MODELLING OF LOCAL THERMAL SENSATIONS OF A CAR DRIVER IN WINTER CONDITIONS

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INTRODUCTION

Air conditioning systems in cars are uneasy to dimension, because thermal exchanges are very complex and not well known. This study, supported by **PSA** PEUGEOT CITROEN and VALÉO has been undertaken to get a model of the thermal behaviour of the driver - MATHER, in order to optimise the car indoor climate and to meet comfort conditions at lower cost.

Most of thermal comfort studies have been carried out for housing where thermal environment of the body is quite different. In a car, surface temperatures are much more influent on the body because the distances range in a few centimeters. Furthermore, their differences can be strong ; for example, the window or windshield can be lower than 0°C, while the lower part under the steering wheel can be more than 50°C, because of the engine. Another difference with housing conditions comes from the high level of the temperature of the air which may be blown, sometimes at high velocity, on the different parts of the body.

METHOD

As thermal sensation is not well known in car condition, we decided to restrain the field of this study to winter conditions : low outside temperature, heating turned on and a man heavily dressed. Many experiments have been carried out in a wind tunnel, with the same car and the same person. Various inside and outside conditions have been tested in a wide range. During all the experiments a great number of temperatures were continuously measured in the car (air and surfaces) and on the body. The driver was asked to define his global and local sensations (head, left arm, etc.) on a 9-point scale. This scale range from very cold-1 to suffocating-9, where 5 means comfort.

Figure 1 represents the information flow diagram of the simulation, with the different modules to run MATHER, which is composed of the human thermoregulation and the thermal sensations submodels.

• *Human thermoregulation model.*

All local thermo-physiological parameters (skin temperatures, wettedness,...) and reactions (sweating, ...) of the body are computed by a 29-node human thermoregulation model, where the body is divided into 7 segments : head, trunk, left and right *arm*, hands, legs and feet, each segment composed of **4** layers. This model is **based** on an existing 25-node model on which we have **been** working for 8 years in building and space conditions [1]. The following modifications were needed for car applications :

The two arms are separated to take into account the lack of symmetry due to the proximity of a cold surface and the greater insolation on the arm which is closer to the window.

Clothing representation had also to be changed because during strong transient conditions, the steady state equations previously used, were not satisfactory. The clothing layer has been divided in two layers, the cloth itself and an air layer between cloth and skin [2].

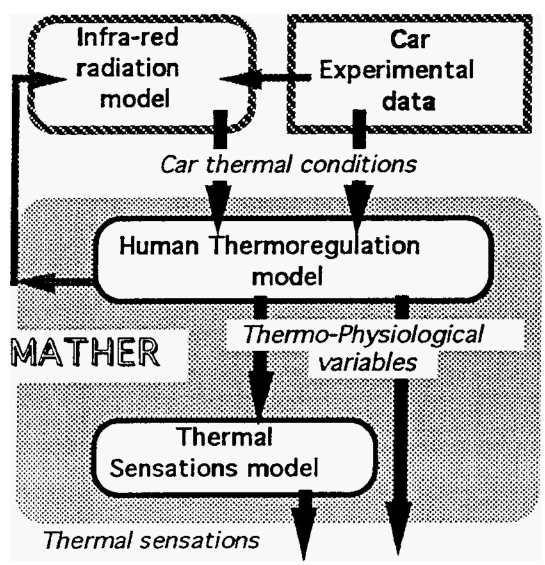

Figure I : Flow diagram of the simulation

Another problem arose because of the seat [3], which modifies the heat and mass transfers on the trunk and legs. The first approach was to consider the seat as adiabatic and to neglect the sweat absorption : all the water produced by the skin is assumed to evaporate in the material. These hypothesis are realistic only for winter conditions, when the sweat rate remains low.

• *Thermal sensations model*

This submodel associates physical and thermo-physiological variables of the body to global and 7 local sensations, on the 9-point scale. The relations used by this model have **been** built up from experimental results. Each of the 7 segments of the body has its own table of empirical coefficients to calculate local thermal sensation. Global sensation is computed from the calculated mean skin temperature. For winter conditions, the local sensation is calculated from the local skin temperature of the segment and the inspired *air* temperature.

• ***The complete representation***

Air temperature, relative humidity and velocity and radiative fluxes on each segment are entered in the model **MATHER.** Infra-red radiative exchanges are calculated by another model, fed by car and body (skin or clothing) surface temperatures. This model has been developped by our laboratory, angle factors are calculated with the Monte Carlo method from the geometric description of the car. Solar radiative fluxes have also been measured during experiments and are entered in the model. Experimental car thermal conditions data are used as inputs to run the models, physiological variables and thermal sensations are determined by **MATHER.** Those outputs can then be compared with data recorded on the car tester during experiments.

RESULTS

One of the numerous experiments is presented here. The car is set in thermal equilibrium with a very cold environment in a controlled wind tunnel: the driver comes from quite neutral conditions, enters the car and starts the engine; the heating system is turned on and controlled, it is able to rise rapidly inside temperature. Then, realistic driving configurations are tested (change of blowing position, car speed,...).

The evolution of mean inside air and dash board surface temperatures is shown on fig 2. This experiment was not used to build up the correlations between sensation and physiological variables.

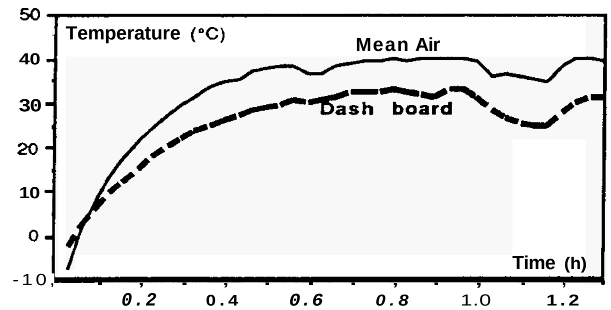

Figure 2 :Temperatures measured in the vehicle

Figure 3 shows the evolutions of mean skin and leg temperatures : experimental (-E) and simulated (-S). Slight discrepancy can be seen, but the general trend is good. Differences can be explained by the poor representation of the exchanges with the seat.

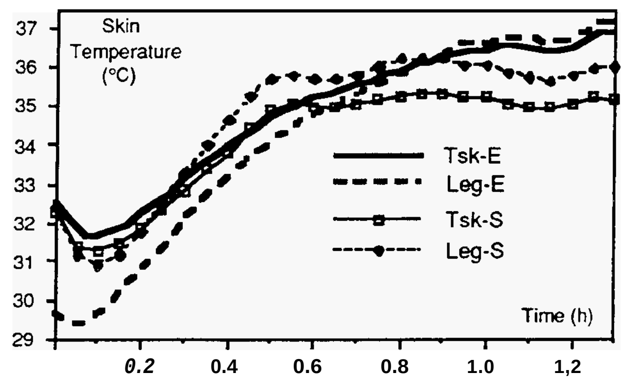

Figure 3 : mean Skin temperatures legs skin temperature

The simulated global sensation (Sglo-S) is compared to the experimental one (Sglo-E) on fig. 4. The observed differences, about one point on the sensation scale, are in the same range as those observed while comparing sensations recorded during the same experiment repeated twice.

Local sensations are not reported here, but their evolutions are very close to the global. The agreement is as good for local sensation as for the global one.

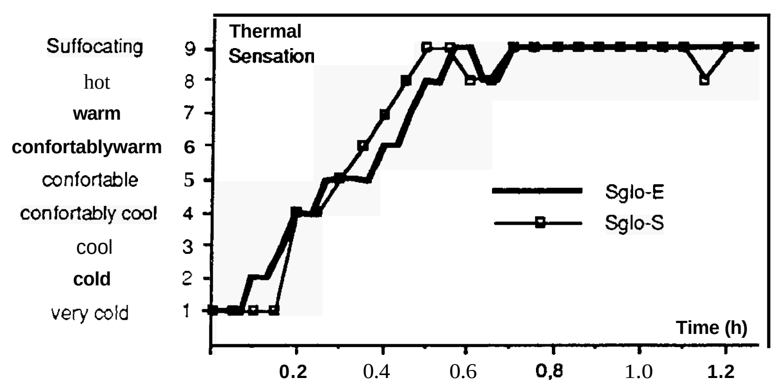

Figure 4 : Global thermal sen

CONCLUSION

The thermo-physiological part of the model has been validated in many conditions (building, ...). Concerning the new part for car applications, it has to be noticed that the model, especially thermal sensations equations, represents only the one **PSA** PEUGEOT CITROËN car tester, and not a mean person.

It is valid for now, only in winter climate (heating turned on, heavy clothing, low sweat rate,...) and for low work rate corresponding to driving.

Many tests have been made, the results show that for most of the conditions the models reacts in the good way while compared to experiments. Improvements are being made, like a better description of the seat, and new correlation for thermal sensations in summer conditions.

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