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Research on thermal insulation performance of different clothing fabrics at different temperatures

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Abstract: *This topic is based on the solar clothing to conduct further research on the type of fabric used. In the previous research, we chose polyester fabric as the solar clothing fabric, mainly because it has better sunlight resistance and better tenacity, and is easier to sew with solar panels. The sports clothing is warm and cold, but also wind and rain proof, in addition to the moisture absorption and special protective properties of the fabric at the same time, the flexibility, scalability and durability of the fabric has certain requirements, this paper on the clothing fabric insulation performance to choose the appropriate solar clothing insulation fabric.*

Keywords: *thermal insulation, cold protection, clothing fabric, environmental protection*

1. Introduction

In the previous research, the team combined the two systems of solar heating and semiconductor cooling to design a solar clothing similar to the design of a hardshell jacket. The clothing is composed of solar heating device, semiconductor refrigeration device, temperature sensor, solar panel, storage battery and other parts. However, the main part of the clothing - the choice of fabric has not been deeply studied, and the thermal insulation effect of ordinary clothing is generally achieved by reducing the heat dissipation of the human body. Conduction, convection, radiation and evaporation are the main ways for the human body to dissipate heat without wet sweat, accounting for about 97% of the total heat dissipation,[1] so this paper mainly studies the thermal insulation performance of different fabrics at different temperatures to select the most suitable fabrics for making solar clothing.

1.1 Research background

1.1.1 Research status at home and abroad

For the study of thermal performance, clothing is generally selected as the basic research object, so the discussion of the research status of this part mainly focuses on the domestic and foreign research on the related performance of cold clothing. Specific domestic and foreign research and patent situation refer to Table 1 and Table 2.[2]

1.1.1.1 Domestic research status

Table 1: Domestic related research papers

Serial number	Article name	Author	The year of publication	Publisher	Content
1	Human test evaluation of thermal performance of winter clothing for crew of naval ships 92	Gu Xinqing, Li Rongjie, Li Yiguang	2000	Journal of naval medicine	The reasons for the poor thermal performance of cold clothing for sailors on 92 naval ships were studied
2	Research on the application of thermal materials in clothing	Su Jianmei	2012	Beijing Institute of Fashion Technology	Based on the thermal and wet comfort performance, a new type of warm and heat clothing was developed
3	The thermal performance of inflatable winter clothing	Su Wenzhen, Song Wenfang, Lu Yehu, Yang Xiuyue	2020	Textile journal	The total and local thermal resistance of the upper body of inflatable clothing under 4 kinds of air volume and 3 kinds of wind speed were tested by "Newton" sweating warm-up dummy experiment.

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1.1.1.2 Foreign research status

Table 2 Relevant foreign research papers

Author	Articles/Patents	Content
Matusiak etc.	Relative Thermal Comfort Index as a Measure of the Usefulness of Fabrics for Winter Clothing Manufacturing	Through testing the air temperature and change under the clothing and the temperature change on the outer surface of the clothing caused by the heat generated by the human body, the thermal and wet comfort index of the clothing was determined
Yang etc.	The Application of Silica and Glass Fibers in Effective Thermoinsulation of Winter Apparels	The composite material of inorganic fiber and polyester fiber was developed and its properties were evaluated. The results showed that the combination of inorganic fiber and polyester fiber could significantly enhance the thermal insulation properties of polyester nonwovens and reduce the heat loss of human body
Arumugam etc.	Development of biaxial stretchable nonwoven paddings using novel polymeric fibers	A new polymer fiber biaxial stretch nonwovens liner has been developed, which has good biaxial stretch and recovery properties and good heat insulation properties

1.2 Research significance

This topic is based on the solar clothing to conduct further research on the type of fabric used. In the previous research, we chose polyester fabric as the solar clothing fabric, mainly because it has better sunlight resistance and better tenacity, and is easier to sew with solar panels. In this paper, the thermal insulation properties of clothing fabrics to choose more suitable solar clothing thermal insulation fabrics. The significance is as follows:

(1) The insulation material has the characteristics of low energy consumption, less pollution, multi-function and so on. Uphold the concept of sustainable development, fully reflect the effective use of resources, environmental protection, clean production and other comprehensive benefits.

(2) The development of new energy-saving building materials is in line with today's human needs and the development trend of The Times, and has important practical significance for the implementation of the scientific concept of development and the construction of a resource-saving society.

(3) Today's energy shortage, the state strongly supports the new energy policy, the better the insulation performance of thermal insulation materials, the greater the production and use of thermal insulation materials, the more energy saved. At the same time, the development of insulation materials than the use of energy itself costs less investment, comprehensive benefits are large, quick effect.[3]

1.3 Research difficulty

Through searching the data, the difficulties of this research are as follows:

(1) Although the garment industry is developing rapidly at present, there is no universal unified standard on the thermal insulation performance of clothing. Therefore, while studying and comparing various fabrics, the team will collect relevant data to investigate whether a set of universal standards can be found for the thermal insulation properties of clothing.

(2) At present, in the process of testing the thermal insulation performance of clothing on the market, it is generally assumed that the human body is static, which is obvious that this research method is one-sided. When the human body is moving, the relevant data changes. Therefore, in the follow-up research process, the team should pay attention to the measurement of the thermal insulation performance of clothing during human movement.

2. Research objects

2.1 Fabric selection

In the current situation of continuous high temperature weather, people have higher requirements for clothing, so all kinds of clothing should meet the needs of the human body, to achieve the optimization of people and clothing, clothing and the environment. In the human ergonomics of clothing and fabrics, suitable for human needs, must meet the following aspects.

(1) Comfort. Clothing should not only be able to modify the body, its comfort and satisfaction is a

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higher realm, unreasonable structure and mismatched materials, sizes are difficult to achieve a comfortable state. (Textures of different fabrics)

(2) Good for health. The weight of the shirt is mainly supported by the shoulders, so in all kinds of clothing, especially in the shoulders of sports clothing, lightweight materials should be used, and at the same time, the fit structure made of nylon buckle instead of elastic band is used at the cuff to prevent the pressure of blood vessels due to excessive tightness. (Influence of the transfer temperature of semiconductor refrigeration and heating under different fabrics on the human body)

(3) Security. The main consideration is the degree of adaptation of different groups of people to different fabrics (sensitive skin groups), as well as the safety of semiconductor cooling and heating systems. (Circuits and parts)

(4) Efficient energy conversion. The semiconductor cooling and heating system converts solar energy into heat energy and transfers the heat energy to the human body to the greatest extent. (Loss in heat transfer)[4]

2.2 Fabric evaluation

Today's international Textile testing standards are AATCC: (American Association of Textile Chemists and Colorists, referred to as AATCC), American Association of Textile Chemists and Printers standard and ASTM: American Society for Testing and Materials (ASTM) standard.

In addition to AATCC and ASTM, there are international standards ISO, the common testing standard in Japan is JIS, and the common standard in China is referred to as GB. Each standard has its own evaluation system for the performance of textiles, and there are differences in testing methods and evaluation indicators. The use of different standard systems to evaluate the same sample will result in different numerical results.[5]

3. Research method

3.1 Thermal insulation performance characterization index

At present, the main indexes used to characterize the thermal insulation performance of clothing in the clothing market include thermal insulation rate, thermal resistance, thermal conductivity, heat transfer coefficient clo value (Crow value), Tog value (Tog value), etc.The specific detection methods are shown in Table 3.[1]

Table 3: Clothing insulation performance characterization index

Representational index	Implication	Unit
Insulation ratio	The difference of heat dissipation with or without a sample and the ratio of heat dissipation without a sample	%
Thermal resistance	The ratio of the temperature difference between the two sides of the sample and the heat flux per unit area passing vertically through the sample indicates the hindering ability of the fabric to the heat conduction	$m^2 \cdot K/W$
Thermal conductivity	Under stable heat transfer conditions, the heat transferred by a material with a thickness of 1m and a temperature difference of 1K on both sides through an area of 1m2 within 1h	W/(m·K)
Heat transfer coefficient	Under stable heat transfer conditions, the heat transferred by the material with a temperature difference of 1K on both sides through an area of 1m2 within 1h	$W/(m^2 \cdot K)$
Crowe value	The thermal resistance of a person sitting quietly or engaged in light mental work, in a standard environment, the clothing needed to feel comfortable	clo
Tog value	In the steady-state heat transfer process, when the temperature difference between the two sides of the sample is 10K, the thermal power transmitted per square meter of the sample	Tog

3.2 Test method

The test of clothing insulation performance is mainly divided into two parts, one is a single test of the fabric used in the clothing. Although this kind of test is simple and easy to operate, the cost is low, but obviously not rigorous enough. Clothing insulation not only depends on the fabric used, but also related to the design of the clothing and the situation of human activity. Therefore, the test clothing overall thermal insulation performance is more in line with the actual life effect. However, such testing methods are expensive and the machines used are not common.

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3.2.1 Fabric layer

3.2.1.1 Evaporative hot plate method

Such methods are for the determination of thermal and wet resistance of textiles under steady state conditions issued by the General Administration of Quality Supervision, Inspection and Quarantine in 2018. The measurement principle of thermal resistance is that the test environment is kept at a constant temperature, the sample is covered on the test plate, by calculating the difference between the thermal resistance value of the air layer with the sample and the thermal resistance value of the air layer without the sample, the value is the thermal resistance value of the sample. The measurement principle of wet resistance is to cover the test plate with a layer of breathable and impermeable film under the above test conditions, and then calculate the difference between the thermal resistance value of the air layer with a sample and that of the air layer without a sample, and the value is the wet resistance value of the sample.

3.2.1.2 Cooling method

The cooling method can not accurately measure the thermal resistance and heat transfer coefficient of the fabric, so the heat transfer performance of different fabrics can only be compared by horizontal comparison. The principle is to place the sample on a test plate heated to a certain temperature, and measure the insulation performance of the sample by the value of the temperature drop of the test plate within a certain time or the time consumed by falling to a certain temperature.

3.2.2 The overall level of clothing

3.2.2.1 Warm body dummy method

Warm body dummy method is currently an important method used to test the overall thermal insulation performance of clothing. It comprehensively considers many factors such as clothing material, clothing style and layer matching, and tests with dummy wearing clothing to avoid the influence of individual differences and psychological factors in real experiments. The test has good repeatability and can realize product testing under extreme environmental conditions.

3.2.2.2 Infrared thermography

Infrared thermal imaging technology uses photoelectric equipment to measure infrared radiation, which can transform the infrared radiation energy invisible to the human eye into infrared thermal image distribution, which can directly express the actual temperature distribution of the human body under the condition of wearing. However, the development of this kind of method is not mature at present, especially the reasonable and scientific characterization index has not been established between the test results and the insulation performance.[1]

4. Results and analysis

1) According to a single test on a variety of fabrics, although this test is simple and easy to operate, it is still a little difficult to find the right fabric for our sportswear. So we have to choose the best, if we can not meet the conditions of our sportswear, we have to choose the most suitable fabric.

2) Clothing insulation not only depends on the fabric used, but also related to the design of clothing and human activities, so we should reasonably arrange the sewing position of the solar panel, the installation position of the circuit in the clothing, so that people should feel comfortable when wearing our clothing, which is also a problem to be considered when selecting the fabric.

3) The sportswear not only requires wind and rain, but also requires warmth and cold, moisture absorption and special protective properties, and has certain requirements for the flexibility, scalability and durability of the fabric. Clothing should be selected moisture wicking fabric, easy to timely sweat, increase the moisture permeability of clothing; Wear resistant and resilient fabrics should be used in the shoulder, elbow and waist of the garment where it is easy to wear. The comfort, health, safety and efficiency of clothing should be considered in the design of clothing. The correct choice of functional fabrics can not only improve the usability of sports clothing, but also make the wearer feel comfortable.

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5. Conclusions and recommendations

5.1 Research conclusion

The comfort, health, safety and efficiency of clothing should be considered in the design of clothing. The sports clothing is warm and cold, but also windproof and rainproof, in addition to the moisture absorption and special protective properties, while the flexibility, scalability and durability of the fabric have certain requirements. Hygroscopic and perspiratory fabric is more suitable for the fabric selection of the garment, which is convenient for timely perspiration and increases the moisture permeability of the garment. Wear-resistant and resilient fabrics should be used in the shoulder, elbow and waist of the garment because these places are easy to wear, and people have a large range of motion after wearing. The correct choice of functional fabrics can not only improve the usability of sports clothing, but also make the wearer feel comfortable and meet the needs of the public.

5.2 Problems and Suggestions

Through literature search and clothing design, testing and comparing the thermal insulation performance of various fabrics, the team noticed that although there are a variety of methods to test the thermal insulation performance of clothing, there is a lack of a universal evaluation standard. Therefore, the team needs to pay more attention to solving the following problems in the future research:

(1) It is difficult to unify the representation indicators, the comparability of research results is poor, and the guiding significance for end consumers is not played. In view of the large differences in the testing principles of thermal insulation performance, a variety of characterization indexes of thermal insulation performance have been derived. In addition, the test often uses temperature, infrared radiation and other indirect characterization, but such factors are not concrete and unstable, resulting in a certain degree of uncertainty in the index itself.

(2) The test environment is not uniform and does not fit the reality well. Ambient temperature, relative humidity and wind speed all have influence on the insulation effect of clothing, especially the influence of temperature and wind speed. In the current relevant standards of thermal insulation performance, there are great differences in the test environment, and different scholars have not adopted a unified test environment in the relevant experimental research, so the obtained research results are difficult to compare effectively.[1]

Under the current trend of lightweight and diversified development of thermal clothing, scientific and effective evaluation of thermal insulation effect is of great significance for related academic research and market consumers. From the practical and practical point of view, this paper analyzes the current evaluation methods of clothing insulation performance, hoping that the research results can provide reference for the improvement and standardization of the relevant evaluation system.

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References

[1] Wu Bingjing, Li Xuan. Clothing thermal insulation performance evaluation method and its

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optimization analysis [J]. Journal of textile testing and standard, 2020, 6 (6): 5-8. DOI: 10. 19391 / j. carol carroll nki cn31-2117. 2020. 06. 002.

[2] Han Zhiqing. Clothes very cold environment design research [D]. Southwest university, 2022. The DOI: 10. 27684 /, dc nki. GXNDX. 2021. 002176.

[3] Gao Xuan, Ni Dan. Current situation and evolution trend of cold-proof clothing materials [J]. Light Industry Science and Technology, 2019, 35(12):106-107.

[4] He Bixia, Qiang Liling. Mountaineering wear based on the outdoor sports function design and material selection [J]. Journal of modern textile technology, 2012, 20 (02): 52-54, DOI: 10. 19398 / j. a tt 2012. 02. 015.

[5] Dong Mei. Selection and Application of Functional Fabrics for outdoor sports clothing [D]. Soochow University, 2016.