

1. Introduction

In developing an automotive HVAC (Heating, Ventilating and Air Conditioning) system, CAE (Computer Aided Engineering) is being applied to enhance the design efficiency. This makes it easier to predict the interior thermal environment during the designing stage. However, regarding the car occupants' thermal comfort, which is an important quality evaluation item, it is difficult to develop models for simulating physiological and psychological responses under the complicated interior environment of a vehicle. Accordingly, no method has been available to predict their thermal comfort with appropriate accuracy. This paper introduces technology for predicting, using a computer, the occupants' temperature sensation, thermal comfort caused by non-steady, non-uniform thermal environment in the car cabin when the air conditioning is turned on.

2. Method

Fig. 1 shows three models created by simulating the process that leads to the generation of thermal comfort.

2.1 Human body thermal

The temperature sensation expressed with words like "Hot and Cold" occurs when the state of the human skin temperature is input to the brain¹⁾. Accordingly, the car occupants' skin temperature distribution will be predicted first on the basis of the thermal environment in the car cabin and the occupants' heat balance.

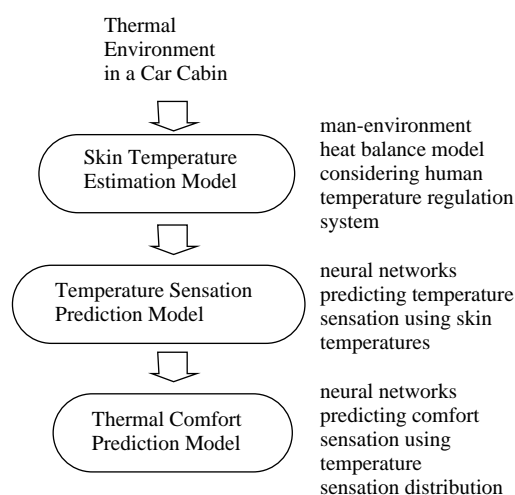


Fig.1 Schematic of the models.

The present models express the occupant's physical contour, muscles, fat, bones and other internal structures using the finite element method. Metabolic heat production and the heat loss to the environment will be calculated at each part of the human body. Our measured perspiration and skin blood flow characteristics for each body part are incorporated into the 2-node model of ASHRAE²⁾ that represents the whole body thermoregulation responses. The occupants' volume of clothes and thermal resistance of the seat are set as the boundary conditions so that the difference in the volume of clothes for each body part and the season can also be considered.

2.2 Temperature sensation prediction models

Next, the temperature sensations of seven parts of the human body including the face, torso, arms and legs and others are predicted according to the estimated skin temperature.

Since the temperature sensation is dependent on not only the skin temperature but also the rate of change, we created the temperature sensation estimation model by using a group of layered-type neural network (hereinafter referred to as N.N.) to which the skin temperature and its rate of change are input and the temperature sensation is output.

2.3 Thermal Comfort prediction model

We have decided to estimate the comfort and discomfort sensation by supposing that such sensations occur on the basis of the distribution pattern of the temperature sensation from daily experiences. The present model has been created with the layered type N.N. to which the temperature sensation distribution estimated in the preceding section is input, and the N.N. outputs the thermal comfort and discomfort.

3. Result

Fig. 2 shows an example of the estimation result obtained when the air conditioning is turned on. As a result of the comparison with the sensory evaluation by subjects, it has been verified that during both air conditioning and heating, the present technique can estimate the skin temperature with an accuracy of $\pm 2^{\circ}\text{C}$ max, the temperature sensation with ± 1 max for 11 stages of the temperature sensation balloting scale, and the comfort and discomfort with ± 1 max for 7 stages of the thermal comfort balloting scale, and that it can estimate the thermal sensation of the occupants with accuracy.

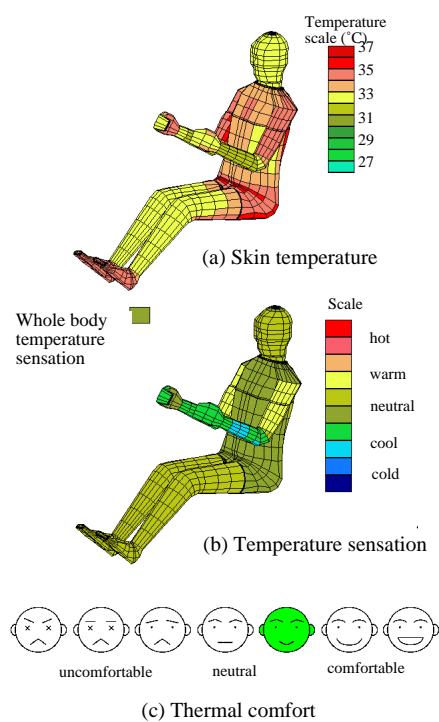


Fig. 2 An example of thermal comfort prediction.

References :

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- 3) Taniguchi, Y., et al. : SAE Tech. Pap. Ser., No. 920169

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