Development of a method for rating climate seat comfort

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Abstract. The comfort aspect in the vehicle interior is becoming increasingly important. A high comfort level offers the driver a good and secure feeling and has a strong influence on passive traffic safety. One important part of comfort is the climate aspect, especially the microclimate that emerges between passenger and seat. In this research, different combinations of typical seat materials are used. Fourteen woven and knitted fabrics and eight leathers and its substitutes for the face fabric layer, one foam, one non-woven and one 3D spacer for the plus pad layer and for the support layer three foam types with variations in structure and raw material as well as one rubber hair structure were investigated. To characterise this sample set by thermo-physiological aspects (e.g. water vapour resistance $R_{et}$, thermal resistance $R_{ct}$, buffering capacity of water vapour $F_d$) regular and modified sweating guarded hotplates were used according to DIN EN ISO 11092. The results of the material characterisation confirm the common knowledge that seat covers out of textiles have better water vapour resistance values than leathers and its substitutes. Subject trials in a driving simulator were executed to rate the subjective sensation while driving in a vehicle seat. With a thermal, sweating Manikin (Newton Type, Thermetrics) objective product measurements were carried out on the same seat. Indeed the subject trials show that every test subject has his or her own subjective perception concerning the climate comfort. The results of the subject trials offered the parameters for the Newton measuring method. Respectively the sweating rate, sit-in procedure, ambient conditions and sensor positions on and between the seat layers must be comparable with the subject trials. By taking care of all these parameters it is possible to get repeatable and reliable results with the Newton Manikin. The subjective feelings of the test subjects, concerning the microclimate between seat and passenger, provide the evaluation of the Manikins output ($R_{ct}$ and $R_{et}$ values).

1. Background
Vehicle seats have to meet and fulfill many requirements and customer needs. The safety aspect is of prime importance, especially in case of a crash. To operate a vehicle without restrictions it is necessary to be able to access all control instances. The seat position is also responsible for a sufficient visibility field. Last but not least a high comfort level offers the driver a good and secure feeling and has a strong influence on passive traffic safety [1]. One important part of comfort is the climate aspect, especially the microclimate which is generated between passenger and seat [2]. The heat and moisture management between different assembled materials and their layer construction can influence the passengers comfort feeling. Accordingly, for seat systems it is important to understand how moisture and heat will be transferred and accumulated through the different layers of a seat. So far there is no unified measurement scenario to determine the thermo-physiological behaviour of vehicle seats.
2. Aim of the research
This research shall investigate whether standardized methods for measuring thermo-physiological comfort of clothing can be adapted for a characterisation of vehicle seats. By using a thermal sweating Manikin it should be possible to ascertain thermo-physiological parameters of seating systems. The aim of the research is to develop a measuring method that provides information about how to determine indicators which will be used to quantify the quality of the thermo-physiological behaviour of vehicle seats. In the end it should be possible to understand the comfort perception of vehicle passengers at the interface with the seat.

3. Materials and methods
Vehicle seats consist of various components and individual materials. A seating system is usually made of the headrest, the backrest, the actual seating area (cushion) and the frame, plus additional equipment like various adjustment options, heating or cooling systems. The material specifications of these components are versatile and depend on the respective requirements. Textiles, leathers and its substitutes, plastics, metals and other materials are used. The seat cover is mostly a 2- or 3-layer laminated structure, consisting of face fabric, plus pad and if necessary a scrim layer. For face fabrics textiles and/or leathers and its substitutes are used. There are three kinds of common plus pad categories: foam, non-woven and 3D spacer. The scrim is a very thin and lightweight textile. It is used as the bottom layer of the seat cover to reduce the friction between the seat cover and the support layer. The support layer is made out of various foam types or alternatives like rubber hair out of natural or man-made fibers.

![Schematic seat construction with face fabric, plus pad and support layer](image)

Figure 1. Schematic seat construction with face fabric, plus pad and support layer

In this investigation different combinations of typical materials were used without any additional equipment. Fourteen woven and knitted fabrics and eight leathers and its substitutes were used for the face fabric layer, one foam, one non-woven and one 3D spacer were used for the plus pad layer and for the support layer three foam types with variations in structure and raw material and one rubber hair structure were investigated.

For the characterisation of the seats three different measuring methods were used and compared: sweating guarded-hotplate measurements for the characterisation of thermo-physiological parameters of the single and multilayer materials and human subject trials as well as Manikin measurements for the characterisation of thermo-physiological parameters of the complete seat. To characterise seat cover materials by thermo-physiological aspects (e.g. water vapour resistance $R_{et}$, thermal resistance $R_{ct}$, buffering capacity of water vapour $F_d$) regular and modified sweating guarded hotplates will be used according to DIN EN ISO 11092 [3], methods which are current state of technology. Subject trials with six (five male, one female) test subjects in a driving simulator will be executed to rate the subjective
thermo-physiological sensation while driving. To find correlations between the perception of the test subjects and the Manikin output it is necessary to conduct the subject trials and the Manikin measurements under controlled, similar conditions. Two climate scenarios will be carried out. The results of the warm climate conditions $32 \pm 0.2$ °C, $40 \pm 2$ %rh and $0.4 \pm 0.1$ m/s will deliver the parameters for the water vapour resistance measurements $R_e$ with the sweating Manikin under isothermal warm conditions e.g. in summer time. To investigate the driver’s behaviour in cold climate conditions, trials will be carried out under cold conditions $15 \pm 0.2$ °C, $50 \pm 2$ %rh and $0.4 \pm 0.1$ m/s. This scenario will be correlated with the thermal insulation $R_c$ measurements of the none sweating Manikin. The Manikin measurements can take place during the whole year but for the human beings it is important to take into account the acclimatisation for cold and warm environments, to get comparable results.

In the subject trials at first temperature and humidity sensors (MSR Electronics GmbH), will be placed on the back, buttocks and thighs of the test subject as well as forehead sensor (3M Deutschland GmbH) and heart rate sensor (Polar Electro GmbH Deutschland) to record physiological data like skin temperature and humidity, core temperature, heart rate etc. The seat is also prepared with temperature and humidity sensors on and under the seat cover. Then the test subject enters the climate chamber and gets used to the climate conditions prevailing there in sitting position. To stimulate the metabolism heat production the test subject has to walk on a treadmill. Afterwards the test subject sits in the seat and starts to drive in the simulator (see figure 2).

For an objective product measurement the thermal, sweating Manikin will be used (Newton Type by Thermetrics) to measure the thermal insulation $R_c$ and water vapour resistance $R_e$ values of the seat. The thermal, sweating 34 segments Newton, corresponds in size and shape to the body of an adult, western standard man, clothing size 50. The Manikins’ body height is 1.75 m with a weight of 30 kg. In order to simulate the real weight load of a sitting standard man the thighs are loaded with a weight of 15 kg. The Manikin is dressed with the same clothing as the test subjects and the seat is prepared with the same sensor technique as in the subject trials. The $R_c$ measurements take place in a climate chamber with $15 \pm 0.2$ °C, $50 \pm 2$ %rh and $0.4 \pm 0.1$ m/s and the Manikin segments will adjust to $32$ °C. The $R_e$ measurements will be carried out under isothermal conditions of $32 \pm 0.2$ °C, $40 \pm 2$ %rh and $0.4 \pm 0.1$ m/s. The sweating rate for the $R_e$ measurements were taken from the test subjects data und are realized in a work cycle, starting with an high sweating impulse and followed by a slighter sweating rate.
4. Results and discussion
Below the results of the material characterisation with the sweating guarded-hotplate are given for the selected samples listed in Table 1. The results confirm textile seat covers have better water vapour resistance values than leathers and its substitutes (e.g. in figure 3).

Table 1. Selected sample set for the material characterisation on the sweating guarded-hotplate

| Sample | Face fabric                                      | Plus pad              |
|--------|-------------------------------------------------|-----------------------|
| M1     | Perforated artificial leather                   | sewed with non-woven  |
| M2     | Lacquered leather                               | sewed with spacer     |
| M3     | Natural leather                                 | sewed with non-woven  |
| M4     | Woven (PES tetralobal yarn construction)        | laminated with spacer |
| M5     | Woven (99 % PES/ 1 % PUR)                       | laminated with foam   |
| M6     | Woven (75 % PES/ 25 % WO)                       | laminated with non-woven |

![Water vapour resistance](image)

**Figure 3.** $R_e$ Water vapour resistance values measured with the sweating guarded-hotplate e.g. for Sample M1-M6

In order to define a sweating rate set-point for the measuring procedure with the Manikin, the absolute humidity values of all test subjects measured on the seat cushion covers were taken. The aim was to receive the same absolute humidity values with the sweating Manikin on the cushion cover. One example is given in figure 4. The two curves show that it is possible to receive the same absolute humidity values on the cushion cover measured by all test subjects and the Newton Manikin. Therefore the Manikin must be prewetted in hanging position with a high sweating impulse. Then the Manikin is placed in the seat, a slighter sweating rate is adjusted and the $R_e$ is measured until a steady state value is reached over a time period of 30 minutes.
Figure 4. Absolute humidity on the cushion cover measured by 6 test subjects and the Manikin

The Manikin measurements indicate that not only the seat cover (face fabric and plus pad) has an influence on the perception of temperature and humidity in the microclimate between passenger and seat. The support layer also has a great influence. The $R_e$ values on the complete seat are higher when a standard foam is used (full coloured bars in figure 5) in comparison to a structured foam with integrated holes and channels (hatched bars in figure 5). Figure 5 also shows that with M5 (foam is used for the plus pad layer) the influence of the support layer is not so significant in comparison to M6 (non-woven is used for the plus pad layer).
5. Conclusions

It is possible to adapt standard measurement methods from the clothing physiology to determine the thermo-physiological behaviour of vehicle seats. This paper shows how the parameters from the subject trials deliver the parameters for the Manikin water vapour resistance measurements. Influenceable parameters like ambient conditions, sensor position, clothing etc. have to be set as similar as possible in the subject trials and Manikin measurements in order to get comparable results. The given example of the measuring procedure for the water vapour resistance measured by the Manikin demonstrates that different material combinations provoke different water vapour resistance values for the complete seat. The next step is to define a classification system for rating the seats in accordance to the subjective feeling for temperature and humidity. To hand out recommendations for further developments of vehicle seats with optimized climate comfort, thresholds for $R_e$ and $R_c$ values have to be determined.

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