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Research Article

SMTEX - Measurement System of Heat Transport and Steam in Textiles

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Abstract

This work demonstrates the development and construction of a system composed of various devices dedicated to measurement and control of temperature and humidity able to simulate the human body's behavior regarding its latent heat, sweating, influence on exposure to wind and cold controlled. The system also comprises of mobile sensors able to measure the temperature and humidity between tissue layers disposed on the main assembly, simulating the formation of microclimate between the skin and worn textile article. The structure built at the end of the work has modular and optional interconnection with external datalog systems, expanding the future research and development.

Keywords

Moisture transport; Thermal insulation; Comfort; Simulation

History

The thermal studies and their effects on the body as well as influence in everyday life is scientifically documented since 1894 when it was founded by the American Society of Heating and Ventilating Engineers (ASHVE), which brought together professionals linked to the development of heating and cooling equipment. Later the association merged with other similar and consolidated in 1959, as the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) keeping research and developing specific standards in environments of temperature control area.

A little further into the past, several sources mention that studies using dummies and temperature comparisons were started by Otto von Guericke around 1620 in Germany [1], but not included in their key findings and studies that had focused on meteorology and physics pressures (Figure 1).

Modern research involving thermal insulation was developed during and after World War II, when he was a dire need to maintain the man exposed to the atmosphere of different places and for long periods [2]. This focus of research large American and European military laboratories have developed various methods and started specific search areas for this purpose.

There are researchers who focused exclusively to the study of

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behavior of garments in relation to the human body, many located in Asia, Germany, Portugal and USA.

The development of thermal mannequins with controllable functions and new sensors capable of measuring the transport of gases, vapors and water allow technological advances directly linked to the preparation and manufacture of high-performance textiles (Figure 2).

Justification

Previous studies of Gibson [3], had already demonstrated the difficulty in measuring the vapor transfer in textiles. Among the observed behavior, it was noted that the molecular forces, and gas could no longer influence viscosity and the membranes being omitted by the inertial force and the relationship between pressure and movement porosity [4].

The decentralized developing technology for measuring transfer heat and insulation placed in the current market equipment and standards that do not use similar parameters to the use of clothing.

Many laboratory equipments perform only one level of comparison that is isolated temperature, humidity, vapor or porosity. Thus, it is not possible to measure the desired behavior directly influenced by the interactions between each existing property.

The development and construction of thermal mannequins or acquisition is very expensive as well as fixing some study variables and the equipment isolated [5]. In this scenario, the development of a multipurpose device system tends to be a great opportunity to study and future research.

Methodology

This work was divided into two parts, the first, in the survey of the main generalities of use of textiles, critical points that influence the human body as the isolation and transport of steam and moisture. The human body behavior, their temperatures and disposal of liquid for parameterization of the equipment components were also studied.

The second part was the research of components available in the market and the study of catalogs in search of the best options sensors, gauges and indicators for system instrumentation.

In the latter part, drawings for machining specific parts and assembly of the devices were defined. After mounting operation, tests were conducted and configuration was displayed.

Development

Module 1 - **Heating sweating and discounts:** This module is responsible for heat control of main body through direct adjustment of power supplied to the resistance involving the body, help this control is received direct measurement of the internal temperature by thermocouple and on the console which also has digital control desired temperature and limit temperatures option (Figure 3).

The control of perspiration has two operating modes: automatic mode and intermittent mode operates through the selected key on the panel. The automatic mode drives the peristaltic pump to work at the speed set, as the panel transfers the water contained in the external reservoir to the interior of the central body. The intermittent

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drive conducted by activating the button panel, which allows only the pulses at the pump by sending small amounts of water being used for replacement or small corrections (Figure 4).

The water level inside the main body obtained was by measuring direct pressure to the bottom of the inner container. This measurement is relatively, the external pressure no to pressurize the line and accidentally break the internal diaphragm sensor. This was the part of operation that was been handled with utmost care. The sensor reading transmitted to universal indicator, having the conversion of internal configuration required for displaying the corresponding internal volume in ml (Figure 5).

Module 2-Temperature sensors and relative humidity: This module has two identical sets of temperature and humidity sensors configured relatively to operate with indication °C and RH% yield prepared using probes that can be movably inserted in different positions and heights of the simulated skin sample and the environment or wind tunnel (Figure 6). There is concern about the saturation of the sensors with water, but the same have regeneration procedure that returns the initial readability (Figure 7).

Module 3 – Wind speed and environment: The last module controls the fan (Figure 8) used in the wind tunnel and direct the reading of your speed, assist in the monitoring temperature probe and



Figure 1: Mannequins 1935-1950.



Figure 2: Modern mannequin.



Figure 3: Module 1.



Figure 4: Main body heater.



Figure 5: External reservatory.



Figure 6: Module 2.



humidity equal to those used in module two, receives the indication characteristics of the ambient air that passed through the system (Figure 9).

Possibilities tests

The equipment allows the direct simulation of heat emitted by human body. With different basal heat body temperature ranging from $36.5 \,^{\circ}$ C, to complete physical activity even at $39.0 \,^{\circ}$ C, it is possible to measure the temperature of the probes and the relative humidity between the skin and the textile article, and the second probe the seasons and relative humidity outside the textile item (Figure 10).

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In different configurations can accomplish the main tests:

1. Body / microclimate / Textiles / Environment (EXAMPLE)

2. Body / microclimate / Textiles / microclimate / Textiles

3. Body / Textiles / microclimate / Textiles / Environment

4. Body / Textiles / microclimate / Textiles / microclimate / Textiles

With the help of third probe and simulation of wind incident on the article, we can make other settings:

1. Body / microclimate / Textiles / ventilated Environment

2. Body / microclimate / Textiles / microclimate / Textiles / ventilated Environment

3. Body / Textiles / microclimate / Textiles / ventilated Environment

4. Body / Textiles / microclimate / Textiles / microclimate / Textiles / ventilated Environment

Within these main settings, the loss of liquid by the main body as well as changed the height difference between the simulated layers can be measured (Table 1).

You can perform the liquid replacement externally forcing the steam crossing and moistening the sample similar to the body sweat.

Final Result

The equipment comprises a base support plate (1), a support with three racks indicators of sensors and controls (2), a main body heat and steam generation simulating the human body (3), a reservoir 100 ml for fluid replacement and sweat simulation (4), holders for storage of accessories (Figure 11 and Table 2).

Conclusion

The proposed objectives have been achieved by providing new equipment, unprecedented capable of performing various







Figure 9: Wind unit.



Figure 10: Microclimate.

Table 1: Thermal sensation scale.

Bedford comfort scale		ASHRAE sensation scale	
Much too warm	7	Hot	7
Too Warm	6	Warm	6
Comfortably warm	5	Slightly warm	5
Comfortable	4	Neutral	4
Comfortably cool	3	Slightly cool	3
Too cool	2	Cool	2
Much too cool	1	Cold	1



Figure 11: Complete equipment.

Table 2: Equipment specifications.

Description	Value	
Internal capacity of the central body	500,0 ml	
Capacity of the outer shell	100,0 ml	
Maximum temperature of the central body	90,0 °C	
Probe temperature measurement range	0,0 a 99,0 °C	
Moisture measurement range of the probe	0,0 à 99,0 %UR	
Maximum wind speed	3,9 m/s	
Minimum wind speed	1,0 m/s	
Maximum arterial runoff pump	1,0 ml/s	
Minimum arterial runoff pump	0,3 ml/s	

comparative tests in a controlled manner and allowing the opening of new themes studies to be developed with their use.

It will take initial tests for training its correct use and calibration as well as parameterization of the behavior observed for the most common products in the market (Figure 12).

The equipment was designed in such a way to have easy maintenance of spare parts and to increase its durability.

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