Research on application of carbon fiber heating material in clothing

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Abstract: With the development of society, the way of keeping warm clothing is also developing. Carbon fiber has the advantages of high efficiency, safety, mobility and comfort. As a heating element, it has good application prospect. In this paper, the main technology, application issues and design method of carbon fiber heating garment are analyzed, and the key problems in industrialization are also put forward.

1 Introduction
In recent years, the use of carbon fiber and other carbon materials as far infrared thermal clothing develop rapidly. At present, the domestic research and development of the production of hot products of this type of unit not less than ten, but most are still in the trial stage, has not yet formed a real industrialization [1]. The design and application of carbon fiber heating garment will play an important role in promoting the industrialization process.

2 Characteristics and Application Issues of Carbon Fiber Heating Garment
Heating clothing is different from the warm clothing. Warm clothing is controlled by the loss of body heat to achieve the purpose of warmth, and heating clothing is generated heat by the external source to use thermal effect on the human body actively [2]. Electric energy, chemical energy, solar energy can be used as heat source and the application of electric energy is the most mature. According to the different raw materials, electric heating clothes can be divided into electric heating clothes and carbon fiber heating clothes. The latter has many advantages compared with the former, which has become the mainstream choice in the design of electric heating clothing.

2.1 Characteristics of carbon fiber heating garment
The heating body in the carbon fiber heating garment is a carbon fiber fabric with carbon content above 99% [3]. The heating area is large, the far infrared emission rate is as high as 0.95, and the thermal conversion rate can be effectively improved, and the power consumption can be reduced. The carbon fiber has a good amount of heat when working in 1.5-12V low voltage working area [4]. Therefore, compared with the traditional electric heating clothing, the carbon fiber heating garment has high safety. According to the characteristics of carbon fiber flexible heating body working under low voltage, the battery type mobile power supply can be used as the power supply of the heating clothes.

Compared with the traditional electric heating wire heating, carbon fiber heating has a rapid temperature rise. When the power is disconnected, the temperature recovery speed is fast. Therefore, the carbon fiber heating clothing has the characteristics of accurate temperature control. The utility model relates to a carbon fiber cloth which is designed and manufactured for the heating clothes of the carbon fiber heating garment. Compared with the traditional heating clothes, the heating clothes made of the utility model have better wearing comfort.
2.2 Application issues of carbon fiber heating garment
The utility model has the advantages of high heating efficiency, mobility and safety, which is characterized in that the carbon fiber flexible heating body is distributed in the heating part of the human body. The whole piece of clothing can produce a large amount of heat in the time allowed by the battery. Therefore, the utility model is especially suitable for the special operation protective clothing with cold proof requirements in cold areas, such as the outdoor service clothes of the armed police soldiers, the high-altitude mountaineering clothes, the cold storage working clothes, the submarine work clothes, etc. The heating temperature of this kind of clothing is generally about 40°C to meet the comfort of the human body.

In the theory of traditional Chinese medicine, hot compress therapy plays an important role in the treatment. It has the functions of expanding blood vessels, relaxing tendons and activating blood circulation, relaxing muscles, tendons and ligaments. The application of carbon fiber flexible heating body small local area in the clothing, generate heat in specific areas, can make the clothing with hot compress health care function. It also can improve the blood circulation of the human body, and be derived from the development of a waist, knee, shoulder and other health care apparel products. The temperature of this type of clothing should be slightly higher than the body temperature, usually around 55°C to show the effect of hot compress. Hot spots can be designed for the focus points.

3 Carbon Fiber Heating Element

3.1 Classification of carbon fiber heating elements
Heating element is the heart of the heating garment, its quality and performance is the key issue for industrialization of heating clothing. At present, most of the heating clothes are made of carbon material with far infrared heating function. According to the different forms of heating, and can be divided into linear heating and surface heating.

Line body shape is linear and the heating area is lower than the body surface heating. Its temperature distribution uniformity is not better than surface heating element, but can be made of various shapes with good strength and durability of unidirectional tensile strength. At present, the utility model is mainly made of a carbon fiber filament wrapped with an insulating layer and is made into a heating wire, and then a heating element which is made of the required parts is coiled to make the outlet heating element.

The surface of the heating body is mostly flat, and it is not suitable for the three-dimensional tailoring of the human body. Uniaxial tensile force, strength and durability are also lower than the linear heating body. According to the different production methods, can be divided into the following categories:

(1) A conductive coating is formed by mixing the superfine carbon powder and the shortcut carbon fiber powder, and then the conductive coating is coated on the plastic film or the fabric to form a carbon surface heating element.

(2) Heating element made of carbon fiber paper as surface heating body.

(3) Heating element made of carbon fiber fabric as surface heating body.

3.2 Properties of carbon fiber heating elements
No matter what kind of material is used as the heating body, the resistance value of the heating element is better than that of the heating element. That is to say, the heating element can keep the same resistance value in the whole process of the electric heating service, and provide constant heating power. In the actual production process, due to the selection of raw materials and production process of many factors often cause resistance to change, not only the heating element and ordinary heating body, subjected to thermal fatigue performance of cold, heat, cold, heat cycle test, but also bear the tension and deformation of clothing folding, pressure load under test, test of erosion and subjected to temperature and humidity changes in the use of clothing. Therefore, in the heating element, especially
the design of flexible heating elements, the various factors affecting the resistance should be fully considered to ensure the stability of the heating performance.

The uniformity of the heating temperature of the heating element refers to the heating temperature at each point in the heating area. If there is a serious difference, there may be part of the heating element burn through, and even the formation of an accident, very dangerous. The surface heating wire heating body than this phenomenon occurs, the uniformity of coating, fabric, paper thickness uniformity, yarn thickness uniformity, carbonization degree of uniformity of the heating temperature uniformity of the influence, which the connection between the electrode and the heater are areas of high incidence of accident.

Although the heating power supply are generally below 12V, electrical safety is high, but the local high temperature burn may still occur. Therefore, it is necessary to take full account of the flame retardant requirements of the heating elements in the design of heating clothing. In addition, if the hardness of the heating element is higher, the comfort of the clothing will be affected, so to improve the heating element and the comfort of the electric heating clothing for the industrialization is also very important.

4 Power Supply in Carbon Fiber Heating Garment

4.1 Battery for heating clothes
The heat generating clothing is produced by a direct current or pulse current through the heating body. In order to achieve the desired effect, the heating parts, heating area and heating power of clothing should be designed in advance. The heating power of the heating clothes can be designed after the heating area and the heating temperature are determined, and the corresponding battery is provided.

The battery performance of heating clothing should meet the following points:
(1) Discharge performance should meet the requirements of low voltage and high current requirements of electric heating clothing. The current choice is of 3-12V voltage and 1-5A current.
(2) There should be sufficient capacity to ensure that the electric heating continuously for more than 2 hours.
(3) Small size, light weight, easy to carry.
(4) Long life, can be repeated more than 100 times.
(5) The price is low, can be accepted by the user.

According to the comprehensive analysis of the above requirements, the lithium battery has the absolute advantage in many kinds of batteries. The domestic lithium battery has been able to meet the application requirements of heating clothing.

Battery life is a common problem in the localization of lithium batteries, in the mobile phone, computer, digital camera batteries exist. The number of rechargeable batteries is lower than that of imported batteries, and the discharge performance is very fast. From the perspective of industrialization, we look forward to the domestic lithium battery life to catch up with imported batteries.

For general lithium batteries, the greater the capacity is, the heavier the weight of the battery is. Therefore, as the design of the power supply, it is necessary to find a balance between the capacity and the weight, so that both can be taken into account. Based on this consideration, the proposed battery capacity is proposed to guarantee the continuous heating for 2 hours. At present, we have developed a heating element with far infrared emissivity of 0.95, which is not only helpful to improve the thermal conversion rate, reduce the energy consumption, but also extend the battery life.

4.2 Other power applications
Only when some heating clothing at a fixed place is used and the movement of the human body does not occur when wearing, can use the power adapter to convert AC to DC, which can effectively reduce the heating garment making and using cost. In addition, the combination of the use of the traditional lithium battery and solar charger in outdoor heating clothes can further solve the problem of limited endurance of electric heating clothing.
5 Design of Carbon Fiber Heating Garment

With the development of the protective clothing and the health care clothing market, the style of the hot clothes has been changing with the demands of the consumers. There has been a variety of styles, such as underwear, vest, jacket and so on. In the design of carbon fiber heating clothing style, in addition to the need to consider the conventional clothing style design of the formal beauty of the law has its special functional design focus.

5.1 Heat dissipation principle of human body and clothing surface

The function of clothing is based on the premise of the human body and clothing environment system. In general, the indoor temperature is much lower than the body temperature. Under the condition of no sweat, four of the total heat dissipation is radiated by the heat conduction, convection, radiation and evaporation. The remaining heat dissipation of the other 3% is lost with the physiological processes such as respiration and excretion. In the design of heating clothes in different environments, we should pay special attention to the three factors of human body, clothing and environment.

In the design of heating clothing, not only should pay attention to the heating element to heat conduction and radiation to the human body, but also must try to organize their own heat and the body’s own heat through convection.

The way of conduction and radiation is radiated outwards, and the part of the water vapor produced by the human body in the process of heat dissipation by means of evaporation is taken into account. The material with high moisture permeability index is adopted to maintain the comfort of the human body when wearing clothes.

5.2 The design of sandwich type heating element

Heating element is the core of heating function. In order to heat the optimal use and minimize heat loss, transfer to the human body needs parts of the heating elements in the design of clothing structure often used in sandwich type design, the heating element is arranged in the middle of the fabric and clip, forming a heating layer specific to the type of clothing. According to the influence factors of cooling, heating clothing folder should be selected to conduction, convection and radiation of the fabrics and materials. As soon as possible to the heat needed by the body parts, and the fabric should choose not to conduction, convection and radiation of the fabrics and materials, to prevent heat loss.

At present, the heating element and the circuit element of carbon fiber heating clothing is still difficult to do waterproof and washing resistant. It can be designed easily detachable folded by a heating element, circuit element, forming a set of independent components, as shown in Fig.1. The user can use, but also enhance the lasting use and reliability of clothing.

![Figure 1. Heating component of carbon fiber heating clothes](image)

5.3 Cold and warm style design

According to the application characteristics of special clothing in cold region, the design details of carbon fiber heating clothing should be in line with the principle of human body heat dissipation, and also meet the environmental and working habits. According to the principle of body heat, must by increasing the airtight design clothing in the collar, placket, cuffs and hem open clothing details, improve the tightness of clothing, keep the surface temperature.
According to the influence of weather conditions on the alpine area of special operations, combined with the influence of wind and movement of external forcing factors in convection on the human body, in the front clothing can use windproof fabrics. Combined with the characteristics of heat more concentrated on human back, breathable fabric can be chosen in the clothing back, as shown in Fig.2.

![Figure 2. Forced convection of human body for heat dissipation](image)

6 Conclusion
This paper discusses the key points of carbon fiber heating in clothing design. As the functional clothing in the process of industrialization it is still in its infancy. Although the heating element and the battery still have some problems, they have a broad market space.

References
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