Evaluating comfort using the SATRA STM 511 sweating guarded hotplate

The heat and moisture transmission properties of component materials are acknowledged contributors to overall footwear and garment comfort, and SATRA can test sheet samples of materials to help manufacturers assess this aspect. DAVID McKEOWN explains more.

The sweating guarded hotplate, often referred to as a 'skin model', is a device for measuring the thermal resistance or water vapor resistance of a material, or a composite. The test simulates the transfer processes of heat and moisture through materials next to the skin and measures the rate of transfer of heat or moisture in such processes. It is, therefore, particularly relevant for assessing the ability of clothing and footwear to transmit moisture or heat, primarily under steady state ambient conditions.

However, the sweating guarded hotplate can only be used to assess sheet materials (figure 1). It is difficult to use when assessing materials cut from footwear, as obtaining a sufficiently flat piece of material of the necessary area is usually impossible. Therefore, thermal and moisture vapor resistance tests on finished uppers or whole footwear cannot be carried out with this equipment.

The test method detailed in EN 31092/ISO 11092 and ASTM F1868-02 is a steady state test suitable for measuring thermal resistance and water vapor resistance of fabrics, films, coatings, foams and leather (figure 2). It is the approved method for assessing the performance of breathable and insulating materials for a number of footwear specifications, particularly those used by the military. The method also has applications in clothing, sleeping bags, upholstery, and similar textile-type products.

EN 31092/ISO 11092 and ASTM F1868-02 specify two tests to measure different parameters. One is used for measuring water vapor resistance (the

Figure 1: Placing a specimen on the hotplate prior to testing

Figure 2: All layers of a footwear composite are tested

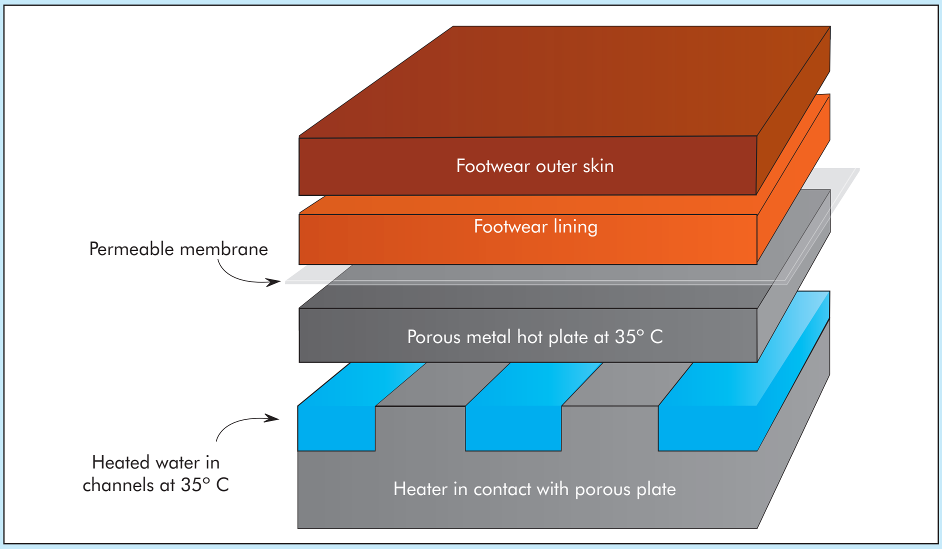

Figure 3: The principles, left, and operation, right, of a guarded hotplate

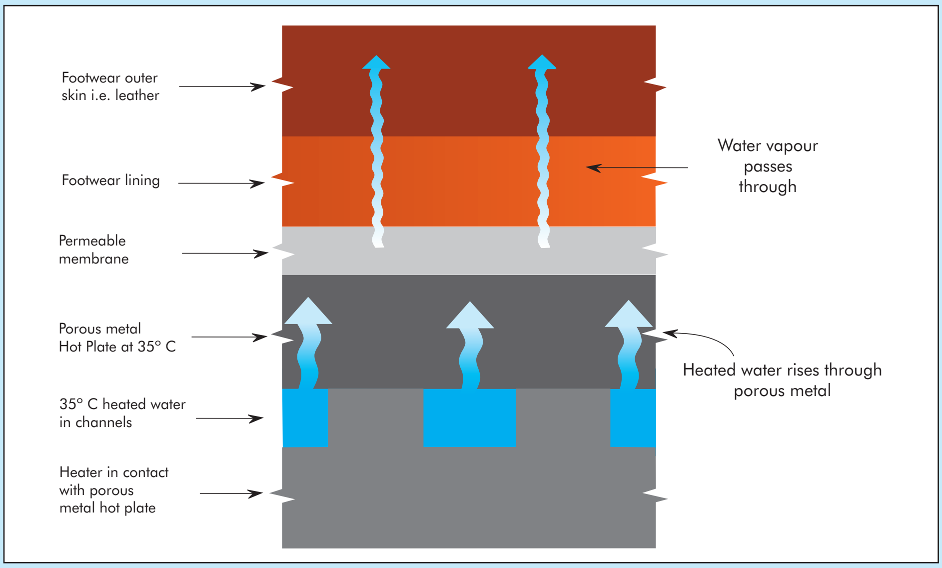

Figure 4: The operation of a sweating guarded hotplate

water vapor pressure difference between the two faces of the test sample, divided by the resultant evaporative heat flux per unit area in the direction of the water vapor pressure gradient). The other method measures thermal resistance, defined as 'the temperature difference between the two faces of the test sample divided by the heat flow per unit area'.

The SATRA STM 511 consists of a measuring unit and thermal guard ring, fitted with heaters and temperature sensors and equipped with a water supply. The measuring unit incorporates a 3mm-thick porous metal plate with a surface area of 0.04 sq m, attached to a conductive metal block containing heating elements.

A thermal guard surrounds the metal plate located within a measuring table. The top surfaces of the measuring unit and thermal guard ring are flat and level. The surface of the unit is porous to allow water, at the same temperature as the unit, to evaporate. The unit also incorporates a water reservoir. The plate and guard ring are mounted in a very precise environmental chamber where the temperature and humidity are tightly controlled.

When determining thermal resistance, no water is used and the heat flux is measured through the test specimen after steady state conditions have been achieved.

If measuring water vapor resistance, however, a thin water vapor permeable membrane is placed over the surface of the measuring unit with the test sample placed on top. Water fed to the heated plate evaporates and passes through the membrane as vapor. Hence, the test sample is not in direct contact with the water. The heat flux required to maintain the plate at steady state temperature is a measure of the water evaporation, from which water vapor resistance can be determined.

The equipment mimics the heating and sweating mechanisms at the surface of human skin. Hence, the performance of breathable fabric/membrane systems can be studied under theoretically more realistic conditions than conventional water vapor permeability (WVP) tests. The temperatures of the measuring unit and thermal guard ring are controlled at 35°C ± 0.1°C to mimic the temperature of the skin, and the test specimen is laid over the measuring unit and thermal guard ring to overlap the thermal guard.

When measuring water vapor resistance, the temperature of the environmental chamber is set to 35°C and humidity to 40 per cent RH. When measuring thermal resistance, the temperature of the chamber is set to 20°C and humidity to 65 per cent RH.

Operation is, in principle, very simple (figures 3 and 4). The hotplate and guard ring are temperature controlled and the environmental chamber is set to the appropriate temperature and relative humidity. Initially, the bare plate constants of the equipment for water vapor resistance or thermal resistance are calculated, the measurements taken without a test specimen in place. With the specimen in place, the apparatus is allowed to settle down and achieve steady state in which the heat lost from the upper surface of the test specimen is equal to the heat input from the measuring unit. Once steady state conditions occur, the power (watts) required to heat the measuring unit is measured over a period of time.

The result for a particular material is the value obtained with the test specimen in place minus the bare plate constant determined as above. It is based on the power required to maintain the steady state conditions, the temperature of the hotplate, and the surface area of the hotplate.

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