Comfort Rating for Upholstery Systems

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Abstract Nowadays long-distance drives or sitting workplaces are normal. As consequence a human sit up to 7.5 h per day. Therefore, the comfort while seating is getting more and more important. The comfort of upholstery systems such as car seats, office chairs or upholstered furniture is influenced by different ergonomic properties in particular the thermophysiological comfort.

On one hand, the thermophysiological comfort of an upholstery system can be characterized by Hohenstein Skin Model (sweating guarded hot plate) according to ISO 11092(1). With the Skin Model the specific thermophysiological quantities of textiles as layers are determined. Under stationary measurement of the Skin Model the water vapor resistance R_{et} is determined, which characterizes the insensible sweating. Higher sweating rates (sensible sweating) can be described by buffering capacity of water vapor F_d and buffering capacity of liquid sweat K_f(2, 3). In the next step a sitting human can be simulated by the sweating buttocks model or thermal, sweating manikin “Sherlock” (Newton type by Thermetrics). By combining these measurement systems with humidity sensors within in the upholstery the moisture management of an upholstery system can be determined.

On the other hand, the contact area of the human on the seat and pressure distribution on the seat are important aspects which influenced the ergonomic comfort of upholstery systems, too. The pressure distribution of a sitting person can be qualified by measurements with a pressure pad. Handheld scanner systems like Artec Eva, Creaform Revscan and or low-cost devices as the Kinect sensor offer the opportunity to scan objects like seats. The three-dimensional information of seats, chairs or furniture can be compared with 3D data of target groups. As a result, the contact area can be identified in regard of size and shape.

Keywords: seat comfort, comfort, 3D scanning, pressure pad, clothing physiology

1 Introduction

Comfort is not uniformly defined. From physiological point of view, comfort is a multidimensional concept influenced by several factors e.g. physical, physiological, psychological and environmental aspects. One theory says that comfort is the absence unpleasant feeling (discomfort)(4).

Nowadays the comfort while sitting is getting more and more important. Depending on the clothing the human body is in direct contact with the upholstery system e.g. vehicle seat, office chair, couch. More precisely shoulders, back, buttocks, thighs and lower legs have contact areas with such an upholstery system. Further long-distance drives or sitting workplaces are getting normal. As consequence a human sit up to 7.5 h per day(5). Hence, the comfort of upholstery systems is important. For the comfort characterisation of upholstery systems while sitting different aspects should be considered: sensorial, thermophysiological and ergonomic comfort.

2 Methods und Discussion

2.1 Sensorial comfort characteristics

The sensorial comfort characteristics are mainly determined by the textile's surface structure, which can be characterized by specific quantities.

If a fabric is clinging on moist skin, this is felt as uncomfortable by the wearer. The intensity of "wet cling" on the skin can be expressed by a **wet cling index i_K**. For measurements a special apparatus mainly consisting of a sintered glass plate is used, which in its surface roughness equals human skin. The porous surface of the sintered glass plate is moistened with distilled water. The force, which is necessary to draw the sample horizontally across the sintered glass plate describes the wet cling index i_K(6). The lower values, the less uncomfortable wet cling is felt. Particularly i_K should be below 15.

Under heavy sweating a textile worn next to the skin is felt the more comfortable, the faster liquid sweat is transported away from the skin. This sorption speed can be determined of a water drop of defined size falling above the sample onto the fabric's inner surface. By measuring the contact angle of the water drop the time lapse can be extrapolated, after which the water drop has been completely absorbed by the sample. This time lapse yields the **sorption index i_B**(7). About its sensorial comfort a fabric must be judged the better, the smaller i_B. Particularly i_B should be below 270.

On one hand a textile is felt as too smooth on the skin on the other hand as too rough or scratchy. This characteristic is given by the **surface index i_o**. Therefore, the number and length of the fiber ends protruding from the fabric's bulk is measured(8). Regarding sensorial comfort a fabric must be judged as good if the surface index i_o lies between 3 and 15.

A fabric is felt less sticky to the skin, the smaller its contact area with the skin. This contact area is mainly determined by the fabric's surface structure, particularly by the distant keeping fiber ends protruding from the fabric's bulk. Quantitatively a fabric's contact area with the skin can be expressed by the **number of contact points n_K**. This number is determined optically with a topograph, which gives a 3-dimensional picture of the textile surface(9). A fabric is less sticky, the smaller the number of contact points n_K. Particularly n_K should be below 1500.

The **stiffness s** of a fabric can be expressed by the bending angle against the perpendicular direction of a fabric sample(10). The stiffness s describes, whether a fabric is felt as comfortable or as too flabby or too stiff. By this definition s can assume values between 0 (completely flabby) and 90 (completely rigid). In order to yield good sensorial comfort for sportswear fabrics s should lie between 5 and 27.

2.2 Thermophysiological comfort characteristics

Skin Model

The thermoregulatory model of human skin (Skin Model) simulates the dry as well as the sweating human skin. With the Skin Model the specific thermophysiological quantities of textiles as layers, relevant to physiological comfort, can be determined. So, the thermophysiological comfort can be characterized. Under "normal" or "stationary" conditions the moisture flux from the skin appears as water vapor (insensitive sweating). In this stationary case the water vapor resistance R_{et} including short-time water vapor absorbency F_i can be measured according ISO 11092(1). Further the thermal resistance (thermal insulation) R_{ct} is determined under these stationary conditions. In general upholstery systems more specifically their material combinations are rated the better, the lower water vapor resistance R_{et} and higher the short-time water vapor absorbency F_i.

For the clothing physiological properties of textiles not only their stationary thermo-physiological properties are important but also the capacity to buffer sweat pulses which are occurring quite frequently in the practical use of textiles and clothing. Concerning the buffering capacity, it must be distinguished between two mechanisms:

Buffering capacity of water vapor (moisture regulation index F_d): This measurement describes the wear condition where the wearer is already sensibly sweating, but the sweat is still evaporating within the channels of the skin's sweat glands. In the clothes' microclimate an increased water vapor pressure is occurring but still no liquid sweat(2).

With the buffering capacity of liquid sweat (buffering index K_f) a wear condition is comprehended where the wearer is sweating so heavily that there is liquid sweat on his skin(3).

Like the stationary wear conditions, also the instationary conditions can be simulated with the Skin Model. A description of the test procedures is given in the Standard-Test Specification BPI 1.2(2, 3). Therefore, higher sweating rates while sitting during a long-term drive can be described by F_d- and K_f-value. Both thermophysiological characteristics must be rated better with higher values.

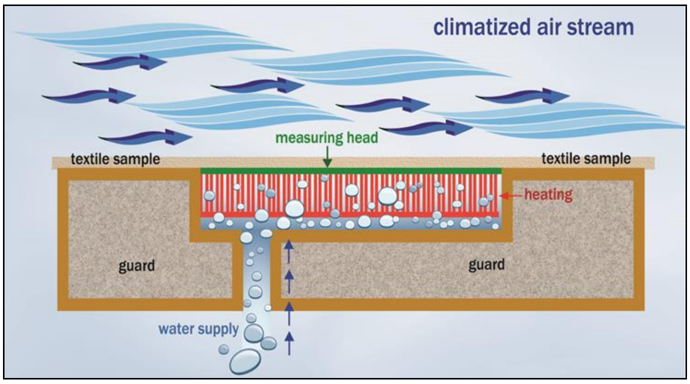

Fig. 1. Schematic structure of the sweating guarded hot plate (Skin Model).

Sweating buttocks

Measurements with the Sweating Buttocks Model (Institut für Holztechnologie Dresden gGmbH) or Seat Test Automotive Manikin (Thermetrics) determine sweat management (moisture accumulation, moisture transport, moisture degradation) of 3-dimensional cushion compositions following real conditions (Fig. 2). Thus, a deeper understanding of the thermophysiological comfort of upholstery systems can be gained.

The Sweating Buttocks Model is placed on the sample with a load of 400 N, which simulates an adult standard man. Further sweating while sitting can be simulated by the Sweating Buttocks Model. There are combined temperature and moisture sensors built-in the measuring head of the Sweating Buttocks Model. These sensors detect the temperature and moisture within the microclimate between Sweating Buttocks Model and cover of the upholstery system. By adding combined temperature and humidity sensors into the material combination of the upholstery system, additional information about the heat and moisture distribution can be obtained.

During the measurement the initial heat flux H_{ci} is detected. It represents the situation of a person sitting on a cold or hot upholstery system compared to skin temperature. In the moment of contact the maximum heat flux $H_{ci\ max}$ from the human body to the cold upholstery or from the hot upholster to the human body (negative values) take place. For a good thermophysiological comfort the amount of $H_{ci\ max}$ should be less than 85 W/m². So, there is no uncomfortable fleeing during the first contact with the upholstery and the upholstery is perceived as hot or cold. A comfortable feeling results with $H_{ci\ max} < 64$ W/m ². Further the time span for aligning the skin temperature and the temperature of the upholstery should the short. Th initial initial heat flux H_{ci} is mainly influenced by the cover material of the material composition.

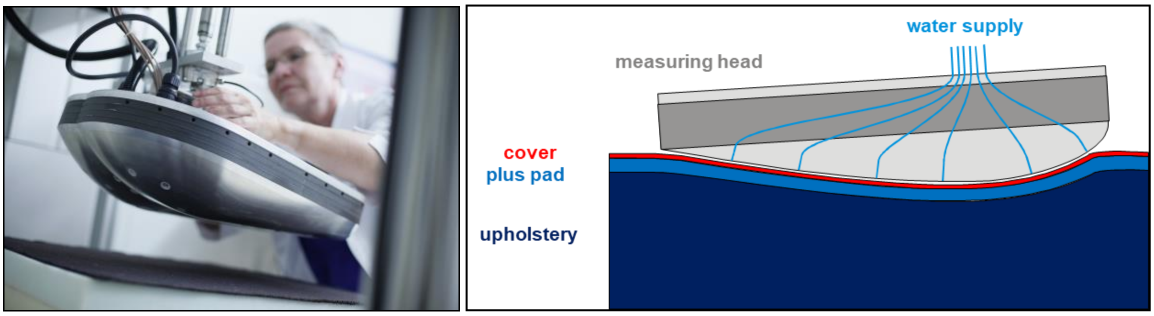

Fig. 2. Sweating Buttocks Model in climatic chamber (left), anatomically shaped measuring head on cushion composition (right).

Thermal, sweating Manikin

For measurements of complete ready-made clothing systems or upholstery systems thermal, sweating manikins were developed since 1980s. Thus, heat and moisture management of a human body can be simulated while taking the shape of the human into regard. In comparison to the thermal, sweating body segments (e.g. Sweating Buttocks) the manikins are highly variable in use.

The thermal resistance R_c and water vapor resistance R_e measurements of ready-made systems can be performed with thermal, sweating manikins. The thermal, sweating manikins Newton and Andy by Thermetrics are the only commercially available sweating manikins (11). Newton is available with 20, 26, 34 or 35 independent thermal and sweating segments. A skin-tight sweat suit distributes the water homogeneously over the manikin's surface. Newton has a wide range of body motions e.g. running, sitting, lying (Fig. 3).

In general, thermal resistance measurements R_c are carried out under non-isothermal conditions and water vapor measurements R_e under isothermal conditions. The measurement of water vapor resistance R_e with a thermal, sweating manikin is standardized in the ASTM F2370(12). Further an ISO standard is in process(13). For calculating the thermal and water vapor resistance for more than one segment there are different calculation models available: the parallel, the serial and the global calculation model.[88] The results of the different calculation models differ significantly for a given clothing system(14). In general, the standards contain an indication which of these models is to be used for the specific application.

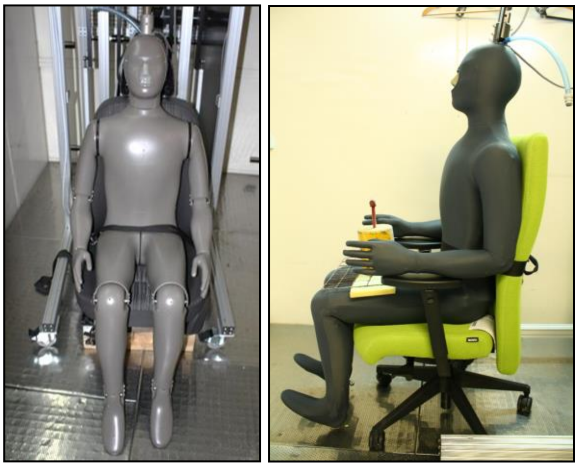

Fig. 3. Thermal, sweating Manikin Sherlock (Newton type, Thermetrics) in sitting position.

2.3 Ergonomic comfort characteristics

Pressure pad

Dealing with the comfort while sitting the ergonomic comfort is important, too. Therefore, the contact area between human and seat as well as the pressure distribution on the seat should be investigated. The pressure distribution of a sitting person can be qualified by measurements with a pressure pad. Fig. 4 shows for example the pressure distribution of a sitting person on a car seat. Further this measurement provides information about the contact area between human and upholstery system.

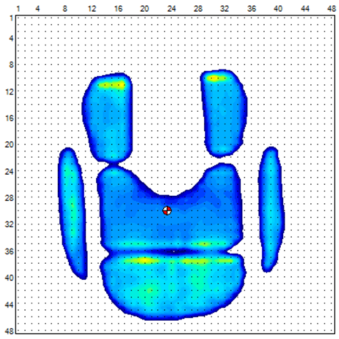

Fig. 4. Pressure distribution and contact surface of a human sitting on a car seat.

3D-Scanning

In fields like automotive it is common practice to analyse seating situations with 3D simulation software for many years(15-17). These tools enable to simulate realistic positions of seat users with the aim to improve safety, efficiency and comfort. Performing human-centered design is based on virtualized human bodies and products. On the one hand digital human models are created by adapting existing manikins in regard of body measurements via parameter setting. Similarly, products are developed and moulded in CAD software. On the other hand, test persons or products are 3D scanned with full body or handheld scanner systems like Artec Eva, Creaform Revscan and or low-cost devices as the Kinect sensor. The three-dimensional information of seats, chairs or furniture can be compared with 3D data of target groups. Amongst other issues the following points can be analyzed:

- Is the seating surface long and wide enough?
- Is the backrest high and wide enough?
- How does the contact area look like in regard of size and shape?
- Are adjustment handles ease to reach?
- Are adjustments efficient?

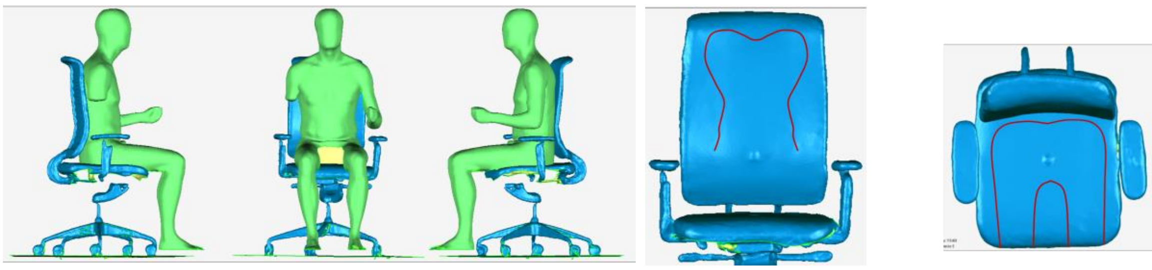

Fig. 5. Comparing individual 3D body scan with office chair.

To perform these analysis, real person's body scans give many advantages. The body forms are realistic. Parametric models tend to look not like real human beings. Although simulation software improved enormously, there are still problems with the visualization of the body surface due to movement. The research in the field of scanning in motion (4D scanning) and capturing human bodies in different postures will lead steadily to enhanced performance of simulation software(18-20). Furthermore, creating a data pool of full body scans in different positions combined with socio-demographic questions allows to choose focused target pool representatives (factory or office workers, specific age groups or BMI cluster etc.). Or, in a next step calculate average manikins with not only average body measurements but as well average body geometry and posture.

3 Conclusion

In conclusion it can be stated that the comfort while sitting is important. It is possible the characterise different aspects of upholstery systems.

The sensorial comfort describes mainly the textile surface structure of the face fabric by five specific quantities: wet cling index i_K, sorption index i_B, surface index i_O, number of contact points n_K and stiffness s.

The thermophysiological comfort can be described by measurements with the thermoregulatory model of the human skin – Skin Model for short. It can simulate the human dry as well as the sweating skin. Under stationary measurements thermal resistance R_{ct} and water vapour resistance R_{et} are determined. For the clothing physiological properties of textiles next to the skin not only their stationary thermophysiological properties are important but also the capacity to buffer sweat pulses which are occurring quite frequently in the practical use of textiles and clothing. Concerning the buffering capacity, it must be distinguished between two mechanisms: Buffering capacity of water vapour F_d and buffering capacity of liquid sweat K_f. A deeper understanding of the thermophysiological comfort of upholstery systems can be gained by measurements with three dimensional systems such as the Sweating Buttocks Model or thermal, sweating manikins.

The ergonomic comfort can by characterized by pressure pads, which determine the contact area between human and seat as well as the pressure distribution. Further the seating situations can be described with 3D simulation software. These tools can simulate realistic positions of seat users with the aim to improve safety, efficiency and comfort.

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