temperature, so that the clothing can be maintained in a comfortable temperature range.

Experiments

Testing of light-absorbing and heating fiber fabrics

Single side pile (color: pink pattern; ingredient: 100% polyester; yarn count: 144F; gram weight: 180 g/m^2), which is common in the market, was selected as the comparison sample to test the light absorption and thermal insulation properties of light-absorbing and heating fiber fabric and single side pile, respectively, and the experimental data were recorded.

A 15 cm × 15 cm cloth was cut to make a sample, and the thermocouple temperature sensor was installed in the center of the back of the sample. The experiment was conducted for 20 minutes under the following conditions, and the temperature change of the sample was measured every 1 minute.

Use lamp: Iwasaki electric lamp PRF500WD.

Exposure distance: 30 cm

Determination conditions: after using the reflector lamp for 10 minutes, immediately cut off the power supply of the reflector lamp, and continue to measure for 10 minutes in this state.

Determination environment: 20 °C, 65% RH

Determination method: The samples were measured side by side, the positions of the samples were changed and measured again, and the average value of the two times was calculated as the experimental result.

The sample platform is shown in fig. 1.

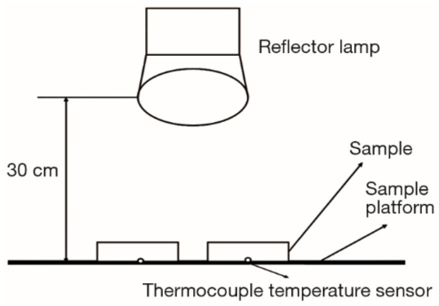

Figure 1. Sample platform

Testing of capsule fiber fabric

Choose a common fabric (color: yellow; composition: 100% polyester; density: 230 T; yarn count: 75D × 75D; weight: 110 g/m^2; fabric weave: plain weave) as a comparison sample. Conduct experimental tests and record the changes of the two under different temperature environments.

Cut a 20 cm × 20 cm cloth into a sample, put it in a dryer for 4 hours, and place it in a dryer with silica gel overnight. Fold the sample in half, install a thermocouple temperature sensor in its center, and then fold it in half to make a test body.

Use a constant temperature and humidity machine to treat the test object in an environment of 20 °C and 60% RH for 2 hours, set the temperature of the constant temperature and humidity machine to 40 °C (without controlling humidity), keep it for 15 minutes, and then set it to 20 °C, 60% RH, keep for 30 minutes, and measure the temperature change in the above experimental procedure every 1 minute.

Results and discussion

Test results of light-absorbing and heating fiber fabric

The change of temperature of light-absorbing and heating fiber fabric with light is shown in tab. 1 and fig. 2.

According to the previous experimental methods, the test data in tab. 1 were obtained. In order to reflect the test results in a more visual way, the test data are plotted to represent the comparison of the test data visually. Through the analysis of experimental data, it can be concluded that the temperature of the experimental subjects increases with the change of time under the illumination condition. At the beginning of the experiment, the light-absorbing and heating fiber fabric did not have too much heating advantage compared with the ordinary comparison sample. After the third minute, the heating speed of light-absorbing and heating fiber fabric was significantly accelerated. In addition, the final temperature is higher when the light stops. After the light stops, the light-absorbing heating fiber fabric and the ordinary comparison sample release heat in a similar curve, and the temperature of the light-

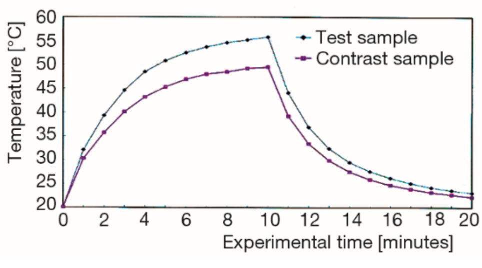

Figure 2. Temperature change of light-absorbing and heating fiber fabric with illumination duration

absorbing heating fiber fabric is always higher than that of the comparison sample. The experiment shows that the heat-absorbing fabric always has better thermal insulation performance under the same working condition than ordinary fabrics.

Table 1. The temperature of heat-absorbing fiber fabric varies with the duration of illumination

Experimental time [minutes]	Temperature [°C]		Temperature difference $\Delta T = T_1 - T_2$
	T_1	T_2	
0	20.1	20.1	0.0
1	32.1	30.3	1.8
2	39.3	35.7	3.6
3	44.6	40.1	4.5
4	48.5	43.2	5.3
5	50.8	45.3	5.5
6	52.5	46.9	5.6
7	53.7	48.0	5.7
8	54.6	48.5	6.1
9	55.2	49.2	6.0
10	55.8	49.5	6.3
11	44.1	39.2	4.9
12	36.9	33.4	3.5
13	32.4	29.9	2.5
14	29.5	27.5	2.0
15	27.6	25.9	1.7
16	26.2	24.7	1.5
17	25.1	23.9	1.2
18	24.2	23.2	1.0
19	23.6	22.7	0.9
20	23.1	22.2	0.9

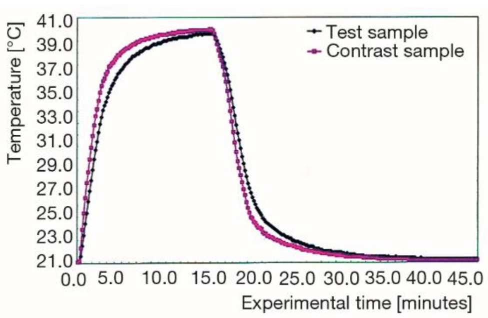

Figure 3. Temperature comparison test chart of capsule fiber fabric and ordinary fabric

Test results of capsule fiber fabric

Table 2 shows the temperature changes of capsule fiber fabric and ordinary fabric with the change of ambient temperature.

Figure 3 is the curve diagram of the data in tab. 2. It can be intuitively seen from fig. 3 that the temperature change of capsule fiber fabric is more moderate than that of ordinary fabric when the ambient temperature suddenly rises or falls. It can also be seen from the curve that the capsule fiber has the most apparent effect within 10 minutes after the temperature changes, and then the temperature control effect gradually weakens. Therefore, the capsule fiber fabric is suitable to be placed in the sensitive position of the human body's perception of temperature change. It can effectively avoid the discomfort caused by the abrupt change in the temperature of the external environment.

Table 2. The temperature change of capsule fiber fabric and ordinary fabric with the change of ambient temperature

Experimental time	Test sample	Contrast sample	Experimental time	Test sample	Contrast sample
0	20.1	20.1	23	22.4	21.7
1	24.3	26.9	24	22.1	21.5
2	29.7	32.6	25	21.7	21.3
3	33.5	35.8	26	21.4	21.0
4	35.4	37.2	27	21.2	20.9
5	36.6	38.1	28	21.0	20.8
6	37.5	38.6	29	20.9	20.7
7	38.1	39.0	30	20.8	20.6
8	38.4	39.2	31	20.7	20.5
9	38.8	39.4	32	20.6	20.4
10	39.0	39.5	33	20.5	20.3
11	39.2	39.7	34	20.5	20.3
12	39.3	39.8	35	20.5	20.3
13	39.5	39.9	36	20.4	20.3
14	39.5	39.9	37	20.4	20.2
15	39.6	40.0	38	20.4	20.2
16	38.3	37.7	39	20.3	20.2
17	35.5	33.9	40	20.3	20.2
18	31.1	28.7	41	20.3	20.2
19	27.4	25.2	42	20.3	20.2
20	25.0	23.4	43	20.3	20.2
21	23.7	22.5	44	20.3	20.2
22	23.0	22.1	45	20.3	20.2

Conclusion

The light-absorbing and heating fiber studied in this paper can be used as lining material and filling material to keep warm continuously. Compared with the ordinary fabric, the temperature curve of capsule fiber fabric is more moderate, so it is suitable for the inner layer of cold clothing.

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Paper submitted: October 5, 2020
Paper revised: October 5, 2021
Paper accepted: October 5, 2021