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Design for thermal sensation and comfort states in vehicles cabins

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ABSTRACT

This manuscript investigates the analysis and modeling of vehicular thermal comfort parameters using a set of designed experiments aided by thermography measurements. The experiments are conducted using a full size climatic chamber to host the test vehicle, to accurately assess the transient and steady state temperature distributions of the test vehicle cabin. Further investigate the thermal sensation (overall and local) and the human comfort states under artificially created relative humidity scenarios. The thermal images are calibrated through a thermocouples network, while the outside temperature and relative humidity are manipulated through the climatic environmental chamber with controlled soaking periods to guarantee the steady state conditions for each test scenario. The relative humidity inside the passenger cabin is controlled using a Total Humidity Controller (THC). The simulation uses the experimentally extracted boundary conditions via a 3-D Berkeley model that is set to be fully transient to account for the interactions in the velocity and temperature fields in the passenger compartment, which included interactions from turbulent flow, thermal buoyancy and the three modes of heat transfer conduction, convection and radiation. The model investigates the human comfort by analyzing the effect of the in-cabin relative humidity from two specific perspectives; firstly its effect on the body temporal variation of temperature within the cabin. Secondly, the Local Sensation (LS) and Comfort (LC) are analyzed for the different body segments in addition to the Overall Sensation (OS) and the Overall Comfort (OC). Furthermore, the human sensation is computed using the Fanger model in terms of the Predicted Mean Value (PMV) and the Predicted Percentage Dissatisfied (PPD) indices. The experimental and simulation results show that controlling the RH levels during the heating and the cooling processes (winter and summer conditions respectively) aid the A/C system to achieve the human comfort zone faster than the case if the RH value is not controlled. Also, the measured and predicted transient temperatures are compared and found to be in good agreement.

1. Introduction

Recently, more emphasis has been placed on optimizing the thermal comfort for vehicular occupants to provide better driving experience and more comfort features. Additionally, optimizing the cabin Air Conditioning A/C system can reduce the vehicle energy consumption; around 30% of the Mile Per Gallon MPG expenditure is related to the A/C system. Traditional climate control strategies classify the in-cabin modeling into; human physiological and psychological perspectives in addition to the compartment zone and the human thermal manikin approaches. However, the current experimental studies still deal with subjective observers and in rare cases thermal manikins. Experimental work aided with visualization tools such as infrared thermography can help in integrating the proposed models with the actual cabin conditions [1].

The control of the cabin's thermal conditions is still challenging due to such systems' fast transient behavior that complicates the prediction of the optimum settings to achieve thermal comfort. Such transient behavior is due mainly to the short trip durations, where 85% of trips involve an average distance fewer than 18 km and with time durations from 15 to 30 min. Hence, through this period the passengers do not achieve the thermal comfort range [2]. Further complications are due to the non-uniformities associated with the in-cabin thermal environment, which is mainly caused by the air temperature distribution, the solar flux, and the radiation heat flux from the cabin surrounding interior-trim surfaces. In addition to the psychological as well as physiological differences among passengers that also plays a significant role. Furthermore, the multiple governing parameters of the cabin thermal comfort such as the solar incidence angle, the glass/glazing properties, the

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