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TESTING OF THE AIR CHAMBER FOR INTELLIGENT CLOTHING ON HOTPLATE

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Abstract *Air is a very good insulator. Thermal insulation properties of garment can be achieved by inflating air into the chamber for intelligent garment. Thermal properties of the chamber change depending on the amount of air in the thermal insulation chamber (air pressure), In order to investigate the thermal properties of the chamber on the hotplate, new frames were made. These frames allow the achievement of the steady-state conditions of the hotplate that could not be achieved by plastic frames.*

Key words**:** *intelligent clothing, thermal insulation chamber, hotplate, frames*

1. INTRODUCTION

The primary function of clothing is to protect from climate and working influences such as cold, heat, rain, dust, wind, injuries at work, etc. As the degree of protection created by clothing increases, the degree of comfort, which occurs during wearing, mostly decreases. One of the discomforts created by the clothing is heat stress. The human body gets heat by exposure to the surrounding conditions and the metabolic system. It loses heat through conductive, convective and radiation exchange between heat and environment and by evaporation of sweat (McCullough, 2005). Normal body temperature is around 37^{o}C. This value is achieved by balancing the amount of heat produced in the body with the amount of loss. Clothing acts as a barrier to thermal and moist transport between the skin and the environment. This barrier is created along with the textile material and the air they surround and the calm air, which is a border on its outer surface (Havenith, 1999). Any heat generated by human activity that cannot dissipate because of wearing protective clothing is stored in the body, and as a consequence thereof, body temperature rises. When body temperature rises above 40°C, mechanism that normally controls the body temperature at 37°C stops working, with possible deadly consequences (Crockford, 1999).

Air gap between clothing and human body is the main factor affecting the efficiency of clothes. Many experiments were performed to analyze the properties of materials, clothing and air layers between clothing and human body (Song, 2007; Yoo et al., 2000; Chen et al., 2004). These investigations include the development of various instruments and mannequin evaluation.

At the Department of Clothing Technology of the Faculty of Textile Technology the prototype of an intelligent article of clothing (jacket) with active thermal protection was made. Various sensors, control units and actuators were integrated into the intelligent jacket. Each chamber has pressure sensors, and temperature sensors are also integrated into the jacket. They measure temperature and ambient temperature between body and garment (First Rogale et al., 2007).

The chambers are made of polyurethane films and joined by ultrasonic welding. Air pressure in the chamber changed, and thus the chamber height changed too. This paper deals with the problems detected in testing the thermal properties of the thermal-insulation chambers on the hotplate and how they have been solved.

2. METHODOLOGY

Measurement samples are made of polyurethane film (PU) developed by Epurex Films GmbH with a mass per unit area of 232 g/m^2. Film thickness is 0.252 mm when loaded by F_k = 0.49 cN/cm^2. The breaking force of the film is 446.6 N, and the breaking elongation is 668.52% (Cubric et al., 2009). The samples were welded on the Pfaff Seamsonic 8310-003 ultrasonic welding machine, Figure 1a. The samples were welded with the same type of the anvil wheel, Figure 1b. The distance between the sonotrode and the anvil wheel was 0.28 mm, while the welding energy was 285 W and the welding speed was 30 m/min.

The measurement samples were tested on the sweating guarded hotplate apparatus (hotplate) developed by Measurement Technology Northwest, USA, Figure 2. The apparatus consists of heater, air gap with variable fan speed, sensors for temperature and relative ambient humidity and airflow speed, control system and chamber for ambient conditions. The heating area consists of three separate heating zones. There is an active thermal zone (test plate) and two zones of thermal guards (ring and lower) with their sensors. The central test plate is enclosed with protective ring and lower guard so that the test can be performed without lateral heat loss. All zones are separately controlled for the same set temperature so that all heating energy fed to the test plate passes through the test sample as one-dimensional heat flow (***, 2006).

a) b)

Fig. 1. Ultrasonic welding equipment, a) Seamsonic 8310-003, b) Anvil wheel

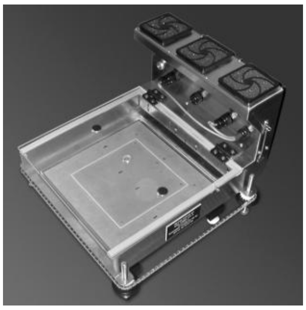

Fig. 2. Hotplate

Thermal resistance in dry measurement is determined according to the formula:

$$R_{ct} = \frac{(T_s - T_a)}{Q/A}$$

Where:

Q/A – heat flow zone (W/m^2)
T_s – hotplate surface temperature (^{0}C)
T_a – ambient temperature (^{0}C)
R_{ct} – thermal resistance in dry measurement (m^2 ^{0}C/W)

The hotplate is located in the climate-controlled chamber where standard conditions were maintained in accordance with the standard ISO 11092:1993. In accordance with the mentioned standard air temperature was 20°C and air humidity was 65% (***, 1993).

3. PROBLEMS AND NEW FRAMES

Preliminary measurement samples were placed in plastic frames with irregular circular shape (Figure 3) and as such put on the hotplate. These frames were taken from the other apparatus and did not correspond to the dimensions of the hotplate. However, we wanted to see if this frame could be used on the hotplate to test the thermal insulation air-inflated chambers.

Preliminary measurements on the hotplate indicated some deficiencies. Plastic frames were inadequate. They allowed the air flow between the chamber and the hotplate and were not able to achieve steady-state conditions of the hotplate, and therefore the measurements could not be achieved. Therefore, new frames were constructed. Two frames were made - outer and inner ones, Figures 4 and 5. The outer frame prevents airflow under the sample. To achieve additional air-tightness, rubber was fastened to the bottom of the outer frame.

The inner frame has such dimensions that the sample fixed by it is not smaller than the dimensions of the hotplate performing measurements. By inflating air into the thermal-insulation chamber, the sample inflates and lifts the inner frame. Since the inner frame is placed into the outer frame, no air flows between the chamber and the hot plate during lifting the inner frame. These new frames proved to be adequate during test measurements on the hotplate, and steady-state conditions could be achieved. Figure 6 shows the frames in which there is a sample. The certain amount of the air is in the sample of chamber.

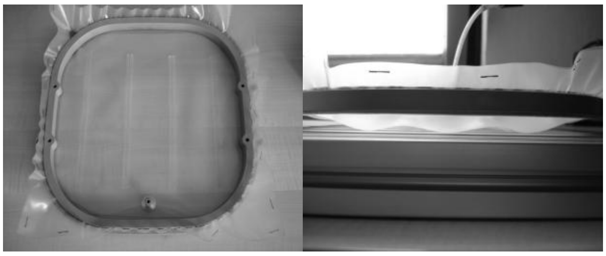
Fig. 3. Plastic frames with a sample

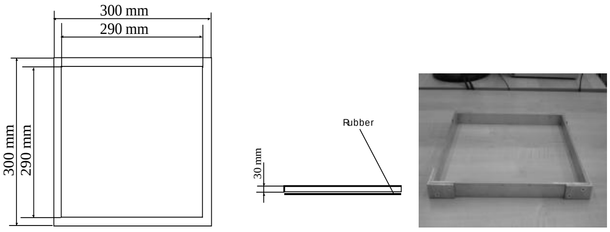

Fig. 4. Outer frame

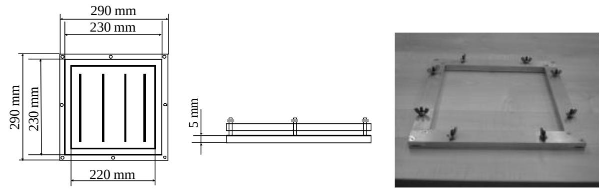

Fig. 5. Inner frame


Fig. 6. Frames with an air-inflated sample

4. CONCLUSION

In the initial testing of thermal insulation chambers on the hotplate using plastic frames no testing conditions could be established. Creating new frames, which are adapted to the hotplate, establishes steady-state conditions for the hotplate, and measurements can be performed. Test results of the thermal insulation chambers in standard conditions at a different pressure in the chambers will be presented in subsequent papers.

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