The Relationship between Active Heating Power and Temperature of the Fingers in EVA Glove

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Abstract. The low temperature and low pressure in the space restrict astronauts' operation when they are wearing Extravehicular (EVA) gloves. Active heating is an effective method for maintaining temperature stability in the gloves; however, research findings in the field are scarce at present. In the study, we designed a structure of active heating in EVA glove, and explore a heating scheme for the structure. We designed a system including environment simulation device, hand simulation device as well as temperature measuring equipment to simulate the parameters of space surroundings and human hands. A electric heating structure was fixed in the limiting layer of the gloves. This structure could maintain the surface temperature of hands which was gauged by the sensors. We adjusted the heating power of heating structure, and confirmed 4 Watt was ideal. The other result is the thumb finger needs more power than middle finger.

Keywords: EVA glove, active heating, temperature of fingers.

1 Introduction

Heat loss is a very universal issue when the astronauts are in extravehicular activity (EVA). Heat loss seems to be related to the task and safety. There is an effective solution to compensate the heat loss of the human body, especially the hands, which is called active heating. In our previous studies, we focused on the effect of low temperature on work efficiency of EVA gloves. The result showed that the low temperature could significantly reduce the grip and fatigue of the hands, the number could be more than 50%. The lower the temperature was, the faster body heat lost. Therefore, design a feasible active heating scheme for EVA gloves is necessary. This technology has been applied and proved in US gloves [1], but China is still in initial stage. For different glove structure and pressure, hand heat loss rate of our gloves would be different with the United States. As a result, we should establish a new active heating scheme to study the relationship between the active heating power and the temperature of the fingers, our target is determining the reasonable choices of the power.

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2 Method

2.1 Heating Method

There were two kinds of heating: body produced heat and active heating. We used heating plates to attach on the inner wall of medical rubber hand in order to simulate human body heat production. Inside the hand was filled with heat insulation material so that the heat conduction could not to the internal. Through reference, the average heat dissipation power of human hand is about 4W [2]. We could consider the fingers and the palm skin area were roughly the same; besides heat dissipating capacity of each finger was the average. Therefore, the number is 0.4W.

Other heating plates were fixed in the back side of limiting layer of the fingers in EVA glove. There were two reasons for this design: one was the temperature of back side was lower than the inner, so the back needed more protection. The other reason was the experiment needed subjects to grip low temperature bar, this design could prevent the heating plate damage.

Heating plates had equal length as the fingers, and the rated heating capacity was 1W/cm2, the maximum operating temperature was 125 °C. Glove active heating on each finger was average so that the heating plates were easy to be controlled. Heating systems in the hand and the gloves independent of each other could be adjusted separately.

Target of active heating was to keep the surface temperature of the fingers exceeded 15.6 °C [3]. Previous studies showed that temperature on the tip of the middle finger held on 15.6 °C could be used as the minimum standard of spacesuit ergonomics design. Although human also could endure when the temperature on the tip of the middle finger lower than 10 °C, work efficiency had been a serious decline, as well as the helmet of the space suit would be fogged. Therefore, we would start active heating if the temperature of the fingers dropped to 15.6°C.

2.2 Environment Simulation

Generally, the heat transmission is realized from the following four ways: convection, conduction, radiation and sweat evaporation. In the space heat transmission is much simpler. The main heat exchange from EVA gloves to the space is radiation. We designed a vacuum tank to simulate the vacuum environment and temperature in the space. As shown in Figure 1, liquid nitrogen flowed into the tank from liquid nitrogen inlet, and vaporized into low temperature nitrogen in circulating pipeline. The low temperature nitrogen would change the environmental temperature in the tank. Residual low temperature gas flowed out from liquid nitrogen outlet. We used vacuum pump to empty the air in the tank in order to simulate the vacuum environment, the pump was connected to air outlet. There were two interfaces on the top of the tank: one connected to vacuum gauge to measure the pressure in the tank; the other one is data interface, the sensors used to test the temperature of the tank and glove transferred the data from this interface. The glove was in the tank and the pressure between inside and outside of the glove was the same; it is different from the EVA glove standard pressure (39.6KPa) because the pressure is not the target of the study, and this design was safer.

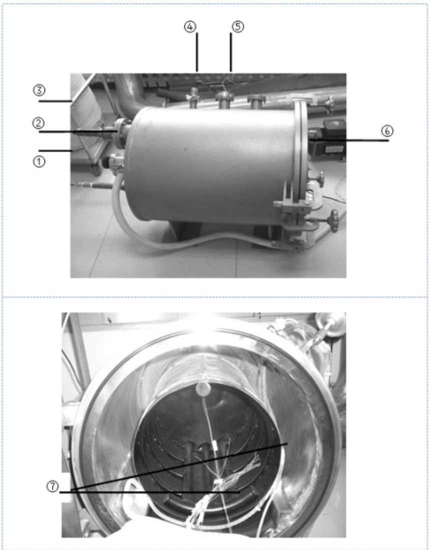

Fig. 1. Vacuum tank (Where, 1 Liquid nitrogen inlet; 2 Air outlet; 3 Liquid nitrogen outlet;4 Interface for vacuum gauge; 5 Data interface; 6 Door; 7 Circulating pipeline)

2.3 Measurement

Two kinds of data were needed to measure in the study. One class was used to adjust the experiment parameters, such as temperature and pressure in the tank, as well as the heating plate temperature. Another kind was used for data analysis, such as hand skin temperature. Pressure was measured by vacuum gauge, temperature data was acquainted by sensors of real-time monitoring. Based on data acquisition channels restriction, we only selected 15 representative temperature measuring points.

Although each finger had one heating plate, the heating power is basically the same because the resistances were connected in parallel. Therefore, we could estimate each heating plate temperature by measuring only one of the heating plates. According to the pre-experimental results, we selected middle finger. The measurement points should be hung in the test tank in order to ensure the data was the environmental temperature, not the temperature of tank surface.

2.4 Procedures

The experiment has three main goals:

1. Find a pressure suitable for the formal test;
2. Simulate a vacuum environment, and observed temperature of fingers dropping without active heating.
3. Ensure an active heating scheme, and gives its heating effect.

At the beginning of the experiment, giving the fingers active heating power was 2W in a specified pressure. If the temperature of the finger was more than 15.6 °C when the inner surface temperature of middle finger was stable, The experiment only stopped in two cases: temperature was above 15.6 °C or the power reached to 4.5W.

The part two was the finger temperature measurement experiment without active heating. The EVA glove was put into the tank and fitted to the grip bar before the test. We could record the stable temperature data when the experiment was performed 1-1.5 hours.

The third part tested gloves active heating scheme, we focus on two fingers: middle finger and thumb. The experimental conditions t was the same as part two, active heating power were 2W, 3W, 4W.

3 Results

3.1 Experiment 1

As shown in Figure 2, under different pressure conditions(the environmental temperature is -130 °C), EVA gloves is supplied the active heating in order to keep the finger temperature higher than 15.6 °C.

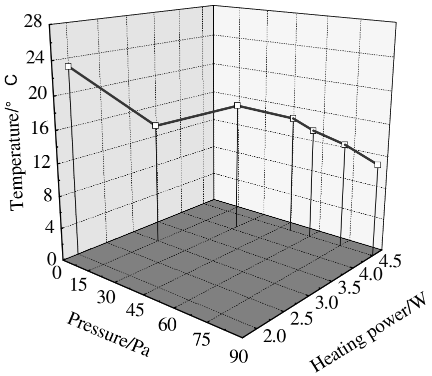

Fig. 2. Finger temperature under different pressure (active heating)

3.2 Experiment 2

As shown in Figure 3, environmental pressure drops to 0.1Pa, each layer temperature of middle finger has different temperature curve. It is shown that the environmental temperature drops to -120 degree 50 minutes later. Because of the heat insulation ability of EVA gloves, hand surface temperature is maintained at 20°C. With the extension of time, hand temperature is declining. After about 75 minutes, the temperature lower than 15.6 °C. The result is thermal protection of EVA gloves may not enough to sustain the normal manual operation (5-8 hours) in space, Active heating is necessary.

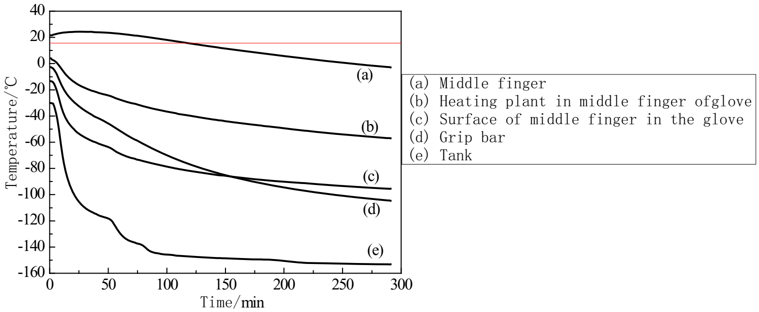

Fig. 3. Each layer temperature of middle finger under low environmental temperature (0.1 Pa)

3.3 Experiment 3

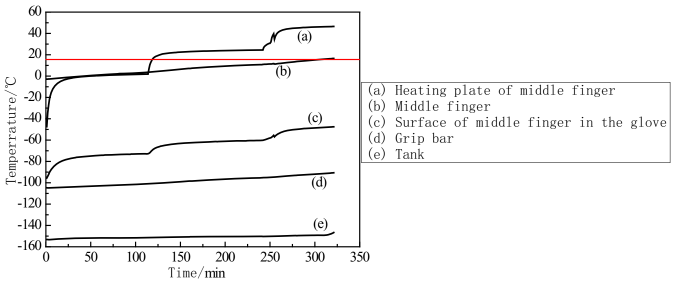

Fig. 4. Middle finger temperature in active heating (0.1Pa,-150°C)

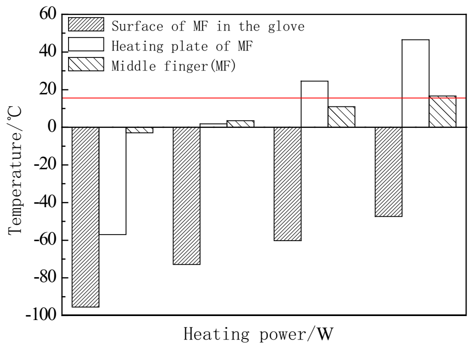

Fig. 5. Comparison of middle finger temperature in different heating power (0.1Pa, -150°C)

1. Figure 4 and 5 can be shown that the middle finger temperature reach to 15.6 degrees only when the heating power is 4W, although the temperature rise with the increase of heating power. The power of heat is higher than optimum value (2.5W) because the heating is average. This result is consistent with theoretical calculation [2].

2. Thumb: From figure 6 and figure 7 it can be concluded that when the active heating power is 4W, thumb temperature can reach to 15.6 degrees. It can meet the basic requirements of active heating. But compared with the middle finger, thumb temperature is slightly lower.

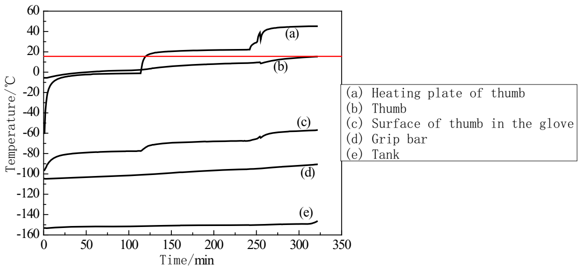

Fig. 6. Thumb temperature in active heating (0.1Pa,-150°C)

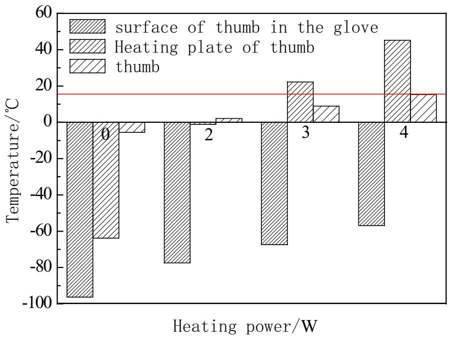

Fig. 7. Comparison of thumb temperature in different heating power (0.1Pa, -150°C)

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