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Computational Analysis Of Air Flow And Temperature Distribution In An Air Conditioned Car: A Review

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Abstract: *The thermal environment and air quality in a passenger car can affect driver's and passengers' health, performance and comfort. Due to spatial and temporal variation of state variables and boundary conditions in the vehicle cab, the heating, ventilating and air-conditioning (HVAC) does not have to be designed to provide a uniform environment, especially because of individual differences regarding to physiological and psychological response, clothing insulation, activity, air temperature and air movement preference, etc. Therefore the system should be able to generate preferred local environmental conditions, even on individual body part level.*

Spot, or distributed, cooling is an energy efficient way of delivering comfort to an occupant in the car. The present paper focuses on the design and experimental analysis of the energy efficient HVAC system with spot or localized cooling .Traditional vehicle air conditioning systems condition the entire cabin to a comfortable range of temperature and humidity regardless of the number of passengers in the vehicle. Localized cooling, on the other hand, focuses on keeping the passenger comfortable by forming a micro climate around the passenger. Spot cooling was achieved by strategically placing multiple nozzles in the vehicle directed at specific body parts. This paper focuses on the numerical study of the temperature field and air flow inside a passenger's cabin with different human load.

The main goal is to investigate the distribution of temperature and air flow with various human loads inside the passenger compartment in the steady-state conditions.

Keywords: *Thermal Comfort in a Passenger Car; Temperature field in Passenger's compartment; Air-flow Conditions in Car's Passenger Compartment*

I INTRODUCTION

Air flow and temperature will be varied due to various human load inside the cabin . The principal factors affecting human thermal comfort are the air temperature, its relative humidity, the mean radiant temperature and the relative air velocity. The thermal comfort is a complicated problem because it is related to both psychological and physiological factors, the air-flow and temperature fields are identified as the most important factors. This makes it necessary to investigate the air-flow field and the temperature distributions inside the passenger compartment in the design process or to improve the thermal comfort conditions for the passengers.

The present investigation attempts to provide the fundamental understanding of localized cooling in its ability to maintain human thermal comfort by experimentally studying the impact of individual or combined local cooling streams on passenger comfort. The study uses Thermal Comfort rating as well as Thermal Sensation rating to record passenger comfort feedback while subjected to local cooling streams at various flow rates and temperatures in the vehicle environment.

II. PASSENGER THERMAL SENSATION AND THERMAL COMFORT

Thermal sensation of individual body parts is different due to different properties and different sweating rate. Consequently, individual body parts have different sensibility for thermal sensations

1. Back, chest, and pelvis strongly influence overall thermal sensation, which closely follows the local sensation of these parts during local cooling.
2. Head region, arms and legs have an intermediate influence on the overall thermal sensation.
3. Hands and feet have the least impact on overall sensation.

PREFERABLE LOCAL MICROCLIMATE CONDITIONS

Main requirements regarding preferable combination of local air velocity and temperature the system should meet are:
To attain and keep local skin temperature within comfort range, which will give sensation of thermal comfort,
To penetrate natural airflow around the body,
To avoid draught or eye irritation,
To supply the breathing zone with fresh clean air.

III. SPOT COOLING

One of the limitations in delivery of cooling to the occupants using current HVAC systems is that a significant portion of compressor work is expended in cooling the large thermal mass of the vehicle. The cooling requirement of a passenger is about 1-1.5Met (100-150watts). The total amount of energy spent in cooling a 1-1.5 Met individual is disproportionately large. A focal source of air delivered as a diffuse stream distant from the occupant from large HVAC vents causes the airflow to not reach the occupant at optimum desired velocity for comfort. In the spot cooling approach, airflow is delivered in a distributed fashion. By going to distributed airflow delivery much higher air velocities are achieved around the occupant. Delivery of cooling is much more direct and instantaneous on the body part of significance. In HVAC systems designed with spot cooling, it is possible to efficiently shift the focus of comfort delivery from maintaining a comfortable cabin to maintaining a comfortable occupant.

According to Standard ISO 7730, the local discomfort can be evaluated by the index of predicted percentage of people dissatisfied due to draught (DR). This index is applicable in steady-state moderate indoor environment for sedentary (~1 Met), thermally neutral persons dressed in normal indoor clothing, but without possibility of control over the air velocity/ temperature. Percentage of dissatisfied of 20% is stated as upper allowable limit. DR is calculated from local air temperature ta (°C), local air velocity va (m/s) and turbulence intensity TU (%) [8, 12]:
However, moderate conditions rarely occur in passenger car during the transients and DR cannot be extrapolated for elevated temperatures, therefore different models and criterion s are needed.

IV NOZZLES- LOCATION AND AIRFLOW:

The location and directivity of the nozzles were key to the success of spot cooling. The design considerations that were taken into account for spot cooling were the following: a) Local control had to be provided to the occupant to direct the nozzle towards and away from the body; b) Each spot cooling technology had to work for ten percentile to ninety percentile of the population. To be effective in delivering cooling the nozzles had to be close to the passenger. Due to occupant size and seat position variation, airflow spread on the body dictated that a minimum nozzle standoff distance be maintained from the occupant..CFD analysis was performed to locate the nozzles for cooling of each targeted body part. . The nozzle diameters were determined by air exit velocity considerations. The nozzle locations and nozzle velocities were dictated by the cabin air entrainment dynamics, airflow spread, the circulation pattern induced by the nozzle flow and the range of body surface impingement, velocities well tolerated by the occupant. CFD analyses were very useful in optimizing the nozzle location and evaluate the sensitivity of nozzle directivity on cooling performance.

Figure 2- shows. The overhead local cooling nozzles. For the passenger side with the manikin in place, four nozzles are trained at the manikin. The inside two nozzles are aimed at the face of the manikin and the outside two nozzles are aimed at the chest of the manikin. Similar arrangement of nozzles is made for the driver. The 29 °C EHT Equivalent Homogeneous Temperatures (EHT) in car temperature was selected as the optimal elevation level due to the fact that, if any lower, it will not provide meaningful energy saving to the HVAC system by way of compressor, and if any higher, it will surpass the capability of the present day thermo electric devices to provide local cooling.
each of the local cooling locations was examined under two airflows and two discharge temperatures that were estimated to contain the optimal parameters.Comfort riders and manikin were employed to assess the effectiveness of the local cooling and to optimize the delivery of local cooling airflow and discharge temperature.

Table 1. Airflow and Temperature Matrix for Individual Locations (“L” and “H” represent “Low” and “High”, “F” represents “Flow” and “T” represents “Temperature”. Footnotes represent body parts)

1. FACE COOLING:

Airflow from the front face cooling nozzles was directed towards the lower face of the passenger. Two different options were investigated for face cooling a) nozzles located in the front on the headliner and b) nozzles located in the rear in the seat head rest.

2. CHEST COOLING

Chest cooling nozzles for the front passengers could be mounted in two ways a) symmetrically with respect to the occupants on the headliner and roof console, and b) asymmetrically both on the A pillar or cabin frame.

V. CONCLUSION

An overview of preferable micro climate conditions in warm indoor ambient is given in this paper. The data presented here are based on numerous experiments with human subjects under different ambient conditions. Focus was on combination of air temperature and local velocity of airflow in the region of head and upper body, as thermally most sensitive parts of human body. The results showed that values proposed by standards for thermal comfort, generally used for assessment of indoor thermal environment, could be too restrictive. Preferable conditions are shifted towards higher air velocities. Furthermore, micro climate parameters that will provide thermal balance of the passenger's body with the surrounding (cab interior) and thermal comfort could not be presented by single value, but by the range of values. The chosen combination of the values will be dependent of individual preferences and local and overall micro climate conditions around different parts of the body. The chosen combination of the values will be dependent of individual preferences and local and overall micro climate conditions around different parts of the body. This means that the system must allow precise regulation of local air temperature and velocity in several zones around each passenger's body. Based on the fact that vehicle air-conditioning system should cool the occupant, not the entire passenger compartment, energy saving potentials of individual localized control of airflow parameters could be achieved by increasing the average air temperature in the cab. In the same time, higher air velocities would The temperature distribution and keep heat loss from the body within the comfortable limits. Of course, air discharge must be under full control of the passenger. air flow distribution were simulated in passenger car cabin using CFD analysis in this current investigation. It revealed that the developed CFD model accurately predicted the temperature distribution and air flow distribution in passenger car cabin. The systematic CFD method proposed in this present investigation is may be used to study temperature distribution and air flow distribution for different car models.

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