RECOMMENDATIONS ON CLIMATIZED CABINS AND SEATS

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Abstract: *In view of the high risen demands on the machine operator to a safe and high efficient guidance the best possible "workplace situations" must be available. Beside assisted vehicle operation and ergonomically optimized machine interaction particular importance must be attended to individual adjustments as well as climate management. Though for a good climate in the cabin the newest technologies are applied, still the perceived comfort can become disagreeable in spite of air-conditioning. On longer terms the heat as well as the humidity produced by the driver accumulate in the seat and lead to negative sensations, concentration interferences, tiredness and consequently performance losses. Thus the operator's seat sets a great challenge for agricultural and forestral automotive vehicles already in the matter of ergonomics and safety, concerning hygro-thermal functions however it is probably one of the most complicated development topic. Apart from general interactions between climate situations and best human work performance, assessment and measuring aspects for climate and comfort as well as constructional details for optimized heat and sweat management on drivers's seats have to be respected.*

Keywords: SEAT, CLIMATE MANAGEMENT, CLIMATE COMFORT, THERMAL STRESS, SWEATOR

1. Introduction

Comfort is a multifactoral issue and can be categorized into biomechanical and climatic aspects, influenced by emotional as well as individual situations. It must be realized that various interactions are existing between the comfort spheres, like changes in mechanical properties due to increasing humidity or low convective heat exchange. Additionally the exposed time will change the importance of the comfort factor: short-term discomfort is determined mainly by biomechanical features while with increasing time the climate perception becomes cardinal. But anyway discomfort reduces the work performance, the quality, the safety and endangers at least the worker's health.

2. Thermal Stress

To assess thermal stress the physical workload, the environs climate, the individual capabilities and the clothing as well as the supporting systems have to be regarded. In most articles and references it is assumed that "thermally comfortable" is correlated to core- and skin-temperature or to summarized values (i.e. Ramanathan temperature). However it is not considered that extreme climatic conditions on body parts will significantly influence the global perception, like during sitting.

The driver's cabin of forestral, construction or particularily agricultural machines sets a very special situation, because of big windows for a good overview, hermetic sealing against dust, leaves and flakes, periodic changes of work position and various weather conditions. Therefore a climatized cabin should be supported which ensures an acceptable temperature in the range of 19 to 23°C (at least 26°C, resp. lower 30°C) as well as a relative humidity between 40 and 70% according to the comfort requirements. If the temperature exceeds that range and the clothing system is not adapted capability and motivation will decrease. The humidity should be controlled with respect to their influence on the temperature perception, to ensure the evaporative heat transport and to avoid breathing problems [1].

Though the latest technologies are available for achieving a high degree of climate comfort in the cabin's interior, the feeling of well-being can be impaired in spite of the presence of an air-conditioning system. Over longer time, the heat as well and the humidity produced by the driver accumulate in the seat and lead to negative sensations, impairment of concentration, tiredness and reduced performance. Consequently, the operator's seat itself is challenging enough for the agricultural automotive industry in terms of ergonomics and safety, but when hygro-thermal functions are taken into account too it is probably one of the most complicated development tasks.

3. Optimized Seat Climate

3.1 Methods

By long years of experience collected via studies on the climatic wearing comfort of clothing and as a result of numerous cooperation projects with well-known seat manufacturers, in a joint venture of the ergonomic laboratory at Munich University of Applied Sciences, the c.russ-NETCONSULT and the Institute for Applied Ergonomics the THG-SeatView and the SWEATOR system have been developed to industrial standards.

The THG-SeatView allows two and threedimensional temperature and humidity distributions to be measured over time in optically invisible layers such as in the contact area of human and seat and/or backrest in particular. The results are not adversely affected by the measuring technique and are displayed graphically in compressed form (Fig. 1).

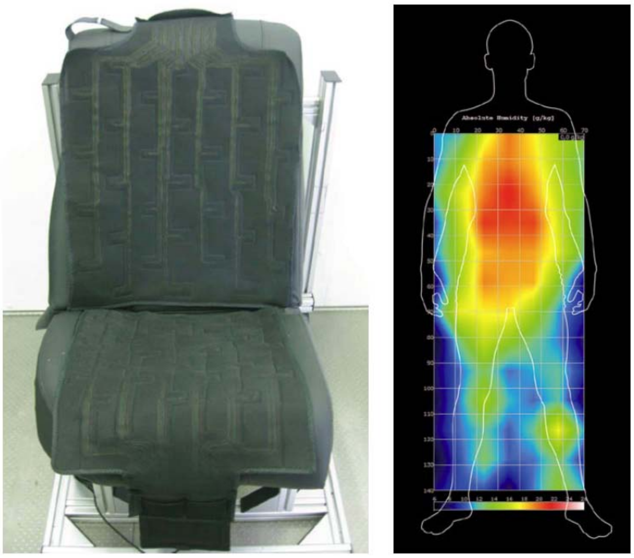

Fig. 1: *Test seat with THG-SeatView and thermo-hygro pattern.*

The SWEATOR is a static, quantitatively reproducible source for humidity and heat which can simulate thermoregulation processes with virtually every test-body profile. This enables a broad range of scientific institutes, R&D departments as well as test and certification centers to easily conduct highly reproducible textile-technical and thermoregulative-physiological parameters. The basic skin model (Fig. 2) allows the examination or comparison of textiles or textile sandwiches as well as complete products like seats or laying systems just by setting the active penetration field on the probes. The transported amounts of heat and humidity are tracked and lead to a prediction and categorization of climate comfort.

By use of the TRG-SeatView and the SWEATOR skin model a climatized (by active ventilation) seat has been optimized according to heat and sweat transport capabilities (Fig. 2) and to the control strategy.

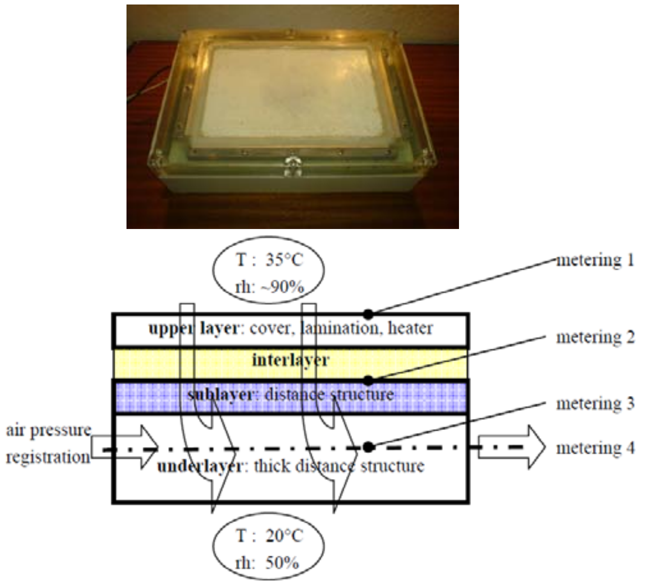

Fig. 2: *SWEATOR skin model as heat and humidity source to analyze transport mechanism of climatized seats.*

With the goal to specify the climatic comfort on driver seats by measurement of the contact climate as well as by query of the user's perception a suitable test setup was developed with standardized conditions, i.e. in a climate chamber. Additionally a data processing method, called clustering, has to be established to get valid test indicators.

The tests were carried out under fixed climate, i.e. 28°C and 60% relative humidity, with the climatizeable seat (Fig. 1). A task simulator guaranteed the reproduction of the movements and stress situations appearing in a real operating situation. After 2-hour test time the ventilation of the seat was activated. The preselected and instructed test persons (n=15) carried underwear as well as cotton trousers, cotton shirt and sports shoes. After a short preconditioning the test person was seated on the seat equipped with the THG-SeatView measuring mats (see figure 1) and the 3-hour test was started. Every 30 minutes the person had to judge her subjective climate perception. For this 5-stage scales were used for dampness (1:convenient to 5:humid), comfort (1:comfortable to 5:uncomfortable) as well as for the temperature sensation (1:convenient to 5:warm). A cold sensation did not appear according to the selected test climate.

3.2 Results

Beside the big data amount, which is produced by the THG SeatView system, individual factors like body height, contact area as well as sitting position complicate the automated extraction of valid indicators, which determine the climate and its perception. An analysis of the measurements required first a grouping of the test subjects in small and big people, strong or weak sweating as well as men and women. Afterwards their temperature distributions and humid distributions were evaluated statistically to specify the sensors or sensor areas which show prestigiously the microclimate with the appearing maximum values and do not average them. Thus a cluster procedure could be defined with specified sensor areas on seat and backrest, in which the climatic interaction is best represented for all experimental subjects and test terms. Figure 3 shows exemplarily humidity distributions at seat and backrest as well as the developed clustering methodology [4]. For the following assessment of the climate interaction the clusters S2 and L2 are used.

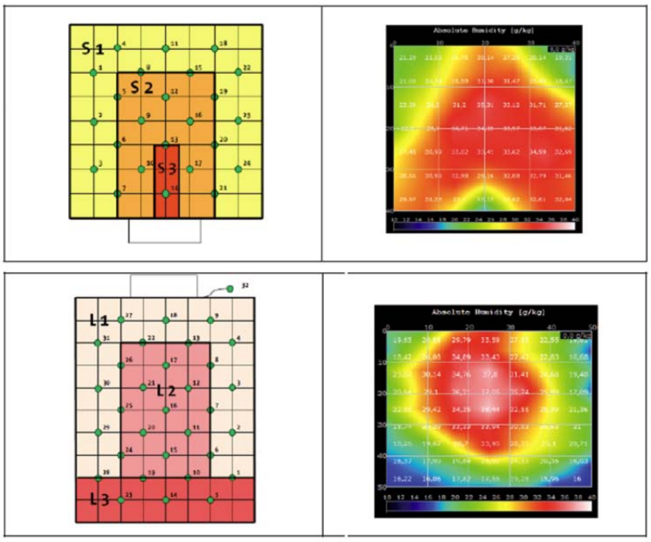

Fig. 3: *Measurement patterns with clustering.*

To correlate the climate perception and its effect on the comfort feeling only the test results at the end of each 30 minutes interval are used. Thus a huge data reduction is achieved despite of an enough precise record of the test dynamics. Figure 4 shows exemplarily for a test group the averaged climate values of temperature, relative and absolute humidity with the corresponding perceptions. The dependence between subjective and objective indicators is clearly recognizable and statistically significant and shows the positive effect of the seat climatization.

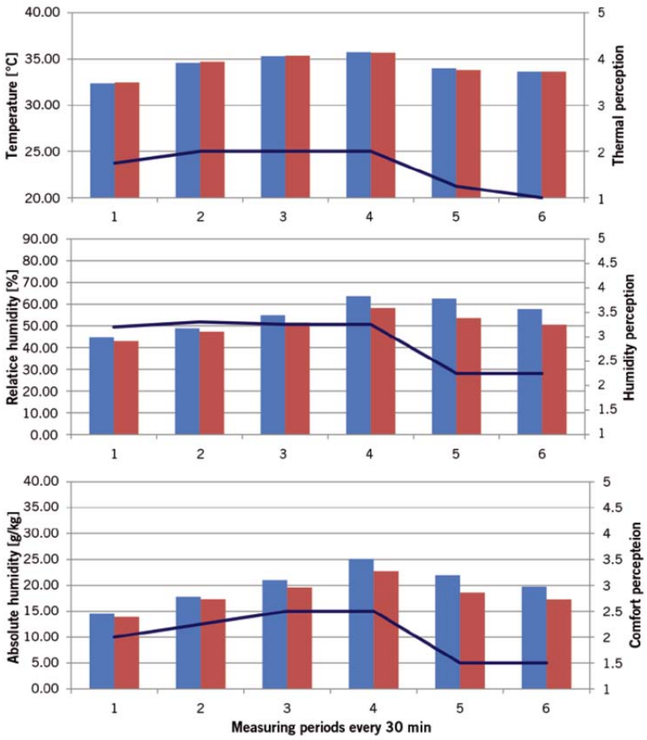

Fig. 4: *Climate (red: seat, blue: bachrest) and perception with ventilation after 120 minutes of the test (period 4 on time axis).*

With respect to the central issue „comfortable or not" most of the test persons specified a "perception switch" to the value 3 for humidity, temperature and comfort. By means of these limits it is possible to deduce suitable temperature and relative or absolute humidity values, where the comfort will significantly change. Despite of individual differences in thermoregulation and climate sensation the evaluations of all test results show a consistent dependence between measures and perception. Based on the perceptual discomfort grade 3 the following values of the climate factors could be established:

- temperature: 35.5°C
- relative humidity: 60% rh
- absolute humidity: 23 g / kg

These limit values are found in good correspondence with various scientific investigations on other body regions or clothing components [2,3].

Finally, of special interest is the question, „which change of climate measures leads to a valid perception change“, so the question after the perception sensitivity. From former studies could be determined that the individual differentiation of the perception correlates with a change of 0.5 steps in the individual grading. Based on all collected data the following, global perceptive resolutions are determined:

- discernable temperature change in the area of 30-35°C: 0.4 – 0.5°C
- discernable change of the relative humidity: 5% rh
- discernable change of the absolute humidity: 2-3 g / kg

Any developer thus has climatic limit ranges at his disposal which determine the transition to discomfort in case of normal perspiration behavior in the test condition described.

4. Summary

With the goal to specify limits or ranges for a good climate comfort on vehicle seats in well climatized environs (cabin) measures were correlated with subjective perception statements in various tests with regard to warmth, humidity and comfort. To compress the extensive measuring data a suitable processing procedure was developed by use of clustering methods, using not only single measuring values or global averages but sectoral characteristics for further calculations and evaluations.

The results demonstrate a good intraindividual correlation between measures and perception values, in particular with regard to temperature and heat sensation or absolute humidity and comfort perception. This enables the fixation of assessment standards for the climate comfort on vehicle seats. However, these are still to be verified for other climates or seat constructions.

By use of the SWEATOR technology the microclimate e.g. on vehicle seats can be simulated according to the human thermoregulative processes. To investigate the required control and setpoint values achieving a valid comfort prediction will be one of the following research goals (Fig. 5).

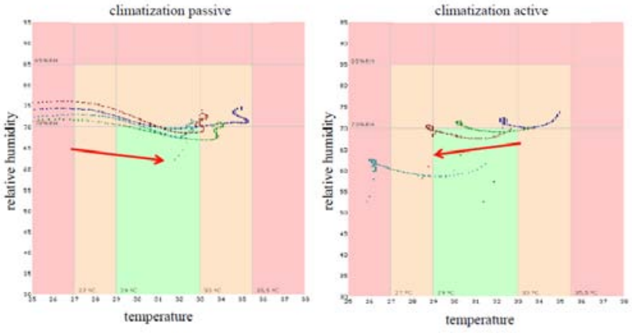

Fig. 5: *Climate (red: seat, blue: bachrest) and perception with ventilation after 120 minutes of the test (period 4 on time axis).*

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