Research and Developing Trend of Porous Textile's Dynamic Heat-moisture Measuring Instrument

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Abstract

This article delves into the importance of coupling heat and moisture for clothing heat and moisture comfort, summed up the common test principle of porous textile's dynamic heat-moisture measuring instrument, and reviews the recent progress of it. Combination of the above analysis, the paper puts forward views that the porous textile's dynamic heat-moisture measuring instrument should be further researched from the extreme environmental conditions, different air layer thickness, heat and humidity parameters quantization and multi-layer fabric of coupled heat and moisture transfer, focus on the combination of theory of heat and mass transfer in porous media and fabric characteristics, to make the process of simulation of heat and moisture of porous fabric perfectly.

Keywords: Porous fabric; heat and moisture transfer; simulation; microclimate

1. Introduction

Clothing comfort is increasingly becoming major characteristics of modern consumer demand, with the improvement of living standards, clothing comfort requirements are also increasing. Microclimate composed of them affected by human metabolism, fabric performance, environmental conditions, is one of the focus in the study of clothing. Fabric is formed by the fibers, fibers have pores, is a typical of the porous medium. In the process of heat-moisture transfer, heat and humidity changes affect the fabric of the fabric parameters, fabric parameter changes, in turn, affect the ability of the fabric heat and moisture transfer, when the fabric store excess moisture, heat will affect its performance, heat and moisture transfer properties of the fabric of mutual influence which is a coupling process, heat and moisture transfer of combined effect of human body sections under clothing comfort. Porous fabric heat-moisture tester is an important tool for measuring thermal resistance and moisture resistance of fabrics.

The studies of heat and moisture comfort of textiles performance have decades of history, scholars at home and abroad have done a lot in experiment method, test equipment, and so on. In1941, A.P.Gagge, who first proposed the concept of clo, it is the clothing insulation index used to describe the body's physiological and psychological indicators, and environmental temperature and humidity [1]. In 1962, A.H.Woodcock, proposed permeability index of clothing I_m, us to describes the garment breathable performance evaluation index[2].These two indicators proposed for the formation and development of thermal and moisture comfort clothing laid the foundation for the field[3].In this paper, porous fabric heat moisture tester for the object, analysis of thermal resistance and moisture resistance testing principles, review recent studies of porous fabric heat-moisture measuring instrument, and summarizes the development trend of it.

2. The Testing Principle of Heat-Moisture Measuring Instrument

2.1 Measuring Principle of Thermal Resistance

Temperature difference on both sides of the specimen divided by the vertical heat flow per unit area through the sample is the thermal resistance, this is similar to the current through the resistance of the conductor [3], the greater the resistance on behalf of the fabric warm and good.

Compared with the thermal conductivity, the thermal resistance of the fabric thickness measurements affected by the surrounding environment is relatively small, and the fabric's thermal resistance can be calculated by heat dissipation of the thermal environment.

There are many measurement standards for thermal resistance: GB/T18398-2001, GB/T24254-2009, 15015831,ASTMF1291 and so on. GB/T11048-2008 is the first test method standards in terms of comfort of textiles, it provides a method for measuring thermal resistance and moisture resistance under steady-state conditions, in the heat exchange process of simulated body - clothes – environment, thermal resistance is when the textiles is in a stable temperature, the dry heat flow the provisions of the area. Its equation is:

$$R_{ct} = \frac{(T_m - T_a)\cdot A}{H - \Delta H_c} - R_{cto} \qquad (1)$$

Where R_{ct} is the thermal resistance (m^2•K/W),T_m is the Test plate's temperature (□) ， T_a is the air temperature in the climate chamber (℃), H is the heating power available to the test panels (W), △H_c is the process of thermal resistance determination the correction of the heating power (W), R_{ct0} is the instrument constant in order to determine the thermal resistance measurement (m^2•K/W).

2.1 Measuring Principle of Moisture Resistance

Vapor pressure difference on both sides of the sample divided by the vertical evaporative heat flow per unit area through the sample is the moisture resistance, it is the fabric on the resistance of water vapor transmission [5].Moisture resistance represent the ability to prevent water vapor permeability of the fabrics, if it is big, the fabric is not easy to let the water vapor permeability, the fabric used in clothing will not help perspiration humidity; on the contrary, water vapor through the fabric easily, Is conducive to the discharge of water vapor.

When the moisture resistance is measured，need to cover on the electric heating test a membrane which can let the gas through but not let the water, make the water in the form of water vapor evaporated though the membrane, and there is no liquid water contact with the sample, determination of the heat required to keep test plates heated flow under certain water evaporation rate, and the water vapour pressure through the sample. Its equation is:

$$R_{et} = \frac{(P_m - P_a)\cdot A}{H - \Delta H_e} - R_{et0} \qquad (2)$$

Where R_{et} is the moisture resistance (m^2•Pa/W)，P_m is the saturation vapor pressure when the surface temperature of the test plate as T_m (Pa), P_a is the vapor pressure when the temperature in the climate chamber as T_a(Pa), H is the heating power supplied to the test panel (W), △H_e is the process of moisture resistance determination the correction of the heating power (W),R_{et0} is the instrument constant in order to determine the moisture resistance measurement (m^2•Pa/W).

3. Development Process of Porous Textile's Dynamic Heat-Moisture Measuring Instrument

3.1 Development History of Porous Textile's Dynamic Heat-Moisture Measuring Instrument

Porous textile's dynamic heat-moisture measuring instruments can simulation of human physiological parameters and measuring the performance of the fabric's heat and moisture. Yoo HS [6] developed a simulated skin model with the vertical hot plate can sweet, as shown in Figure 1, by steam, it can be closer to the actual wear. By measuring the change in water vapor pressure in the system of clothing, research the effect of fibers type, air layer thickness and clothing opening on clothing micro-climate.

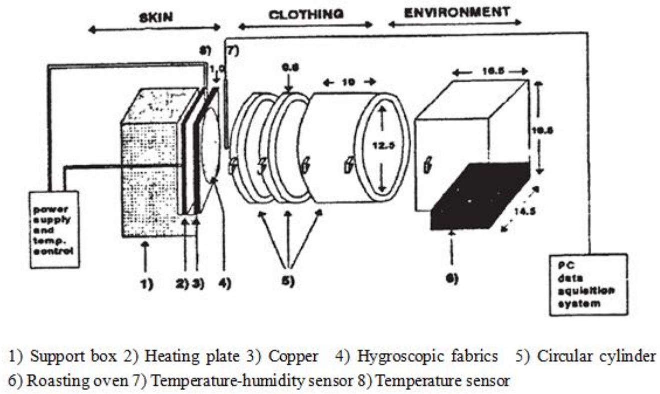

Figure 1: Yoo HS Test Device

In 1982, Harada Takashi [7] researched a climate installation in clothes which can simultaneous measurement of temperature and humidity, it can simulation without evaporation of water vapor and droplets flu -like sweat. This device simulation of wearing multiple layers of clothing and human activity status, at the same time it can measuring the change of temperature and humidity inside the clothes.

Mu Yao, Meiwu Shi [8] developed a fabric microclimate instrument, this instrument used a high sensitivity of the test element, it can test the heat and moisture status when the fabrics are multilayer, distance between the fabrics can be adjusted, level between the fabrics can be changed, used the PC-XT computer to acquisition and process the data, This instrument was more compact.

Xiaohong Zhou[9] developed a fabric heat-moisture transfer characteristics under the low-temperature environment, she used the semiconductor refrigeration device to simulate the low temperature environment, and use sensing technology and computer measurement techniques, continuous dynamic multi-channel temperature and humidity data acquisition.

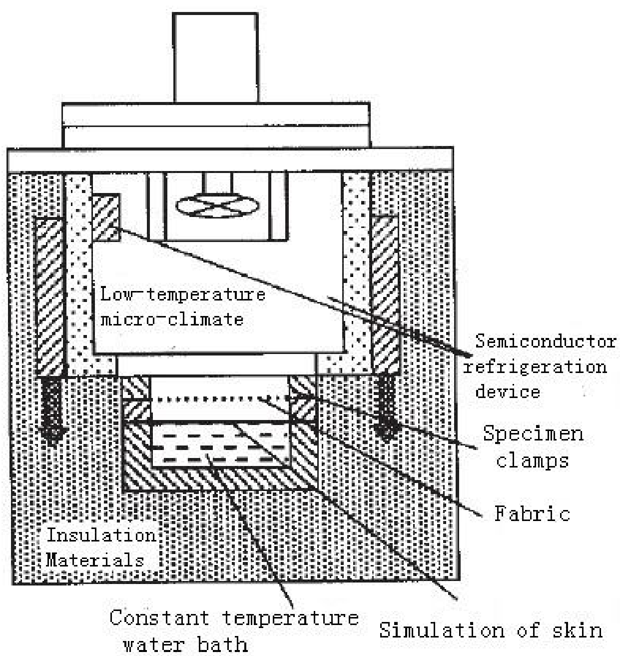

Figure 2: Fabric Microclimate Instrument in Low Temperature Environment

Jintu Fan [10] simulated human sweat in low temperature environment, in the clothing systems, there are several moisture transfer mechanisms, such as moisture absorption and condense, liquid water conduction. Test fabric constituted by three layers, the middle fabric composed of a porous material permeable, upper and lower fabrics covered by the thin layers, retaining shelf temperature is maintained at -20 □,so that the upper and lower fabrics are in a low temperature environment.

Ling Li [11] developed a test device which can simulate skin sweating in different temperature and pressure, achieved a simultaneous measurement and recording-- the ambient temperature, relative humidity and the output power, and used SPSS software to establish a curve regression model of different skin.

Xiuqing Wang [12] explored the single wizard perspiration's thermal comfort in latent sweat conditions, used the heat and moisture physical parameters of the textile to do comparison tests, get a lot of data, such as the samples total heat transfer, microclimate, dry bulb and wet bulb temperature in the environment, simulated skin temperature and so on, established a mathematical Model that the fabric under conditions of heat and moisture transfer latent Khan. Figure 3is schematic diagram of heart and moisture properties parameter tester

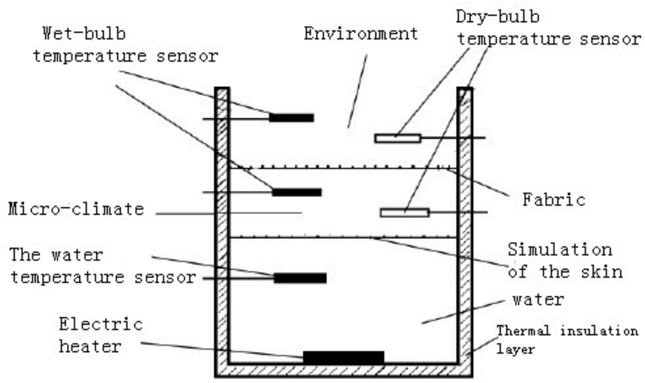

Figure 3: Schematic Diagram of Heart and Moisture Properties Parameter Tester

Danyang Xu [13] combined thermal resistance theory with moisture resistance theory, established a reasonable mathematical model. In terms of thermal resistance, did a research follow symmetric plane table test fabrics' thermal resistance, compared with YG606E fabric thermal resistance measuring instrument and sweating flat instrument. In terms of moisture resistance, designed a new method for measuring moisture resistance of the fabric, compared the results with sweating flat instrument.

3.2 Research Status of Porous Textile's Dynamic Heat-Moisture Measuring Instrument

In terms of the thermal resistance measurements in the fabric, traditional hot plate has a lot of systematic errors because of the thermal structures design, Yisong Chen [14] according to the new algorithm designed a non-symmetry hot plate, compared to conventional hot plate , he used a thick foam board which thermal resistance is Known attached to the measuring hot plate and the lower surface of the film of the thermal shield, structure is more simplified, reduce energy consumption by 50%, while eliminating the uncertainty of systematic errors, standard does not require calibration.

In terms of the moisture resistance measurements in the fabric, traditional hot-moisture plate Cannot let the evaporation through the fabric be measured directly and effectively, only indirectly measure the power by vaporization of sweat, in the same time , the fabric and sweating film are in direct contact, liquid invasive fabrics more or less, will influence the accuracy of measurement. Yisong Chen [15] invented a dampness microclimate measuring instrument which is not contact with the sweating skin directly, it can measure the water evaporation through fabric directly, and then measure the temperature, relative humidity, ambient temperature and relative humidity of the lower surface of the fabric, pure moisture resistance can be measured by dampness formula.

In the world there have been several sweating heated manikin, however does not appear heat-moisture comfort evaluation by thermal manikin, Yisong Chen [16] developed a simulated head which can measuring the hat's thermal resistance and moisture resistance, this simulated head used passive sweat simulation principle, it includes 25 sweat pores, the sweat of each pore controlled by separate valve, when it under constant temperature and humidity environment, we can use it test thermal resistance and moisture resistance of hat, while evaluated the head's heat-moisture comfort in various environment .

4. Trends Forecast

4.1 Extreme Environmental Conditions

In nature, high temperature and low temperature environment are unavoidable, clothing, as the body's protective layer, it must make people comfortable while protect the body, it is necessary to research the porous fabric's dynamic heat-moisture in extreme environments.

4.2 Different Thickness of the Air Layer

For meet the physical and dress effect purpose, Clothing requires a amount of loose, air layer between the fabric and the body is a important part of the micro- climate, because of the fabric 's own gravity, the thickness of the air layer between the fabric and the hot plate is difficult to achieve uniform, which is a simulation test questions need to be improved.

4.3 Heat and Humidity Parameters Quantization

Under certain environmental conditions, the basic parameters of the fabric heat and moisture changes with temperature and humidity, such as water vapor changes in the fabric will affect the physical properties of the fabric, various changes occurring within the fabric will change the process of the heat and moisture transfer of fabric, at the same time, multiphase porous fibrous material cause the internal structure of natural convection and water evaporation easily, will affect the accuracy of test results .

4.4 Multi-Layer Fabric of Coupled Heat-Moisture Transfer

In our daily life, in most cases people wearing multi-layered fabrics, so it is very important to Study on the multi-layer fabric of coupled heat-moisture transfer. There is insufficient in multi-layer clothing deficiencies' research, the research on heating refrigeration is less, less in terms of thermal radiation, heat convection[17].In the actual state of dress, there are also exist air layer between the multilayer fabric, This Situation is the porous textile's dynamic heat-moisture measuring instrument cannot meet today.

5. Conclusion

The research of porous textile's dynamic heat-moisture measuring instrument experienced a long period of time, from the initial simple simulation to the present simulation technology applications make a great progress. Porous fabric heat-moisture tests need heat and mass transfer in porous media theory, through reasonable adjustments applied to the coupling of thermal wet fabric. To analyze and improve the reason of the measured error values generated, and increase the integrity of the simulation process and simulation, in order to more accurately in the actual analysis and measurement.

References

Shi MW. a discussion on the value of clo[J].journal of china textile university.1995,21(1):7-11

Zhou HX. research trends in clothing moisture permeability [J]. Silk. 1986,(4)：40-43

Zhang JC. Principle of Waterproof and Moisture Permeable Fabric & Laminated Fabric Production Technology [M]. Beijing: China Textile & Apparel Press.2003

Industry standard of PRC. Textiles--Physiological effects--Measurement of thermal and wate-vapour resistance under steady-state conditions [S]. GB/T11048-2008

Huang JH. Clothing Comfort [M]. Beijing: Science Press.2008

Yoo HS, Hu YS, Kim EA. Effects of heat and moisture transport in fabrics and garments determined with a vertical plate sweating skin model [J]. Textile Research Journal, 2000, 70(6): 542-549.

Takashi Harada. Clothes inside climate with clothes [J]. Foreign textile technology , 1987 (4): 35-46.

Yao M, Shi MW, Zhang YX. Developing the fabric microclimate instrument type Ⅱ [J]. Textile Standards and Quality, 1991 (6):30-32

Zhou XH. A Study on Heat and Water Vapor Transfer through Waterproof Breathable Fabrics with Micro-pore Membrane under Subzero Climate [D].Shanghai: Donghua University, 2004.

Fan JT, Cheng XY, Heat and Moisture Transfer with Sorption and Phase Change Through Clothing Assemblies ， Part I [J].Textile Research Journal ,2005(75):99-105

Li L. Research on the perspiring performance of simulative skin [D].Shanghai: Donghua University, 2006.

Wang XQ, Zhang C, Gao M. Thermal comfort of single-direction-sweat-transmitting fabric [J]. Journal of Textile Research, 2010, 31(10):40-44

Xu DY. Research of fabric’s thermal resistance and moisture resistance measurement method [D].Shanghai: Donghua University,2011.

Chen YS, Zhan Z. An asymmetric hot plate [P].China, Patent No.103529073 A, 2013.

Chen YS, Cai HZ. A microclimate instrument use the method for measuring the moisture resistance of the fabric [P].China, Patent No. 103134914 A, 2013.

Chen YS, Xu J. A method for measure the hat’s thermal resistance and moisture resistance [P].China, Patent No. 103076272 A, 2013.

Kong FH. Coupled transfer of heat and masks at interface multilayer porous media [J]. Acta Energiae Solaris Sinica, 2010, 31(10): 1281-1286.