Multilevel Approach to Evaluating the Comfort of Functional Clothing

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Abstract: Research has demonstrated that sensorial clothing comfort is a complex function of material properties, garment design, as well as conditions of use. This paper discusses a modern holistic approach to clothing comfort assessment that is based on a multilevel concept, advancing from the investigation of fabric properties to, ultimately, analysis of complete garment systems in controlled wear trials. It describes the value of the measurements made by advanced instrumented measurement systems when used as part of comprehensive research program designed to explain human response to the wear comfort of functional clothing and materials.

Keywords: clothing comfort, instrumented measures of clothing comfort, heat and moisture transport in fabrics, subjective evaluation of clothing comfort.

1. Introduction

Scientific approaches to evaluating the comfort of clothing recognize that human perception of the comfort of clothing is a function of the physical properties of materials and clothing variables, interpreted within the context of human physiological and psychological response. It is determined, not only by material properties, but by ensemble fit and design as well as the specific variables related to use activity and environmental conditions. The most useful approaches to comfort evaluation, therefore, have applied multilevel evaluations designed, not only to predict human comfort response from objectives measures, but to provide a sound technical basis for associating particular factors of materials properties and garment design to human response to clothing wear. This approach has the added benefit of enabling principles of materials and clothing design to be applied to optimize the comfort performance of functional apparel.

2. Objective Measures of Clothing Comfort Performance

Clothing comfort has two main aspects that combine to create a subjective perception of satisfactory comfort performance. These are thermophysiological and sensorial comfort. The first relates to the way clothing dissipates metabolic heat and moisture. The second relates to the interaction of the clothing with the senses of the wearer, particularly with the tactile response of the skin.

2.1 Measuring Thermophylogical Comfort

Thermophysiological comfort has two distinct phases. During normal wear, insensible perspiration is continuously generated by the body. Heat and moisture vapor must be dissipated to maintain thermoregulation and a feeling of thermal comfort. The clothing becomes a part of the steady state thermoregulatory system. In transient wear conditions, characterized by intermittent pulses of moderate or heavy sweating caused by strenuous activity or climatic conditions, sensible perspiration and liquid sweat must be rapidly managed by the clothing in order to maintain comfortable conditions of wear.

Steady state heat and moisture transfer, key parameters in clothing comfort, can be measured using sweating guarded hot plates, or skin models. Our research uses a model developed by Woo and Barker [1] to calculate a comfort range in terms of

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heat generated. The formula for determining the upper and lower limits is

$$\text{Min} = (6.46/I)\,(T_s\text{-}T_a) < \text{Mn} < (6.46/I)\,[(T_s\text{-}T_a) + 3.3\, i_m(P_s\text{-}P_a)] = \text{Comf} \quad (1)$$

$$\text{Max} = (6.46/I)\,[(T_s\text{-}T_a) + 16.5\, i_m\,(P_s\text{-}P_a)] \quad (2)$$

This generalized equation derives from Woodcock's equation for energy dissipation from the body into an ambient environment. It assumes that the thermal comfort zone can be extended by evaporative heat transfer in addition to dry heat transfer. The model contains three groups of functional parameters: those that are a function of fabric type (I, i_m), those that are a function of environment (T_a, P_a, air velocity), and a parameter that is a function of amount of metabolic heat generated (Mn).

Application of this thermophysiological comfort model is discussed in studies conducted at NCSU [2].

2.2 Measuring Sensorial Comfort

Sensorial comfort is determined by the mechanical and surface properties of clothing materials, including transient thermal properties. The Kawabata Evaluation System (KES) has long been used as an effective means of characterizing fabric properties related to hand and sensorial aspects of human response to wear comfort. Sensorial properties are also strongly influenced by thermal touch sensation and, in active wear clothing, by properties associated with liquid moisture transport related to sweat management.

2.2.1 Measuring Liquid Moisture Management

The ability of a clothing material to transport moisture from sweat wetted skin is crucial to perceived wear comfort. A modified Gravimetric Absorbency Testing System (GATS) is used to measure the moisture accumulation associated with the wicking of liquid moisture from sweating skin. The GATS procedure measures demand wettability. The test indicates the lateral wicking ability of the fabric, or the ability of the material to take up liquid in a direction perpendicular to the fabric surface. The GATS apparatus was modified to incorporate a special test cell and cover to assess absorption behavior in the presence of evaporation (Figure 1).

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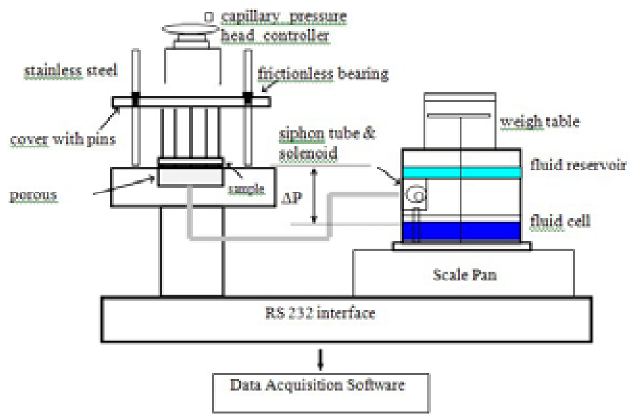

Figure 1 Gravimetric Absorbency Testing System (GATS)

In this arrangement, liquid is drawn from a fluid reservoir by the capillary action of the fabric. The hydrostatic pressure of the fluid delivery system is adjusted by controlling the position of the sample platform. Liquid is delivered to the test material placed on a porous plate.

In this arrangement, liquid is drawn from a fluid reservoir by the capillary action of the Pins, distributed over the area of the test surface uniformly restrain the test fabric. The amount (grams) of liquid siphoned from the reservoir is recorded as a function of time. These data are used to calculate absorption capacities and rates, and the percentage of moisture evaporated by the fabric. Applications of this device are discussed in Yoo and Barker [3].