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Thermal comfort laboratory for automotive seats

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Thermal comfort of passengers and drivers is one of the main concerns of the automotive industry due to its influence on overall comfort. Although manufacturers have been introducing air-conditioning systems inside the vehicle for this purpose, it is necessary to design seats using new materials and heating and ventilation systems to guarantee comfort in the passenger-seat contact area.

To achieve this goal, the Biomechanics Institute of Valencia (IBV) has a Thermal comfort laboratory for automotive seats, which can study the thermal properties of the seats in a range of conditions (from winter cold to extreme heat) and can also assess the level of thermal comfort. This laboratory offers companies the possibility of assessing vehicle seats that improve the passenger's thermal comfort, providing an added value to their design.

Introduction

The importance of thermal comfort over the experience of travelling, driving or even over safety is on the rise in the car industry. Although air-conditioning systems try to cover users' need for comfort and ensure the inside of the vehicle remains at a pleasant temperature, in long trips and in conditions of extreme heat or cold this may not be enough to guarantee comfort. The micro-climate conditions generated in the passenger-seat contact area according to the type of seat material or the active heating and ventilation/cooling systems, where applicable, can considerably affect the comfort of the vehicle's occupants.

Extended contact between passengers and their seat causes increased sweating. The moisture built up between the user and the surface of the seat is one of the main causes of thermal discomfort, and can appear if the material of the seat is not capable of evacuating the moisture or if the seat does not have a suitable ventilation system.

In addition, it should be remembered that, when getting into a vehicle and sitting down under extreme weather conditions, car passengers can suffer heat or cold shock when the surfaces of their bodies (15% to 20% of the total surface) come into contact with the seat, backrest and steering wheel. Heat transfer to the body by conduction from contact with the seat, which is initially very cold or very hot, is a significant factor in the influence the thermal sensation has on a car passenger. This situation can cause long periods of discomfort for the passenger.

To achieve a higher level of comfort, manufacturers in the car industry have developed seats using new materials or with built-in heating or ventilation and cooling systems for conditions of excessive cold or heat, respectively. It is essential to have a precise, reliable laboratory and method in order to characterise the thermal properties of the seats in terms of how they affect the human body and, thereby, to develop new products that offer maximum thermal comfort.

The thermal properties of the seats can be assessed by means of tests using subjects whose physiological constants are monitored in controlled laboratory conditions, or else using a thermal dummy that simulates human behaviour, capable of producing heat and sweat in the areas in contact with the seat. Given the diversity of responses among the various subjects and the low repeatability of the measurements, having a dummy in which it is possible to control the generation of heat and sweat in an objective manner in various areas is the best option when it comes to assessing the thermal properties of a seat.

The Biomechanics Institute of Valencia has STAN (Seat Test Automotive maNikin), a dummy with the most advanced technology, developed

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specifically to assess thermal comfort and moisture transfer of seats in the automotive industry.

Development

Although there is no standard regulation governing thermal/ hygrometric testing of car seats, STAN is similar in theory and in practice to other standardised systems such as the Skin Model (ISO-11092 and ASTM-F1868) used to characterise the thermal properties of samples of different materials, especially textiles.

The STAN dummy has a precise design of anatomical contours for correct adjustment and compression on the seat, with joints allowing it to adapt more easily to the contour of the seats, and matches the measurements of the 50th percentile of the western population. Its configuration allows mass to be added to simulate the weight of a subject, making it possible to control compression on the seat and backrests (**Figure 1**).

Figure 1. Test with seats in the laboratory using the STAN thermal comfort dummy.

STAN is made up of three body segments which, in turn, are divided into a series of thermal segments: the back segment has two thermal areas: a top area and a middle area; the lumbar segment consists of a single thermal area; and the bottom segment consists of three thermal areas: the two legs and the seat area (**Figure 2**).

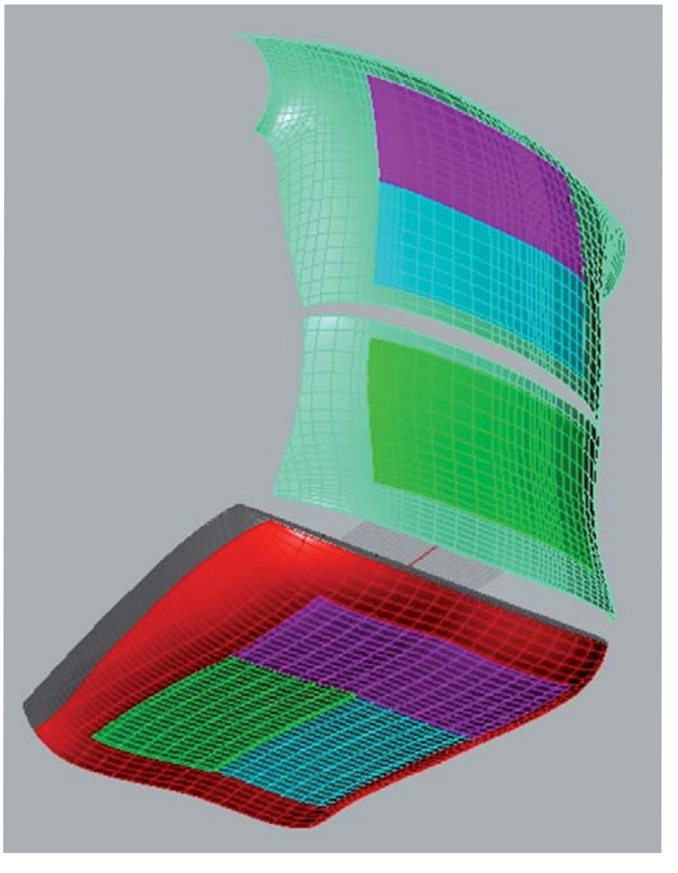


Figure 2. STAN dummy with 3 segments and 6 independent contact areas.

Description of the System

The back and leg areas are made from fibreglass and epoxy material and contain, as mentioned, six independently controlled thermal areas with systems that supply the **production of heat and sweat to simulate human metabolic levels**. The temperature of the dummy and the flow of sweat are controlled from a PC, which also registers data with frequencies of up to 1 Hz.

The dummy is built so that it is capable of reproducing the heat emitted by the body in various areas of contact with the seat in a uniform manner in a range of between 10 and 40 °C (the average temperature of the skin is between 32 and 35 °C). The total heat flux supplied (electric power) by the dummy can reach 800 W/m² and is controlled at all times to maintain the established temperature levels. The control equipment has an accuracy of ±1% of the indication provided in the software.

Likewise, STAN simulates the sweating of a user with levels that can range between 50 and 1000 ml/(hr-m²) according to the situation: extreme heat with large amounts of sweat or small amounts of sweat as in stable conditions of travelling in cool environments.

The main advantage of the STAN dummy compared with other systems commonly used to simulate body heat lies in the fact that **its operation is based on energy transfer** (heat flux supplied to the various areas of the body) and not only on surface temperature, as is the case with most systems. This feature makes the system more realistic and more similar to human behaviour.

Internally, STAN has a structure that allows it to guarantee stable operation through the circuits and areas shown in Figure 3.

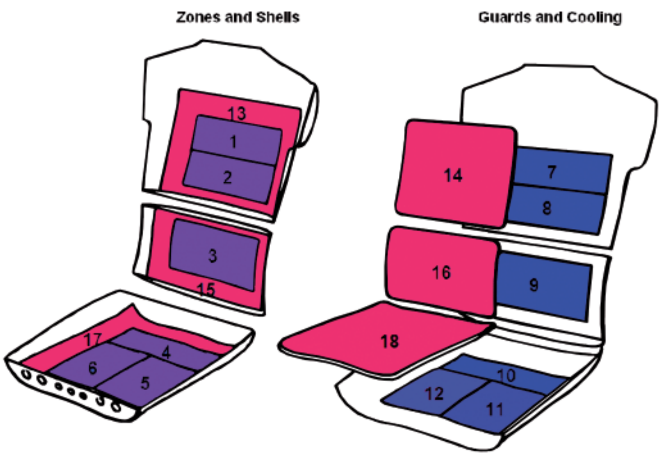


Figure 3. Detail of the different areas that make up STAN.

- Areas 1-6 represent the 6 areas of direct contact with the seat that reproduce the sweat.
- Areas 7-12 represent the closed circuits for cooling each of the sweating areas, simulating the blood flow.
- Areas 13-18 are the internal areas that produce heat to make sure there is no loss of heat through the dummy in the contact surfaces and that the heat transfer takes place in the dummy-seat direction.

Sensors

Skin temperature:

- Each of the 6 areas has a heater that supplies the heat flux and 2 thermistors for measuring the temperatures.

Room temperature:

- 2 probes measure the room temperature
- 1 probe measures the relative humidity of the room

Software

The system has software which can be used to establish the conditions required for each test and to control changes in the variables detected during the tests. (Figure 4).

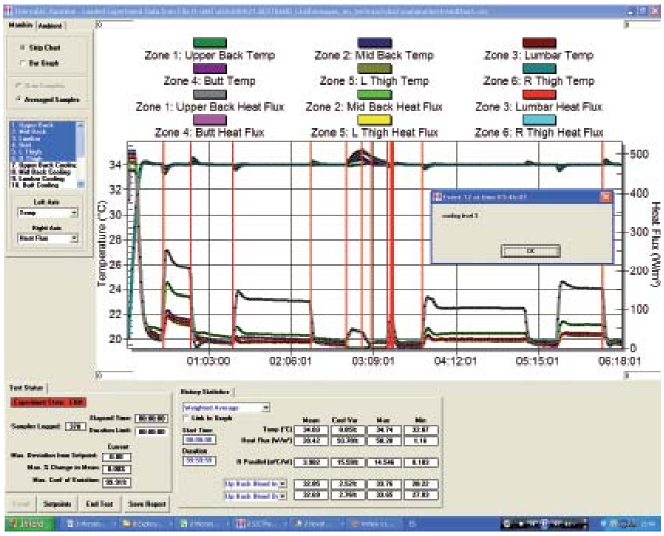


Figure 4. Result of a test analysed using SZCThermDAC software.

The system can register the following parameters:

- Heat flux (W/m2)
- Thermal resistance: Rct = $(m^2 \cdot °C)/W$
- Evaporation resistance: Ret = $(m^2 \cdot Pa)/W$
- Permeability index (Im)
- Surface temperature (°C)
- Room temperature and relative humidity (°C and %)

In addition, two types of tests can be performed, with the option of setting the temperature on the surface of the dummy or setting the heat flux supplied by each area.

Environmental conditions

To ensure high repeatability in the test results, they are carried out in controlled, stable environmental conditions, with a temperature variation of ±0.5 °C, and a relative humidity variation of less than 5%. To achieve these conditions, the tests are conducted inside the environmental test chamber available at

> the IBV (**Figure 5**). This chamber has dimensions of 3120 x 3120 x 2760 mm and can operate within a temperature range of -25 °C to +60 °C and with relative humidity levels of between 30% and 80%.

Figure 5. Environmental test chamber at the IBV.

The system can also be used in stable environments outside the chamber or even inside a vehicle. In this case, comparative tests and repeatability tests are performed to determine the tolerance of the environmental conditions.

Example of application to two seats with ventilation system

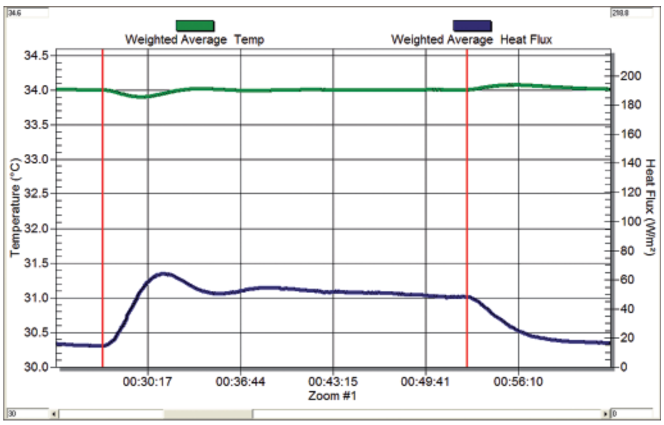
Figure 6 shows the results corresponding to two dry tests (with no sweat) of two seats with different ventilation systems. The graphic represents the average Temperature and Heat Flux values, although this information can be obtained independently for each of the areas. The period during which the ventilation systems are active is marked out by the vertical red lines.

In the case of **Figure 6.a**, the temperature of the dummy undergoes a small change, and the heat flux required to maintain the contact surface at 34 °C increases slightly. In **Figure 6.b**, when the ventilation system is activated, the temperature of the dummy drops considerably, and the flux required to maintain the temperature of 34 °C increases considerably. The interpretation of these results can be summarised in that, on days with extreme heat, the ventilation system of seat A will only slightly affect the passenger's level of comfort, while the system of seat B will counteract the extreme heat of the contact surface and considerably improve the passenger's comfort.

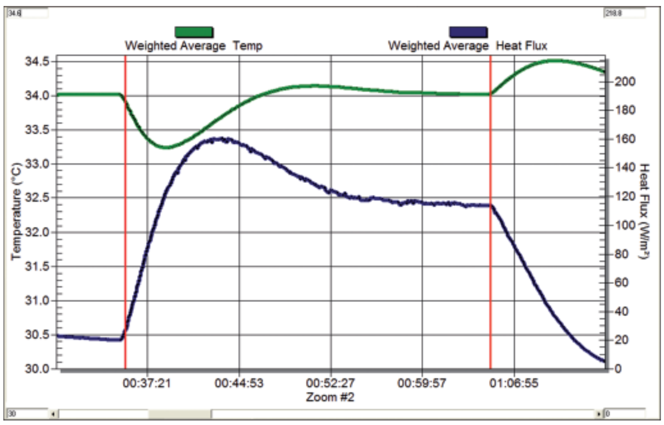
Conclusions

The IBV has high-tech equipment for characterising the thermal properties of car seats, which it uses to run successful tests on seats made from new materials with heating and ventilation systems. Once the thermal properties have been assessed and the data have been correlated with user comfort assessments, the IBV has the material and knowledge required to assess the thermal comfort provided by car, rail and airplane seats.

The IBV offers companies a new service for assessing seats during the product development process, with the possibility of improving the design, accurately knowing the level of comfort provided and offering an added value that sets their seats apart on the market.



a)



b)

Figure 6. **a)** Seat A ventilated with little effect on the surface temperature and on the level of comfort in conditions of extreme heat; **b)** Seat B ventilated with large effect on the surface temperature and on the level of comfort in conditions of extreme heat.