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Car Cabin Thermal Accumulation Analysis of At Various Points

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***Abstract*—**Car cabin heat is the major problem in many countries especially in India. Car owners are facing problems where the temperature is extremely high in the car cabin when they are parked directly under the sun during the summer season. The accumulated heat inside the vehicle cabin is affecting many interiors such as the vinyl materials of the dashboard, the leather covers and the electron IC- components. Also, it represents an uncomfortable operating period for the passengers. The temperatures inside the car can go as high as 60°C and surface temperatures up to 80°C during summer making the persons inside the car uncomfortable, Moreover, the car interior (seat cover, dash board etc.) can also have aging problem and bring damage to other goods present in the car. Therefore cooling of car cabin will result in increasing the durability of interiors of the car; will bring comfort to the persons inside the car and results in minimizing the Air conditioning load. In the present study, experimental and numerical analyses were conducted. The experimental results were obtained from measurements on a car parked unshaded area. Four different cases had been investigated consisting of full windows closing case, windows opening settings by 1cm, windows opening settings by 2cm and sun shade usage case. The temperature at 8 different locations inside the car had been recorded initially and 4 maximum temperature areas in the car have been identified and analyzed. Natural circulation take place with large scale cavity due to natural heat transfer from the dashboard and the rear windshield. The drop down of the front side windows by 20mm caused reduction in the front air gap by 18%. The sunshade on the front had considerably reduced the heat accumulation inside the cabin, where the dashboard surface temperature dropped by 23% and the maximum air temperature was found to be 25% lower.

***Keywords*—** Vehicle cabin comfort, thermal analysis, cars ventilation.

I. INTRODUCTION

Many car users face the same problem of hot car cabin when the car is parked under direct sun light. The heat under such parking condition causes the car cabin and interior temperature to increase up to 80°C average. The accumulation of thermal energy inside the vehicle with undesired temperature rise would cause the interior parts to degrade because they normally are subjected to wear and tear. Degradation may shorten the life span of the various components inside the car. Passengers are also being affected with the thermal condition inside the vehicle itself. The car user is forced to wait for a period of time around 2-5 min before getting into the car to cool down the interior condition either by rolling down the window or running the air conditioner at high speed that really affect the fuel consumption. In developing the automotive heating/ventilating/air conditioning, HVAC systems, Computer Aided Engineering could be used to enhance the design efficiency.

A vehicle thermal comfort model to evaluate the performance of many (HVAC) system designs [Han et al. (2001)] [1] has been developed and CFD technique used to predict the local thermal comfort as a function of air temperature, surface temperature, humidity, direct solar flux, as well as the level of activity and clothing type of each individual. The thermal comfort in a car cabin through measurements of the flow velocity and temperature at different operating conditions using equivalent temperature index [Martinho et al. (2004)] [2]. Results were obtained from measurements on a life-size laboratory model with and without thermal mannequin by scanning the velocity and temperature at various planes inside the cabin.

Fujita et al. [3] have developed a numerical simulation to predict the thermal environment of a simplified car cabin model under different air-conditioning conditions. Their analysis took into consideration of the effect of solar thermal irradiation, the heat conduction among the car materials, the 49 ventilation inside the instrument panel, and the air leaks that take place through the gaps of the interior parts. At the same year, Kataoka and Nakamura [4] have investigated the variation of cabin air temperature under prescribed cooling cycle condition and solar thermal irradiation on the wall to consider the transient and actual driving conditions. Through experimental means, Akiko et al. (2007) [5] of Honda R&D have studied the effect of cabin environment on the driver fatigue. The subjective experiments were carried out on a chamber in order to develop the driver's fatigue model. Hodder and Parsons (2007) [6] have investigated the relation between simulated solar radiation and thermal comfort. In this work, three effects were studied, (a) the intensity of direct simulated solar radiation, (b) spectral content of simulated solar radiation and (c) glazing type on human thermal sensation responses. They concluded that increase in total intensity of simulated solar radiation rather than the specific wavelength of the radiation is the critical factor affecting thermal comfort.

Some solutions are suggested in this topic. Toyota HVAC designers have suggested the installation of Solar Powered Ventilation System which uses an electric fan to draw outside air into, through AND out of the cab in once the inside temperature reaches 68° Fahrenheit. This will lower the cabin temperature to near the outside ambient temperature to help

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make the cabin more comfortable when re-entering the vehicle. It must be turned on prior to leaving the vehicle and cannot perform cooling such as with an air conditioner. The “Car Cabin Temperature Control” is the result of the “Thermal Comfort Engineering”. Many automotive manufactures sooner or later will adopt techniques which now days can be seen only on the luxury cars due to the considerable cost involved. This concern on the comfort level of the occupants in the car, due to the internal climate, needs additional systems implementation to provide desirable level of comfort. The present study aims to provide further information on the nature of the thermal behavior as the solar heat transfer to the car cabin. The objective of this study is to investigate the temperature distribution on the surfaces inside the car cabin. The model is prepared using Solidworks software. The experimental environment experimental measurement was located in the same place and same orientation during the entire experimental measurement program, as in Fig. 1

II. EXPERIMENTAL METHODOLOGY

Four different parking conditions has been studied under normal parking condition i.e., windows glass openings, front shield shading. The cases are described in Table 1. The measurements were taken 3 times for three days to reduce the uncertainty. For each day, the measurements started at 9.00 am till 4.00 pm and the data was recorded on 1 h step interval.

The main parameter in the experimental measurements is the temperature. The ambient temperatures at 8 different spots inside the car cabin were selected initially to identify the maximum temperature accumulated zones inside the car cabin. Four maximum temperature locations were selected for the surfaces temperature distribution in the cabin under different setup. The temperature variations at 8 locations in the cabin have been traced and recorded using K-Type thermocouples and a data logger (FLUKE 2640A). This data logger is capable of simultaneously recording 20 temperature readings through its channels. Its temperature readings have a precision of 0.1°C. Some of these locations where thermocouples are attached include the dashboard, the cabin ceiling (under roof), on left passenger seat, the front and rear windscreens, the side window, the front and backseats.

TABLE I. Description of experimental measurement condition.

S. No	Experimental Conditions
1	All windows are closed
2	All windows were rolled down for 1 cm
3	All windows were rolled down for 2 cm
4	Sunshade is placed under the front windshield

III. EXPERIMENTAL SETUP

Nearly 5:1 reduced scale experimental cabin model has been built based on the measurement of a car. For simplicity, the front and rear compartments of the car model have been neglected. However, the dashboard and four seats have been included for the completion of investigation. Fig. 1 shows the actual model after assembly.

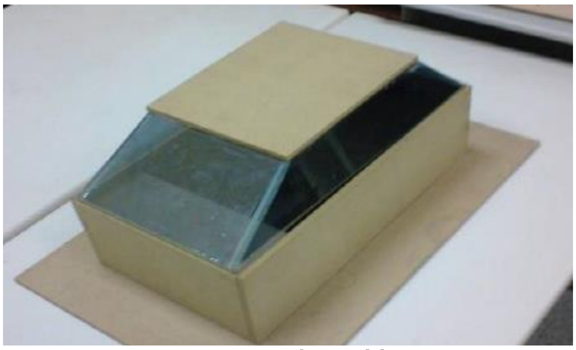

Fig. 1. Car cabin model.

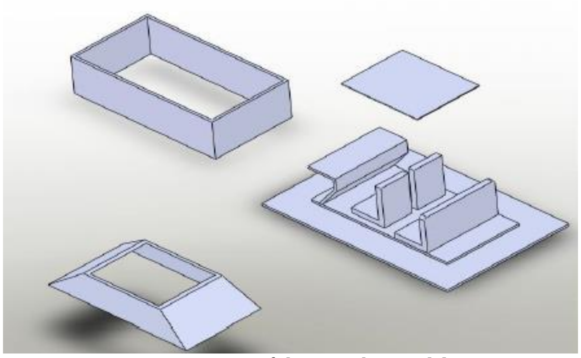

Fig. 2. Interior of the car cabin model.

The front and rear tilted angles are 35° and 45°, respectively. The glass composing the side windows were calculated through Solidworks, a 3D design software. The interior of the cabin model consists of a dashboard and four seats. The dashboard and side panels were all made of wood. All the seats are covered with resin seat cover. The engine and rear compartments of the model were neglected as well. The internal arrangement is shown in Fig. 2.

IV. DISCUSSION

All of the surface temperature measurements results inside the car have shown that the highest temperatures are recorded in the spots near the under-roof, front glass windshield dashboard and rear wind-sheet. The peak irradiation was recorded between 12:00-2:00pm depending on the cloud conditions. The spots exposed directly to transmitted solar radiation has accumulated thermal energy more than the interior spots subjected to convective heat transfer.

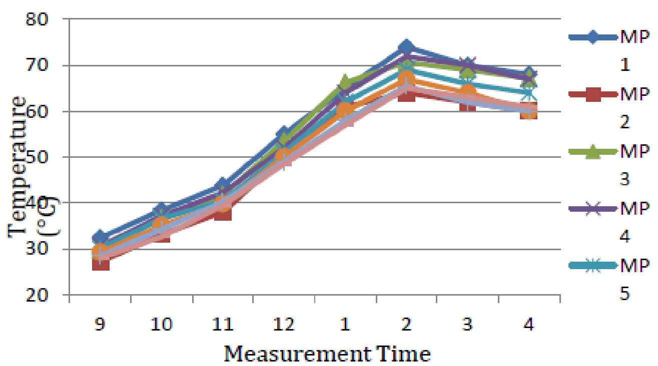

Fig. 3. Temperature distribution at 8 spots, case 1.

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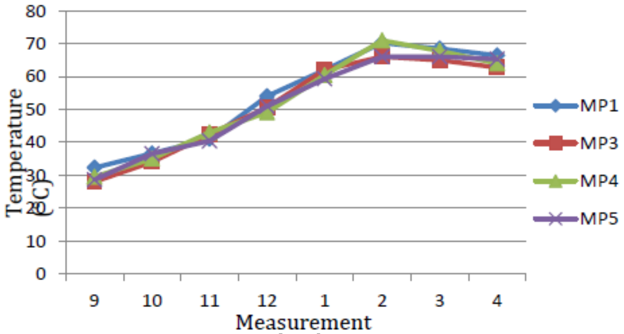

Fig. 4. Temperature distribution at 4 spots, case 2.

In the results shown in Fig.3, 8 different locations has been investigated consisting of dashboard, on left passenger seat, under-roof, front wind-sheet back wind-sheet on back seat side window and side window. The experimental data has been taken with all window closed. The temperature starts rising at 11am and shows steep rise till 2pm. The maximum temperature is observed at 2pm depending upon climatic conditions. From these 8 locations 4 spots has been identified and further investigated for temperature variations with some changes in the setup.

Fig. 4 reveals that 4 spots i.e., dashboard, under-roof, front wind-sheet and back wind-sheet has been investigated with all windows are rolled down by 1cm. it has been found that expect front wind-sheet there is a slight reduction in the temperature mainly under-roof because of possible circulation of air.

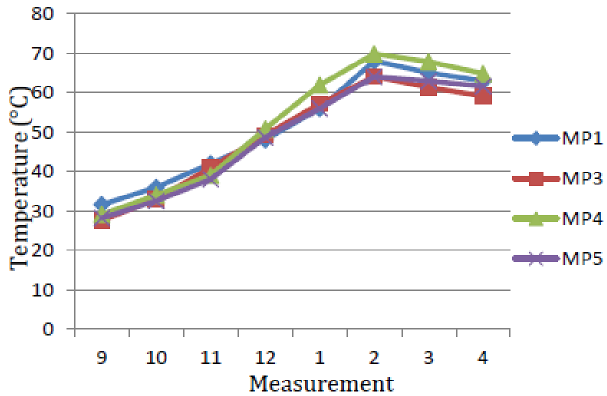

Fig. 5. Temperature distribution at 4 spots, case 3.

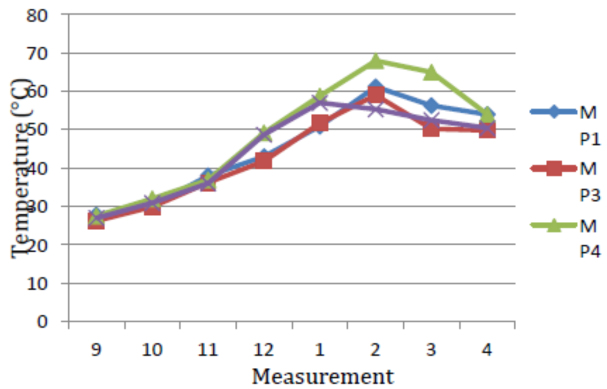

Fig. 6. Temperature distribution at 4 spots, case 4.

The result of temperature distribution for 4 spots with windows rolled down by 2cm is shown in Fig. 5. Again there is slight variation in the temperature of front wind-sheet but there is measureable change in the other 3 measuring points. This is because of the openings caused circulation between the warm air inside the cabin and the ambient air. The maximum change in temperature was observed under roof where temperature reduced by approx. 6.5°C.

Fig.6 represents the results when windows are closed completely but sunshade underneath the front windshield, reduced the temperature on the dashboard surface considerably. The maximum temperature at dashboard in case 1is 74°C while in case 4 it is reduced to 51°C. Moreover there is a considerable change at all the measuring points discussed in other cases.

V. Conclusion

Study on the ‘car cabin comfort’ had been carried out experimentally. The measurements were carried out during the sunny time in the month of July under non shaded parking environment. The effect of all windows closed, windows are rolled down by 1cm and windows are rolled by 2cm and using sun shade underneath the front windshield is discussed and compared. The window, when rolled down, enhances the convection heat transfer inside of the car. Hence this method is capable of reducing the average maximum front ambient air temperatures by 6°C. The usage of sunshades only manages to reduce the maximum temperature by approx. 23°C at the dashboard. It has significant effect in cooling of the car interior surfaces’ temperatures.

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