

Study of Excessive Cabin Temperatures of the Car Parked in Oman and its Mitigation

Sudhir Chitrapady Vishweshwara and Jalal Marhoon AL Dhali

Abstract— High solar global insolation in Oman causes typically very high ambient temperature especially during summer season. During summer if the cars are parked directly under the sun, cabin inside the car will experience a kind of greenhouse effect this will lead to higher cabin temperature and cause problems inside the car like color fading and seat upholstery wear and tear and even cause damage to other cabin elements. The high temperature prevailing inside the vehicle parked under the sunlight is definitely unreceptive to the occupants when they arrive to take a drive. This paper demonstrates a temperature measurements carried out inside a sedan car which was parked under the sunlight to study the temperature pattern inside a parked car. Further investigation was carried out to minimize the temperature rise inside a parked car by developing and installing simple ventilation systems with a set of fans to purge the hot air trapped inside the cabin. A simple ventilation system was developed by means of two fans which drove out the hot trapped air and a secondary fan to cool down the temperature inside the car by providing fresh air for limited time. A solar photovoltaic panel was used to drive the ventilation system which made the ventilation system completely independent from the car power source. The experimental investigation revealed that, on a bright sunny day, the vehicles cabin air temperatures was approximately 22⁰C higher than the ambient temperature, while with the developed ventilation the difference between the cabin and outside air temperature was reduced by 50% approximately.

Keywords— Cabin Air Temperature, Parked Car, Radiation, Solar Photovoltaic and Ventilation

I. INTRODUCTION

The quantum of solar energy density in Sultanate of Oman may be considered at par with other countries which are accounted as highest in the world. High solar energy density is available in most part of the Sultanate of Oman. According to a Study on Renewable Energy Resources in Oman carried out by Authority for Electricity Regulation, Oman [1] the average solar global insolation in the country varies from 4.5 to 6.1 kWh/m² per day. With yearly variation in average amounts to about 4 kWh/m² per day for January to about 6.5 kWh/m² per day for May in which the solar global insolation is highest.

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The above data clearly indicate that solar resources in Oman are among the highest in the world. Unfortunately, this quantum of solar radiation energy invariably contributes towards a very dangerous phenomenon called greenhouse effect inside the vehicles cabin parked under the scorching sun. Vehicles parked under the daylight experience sharp rise in the cabin temperature due to the trapped solar radiation [2], [3]. The solar radiation which enters inside the car is to some extent trapped by the wind shields of the car hence contributing to the greenhouse effect. It's often seen that, vehicles which are parked in the sun especially during hot summer day, experience drastic rise in the cabin temperature, especially steering wheel, seats, dashboards record temperature almost double that of ambient outside temperature.

So it's important to provide a positive air exchange across the vehicles cabin without using vehicles stored energy (battery) and also without causing any threat to the vehicles security. In this regard this research focuses on the design and development of a simple standalone ventilation system driven by the solar energy to provide necessary air exchange across the cars cabin. Hence an investigation with the aim to develop a simple ventilator, which inhales fresh air from outside into the car cabin and purges hot air to the outside, was carried out. It's envisaged during the sunny day, solar energy can be used to run the ventilator fans and associated systems.

In recent years the private passenger vehicles density in Oman has seen a tremendous jump, as it's the only convenient and important modes of transportation for most of the people compared to thinly available public transport. The high density of private passenger vehicles has resulted in the paucity of parking space. For instance, the need for of additional parking spaces are getting more significant especially at the government offices, universities, colleges and shopping area. Alas the available shaded parking space are no match for the existing number of vehicles, hence the alternative choice for those who are unable to park under shade is to park in an open parking space.

It's very evident that we are more concerned about our life as well as our loved ones while we are driving the vehicle, similarly it's also very important to maintain a healthy environment inside especially when the vehicle is parked under the sun. Hence vehicle cabin occupant's health and safety issue is of paramount importance. Few studies have been reported earlier on the issues and matters concerned with

elevated temperatures in the parked car and few of the findings are well reported by Grunstein *et al.*, [4] and by McLaren *et al.*, [5].

The studies carried out in Malaysia by Basar *et al.*, [6], indicate that vehicle which are parked under the sunlight has shown temperature rise inside the cabin approaching 60°C. This higher temperature will make the driver and passenger more uncomfortable while entering the vehicle. Moreover, the vehicles cabin would face aging problem and may damage to the goods kept in the vehicle. According to the findings of Saidur *et al.*, [7], in USA, every year many children die of (hyperthermia) heatstroke after being left unattended in vehicles. They report that from the year 1998 to 2002, the average number of children died of heat stroke was 29 persons per year. In 2003, this number increased to 42 and 35 persons in 2004. Annually, hundreds of children experience varying degrees of heat illness from being left in cars. Studies of Saidur *et al.*, [7] suggests to use auxiliary ventilation system to increase the air flow rate and decrease the steady state temperature inside the vehicles compartment, their experimental results show an reduced temperature inside the vehicle compared to the non ventilated cabin. Similar experimental studies carried out in the Australia show that typically 20°C hotter inside a parked car compared outside temperature on a hot summer day, in such condition children or pets left in such a parked car for periods of the order of 30 minutes suffer heat stress and a number of deaths are reported in Australia each year as a result [8].

Passengers are also being affected with the thermal condition inside the vehicle itself. More often it is observed, that the passengers and drivers are 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 windows or running the air conditioner at high speed that which will results in higher fuel consumption [9]. Jan Null [10] carried out studies on the excessive temperature in enclosed vehicles at Department of Geosciences of San Francisco State University, USA. This study was carried out with reference to the accident of children being left unattended in the closed vehicles. The aim of the study is quantify vehicle temperatures and temperature changes with time under a variety of meteorological circumstances.

The study used temperature sensors mounted on the two types of vehicles parked under the heat of the sun. The first vehicle the window was fully closed and the other with window “cracked” i.e., open approximately 1.5 inches (3.8 cm). the study revealed that there was fast buildup of temperature in short period of time in a fully closed car, while in the “cracked” window car the build-up of temperature was little slower. But the results concluded that both cars reached dangerous temperature level after long hours even if the other car windows are ‘cracked’ hence it may still can cause accident if there are children left inside unattended. From Jan Null [10], studies, it can be understood that with partial opening of windows, only minor mitigation is achieved. Russell Manning *et al.*, [11] also studied steering wheel temperature rise during the parked condition. It was reported

that steering wheel was hotter than the inside cabin by 7.5°C.

In recent past there have been studies of ventilation systems in the parked car which are driven by solar energy. One such works is of John *et al.*, [12] wherein they developed system to reduce the temperature inside the car up to 20°C. The ventilations systems constituted a set of fans and to make sure that the fan gets continuously power supply they have installed the solar panel on the moon roof. However, the car and ventilations system are unsafe safe due to possibilities of theft and when it rains, the water may enter in to the car. Keeping all the findings in mind, study of excess temperature rise in a car parked under the sunlight its mitigation was carried out and findings are reported in this paper.

In order to mitigate the excess temperature rise, a simple proof of concept of solar powered cabin ventilation system was developed and studied at the Caledonian College of Engineering Oman campus. This paper reports the experimental findings of the simple real time tests conducted with developed ventilation system in a car and also analyze the results with reference to the readings obtained during testing.

II. EXPERIMENTAL SET-UP

A. Temperature measurement setup

In order to measure the temperature inside the car, six RTD thermocouples were used, which was wired to a palm size Digital Multimeters (UNT-T make). The Fig. 1 shows the multimeter and thermocouple assembly which was fixed on to the car roof. Each thermocouple was hung vertically from the roof top at distance of approximately 60 mm from the roof top. Each of the thermocouple is strategically mounted such that car cabin temperature at various locations can be recorded without obstructing drivers or passengers.

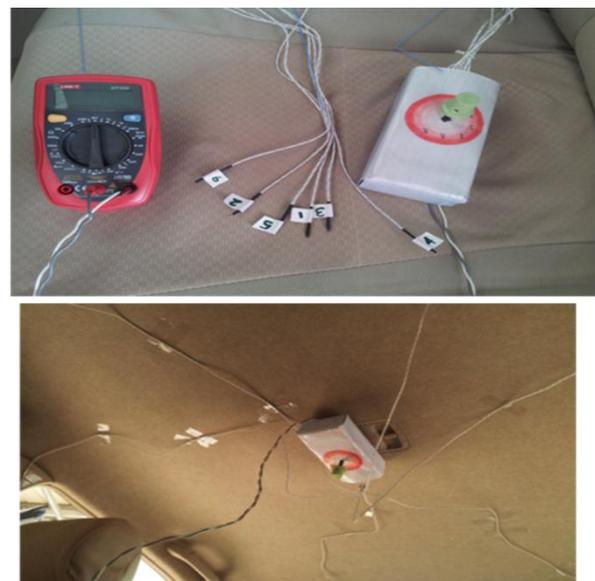


Fig. 1: Thermocouples wiring and temperature measuring setup



Fig. 2: Ventilation system mounted on the rear end of the car

B. Scheme of Experiments

In order to measure the car cabin temperature, the car was parked in an open parking space and care was taken such that there was no interference from local shadows during the measurements. A white color, 2007 make, Toyota Corolla of was chosen for this experimental work. There were no medications done on the chosen car, and all the factory settings were retained all throughout the experiments. While experiments were carried out, the car was parked at a chosen parking space and direction for all the days so as to obtain consistency during experiments. In the current research paper the filed experiments for most of the days in the month of May 2013 is discussed and analyzed. A Constant solar global insolation was assumed during the measurement periods, which was indeed evident as the ambient temperature was considerably similar for all the days of experiments. In order to mitigate the rise in car cabin temperature a standalone ventilation system was developed and fabricated which was driven through solar PV power.

In order to facilitate ventilation inside the car, the necessary circuit and controls supplying fresh air in to cabin was developed and installed on to the car. The ventilation system essentially consists of a pair of suction fans and a blower to blow in the fresh air in tandem. In order to drive the suction fan and blower fan in tandem, a timer circuits was designed and developed such that the suction fans was driven for Two and half minute and the blower fan was driven for half minute in a cycle of 3 minutes. In order to drive these power circuitry elements, commonly available solar PV panel of peak power rating of 10 Watts of dimension of 335 x 235 mm was used. The fan and blower assembly along with circuitry was installed inside the car cabin, such that it mounted on the tray behind the rear seat as shown in Fig. 2. The necessary air circulation pipes were installed which contributed for air exchange process. However, a great care was taken along with necessary safety precautions such that car cabin is secured and functionality of any part of the car is not compromised.

III. RESULTS AND DISCUSSION

Host of experiments were carried out in order to arrive at a conclusive understanding of temperature rise inside a parked car. The scheme of experiments was so chosen so to meet the objectives framed under the study. In ordered to study the performance of the developed ventilation system, car was parked under the sunlight continuously such that ventilation system was switched on every alternate day during the days of experiments. The ambient air temperature was continuously measured during the experimental hours. The most of experiments were carried out during the summer months in Oman and in this paper the findings are reported for the month of May as the solar global insolation is its peak. From the set experiments conducted, as a sample, two consecutive days are presented in this paper.

Fig. 3, Fig. 4 and Fig. 5 represents the record of front, middle and rear of the car cabin air temperature which was averaged with two thermocouples readings for 2nd and 3rd of May 2013. On the May 2nd, the car was parked at the desired parking space at 8.00 AM and readings for each hour were recorded from 9.00 to 17.00 hrs. During the experiments car was parked with all windows up and ventilation turned on, contributing for air exchange across the car cabin. While on 3rd May 2013 the same car was parked in the same parking space at 8.00AM and hourly readings were taken as before but with ventilation turned off.

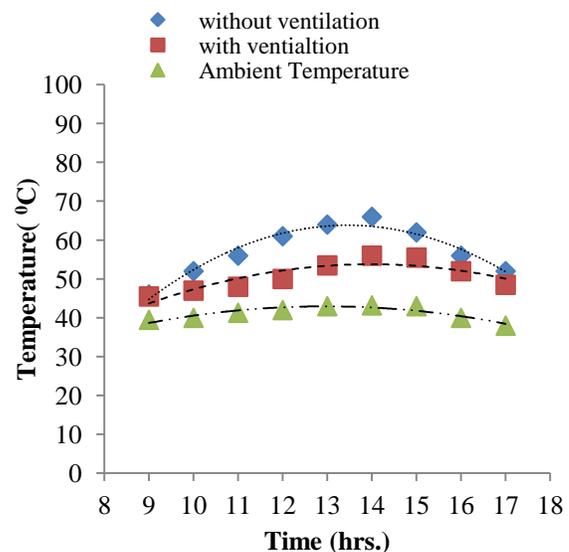


Fig. 3: Temperature measured at the front of car cabin for two consecutive days

Fig. 3 depicts the cabin air temperature time profile at the front end of the car cabin for above said two consecutive days. There were two thermocouples which were mounted in the front end of the car cabin, one at the left side and other one in right side and the average of the two is considered for

discussion. It was observed that the cabin air temperature rose sharply for the first four hours of parking.

The maximum of 66 °C air temperature was recorded at 14 hours when the car was parked without ventilation system, while the two days average ambient temperature at the 14 hours was 43.2°C. Interestingly, when the car was parked with ventilation system the air temperature was 56 °C at the same time period. Since the car windshield allows large amount of solar radiation to penetrate through it and blocks the reflected ones, this contribute for air temperature rise as the materials such as dashboards and seats present in the front cabin absorb the radiation and release heat to the cabin air.

Fig. 4 represents the temperature time profile, of the cabin air temperature at the middle portion of the car cabin. Since side windows of the car are offers lower area for radiation to enter compared windshields in the front and rear, hence they allow only limited exposure for sunlight and radiation to enter the cabin. There were two thermocouples which were mounted in the middle row of the car cabin, one at the left side and other one in right side and the average of the two is considered for discussion. The temperature rise in the middle row of the car was observed to be lower than the front and back rows with in the car cabin. However the temperature rise cannot be ignored as the cabin temperature was 10°C higher than ambient temperature at 14.00 hrs when car was parked with ventilation systems. However, on the previous day when car was parked under the sun with the ventilation turned on the middle row car cabin air temperature was 20°C higher than the ambient temperature for the same hour. Even though air temperature rise at the middle row of the car is not predominantly due to the direct solar radiation entering through side windows, but it may attributed for the natural convection heat transfer from the front and back side of the car cabin.

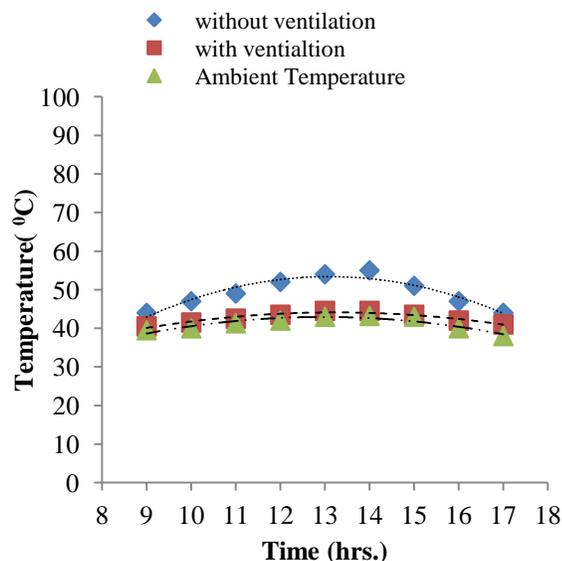


Fig. 4: Temperature measured at the middle of car cabin two consecutive days

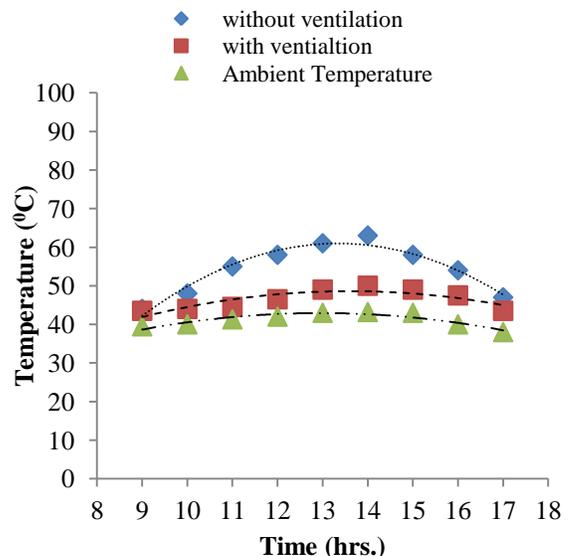


Fig. 5: Temperature measured at the rear of the car cabin two consecutive days

Fig. 5 shows the cabin air temperature time profile for the rear end of the car cabin, as explained earlier two thermocouples were used and their average readings are considered for discussion. The aperture area available for radiation to penetrate through the windshield at the rear end of the car is lower than the front side. Hence the solar radiation entering the car rear windshield is relatively lower than the front side, hence contributing lower temperature rise compared to the front. The record of temperature also testify the above statement and the maximum of 63 °C air temperature was recorded at 14 hours when the car was parked without ventilation system, while the two days average ambient temperature at the 14 hours was 43.2°C. Interestingly, when the car was parked with ventilation system the air temperature was 50°C at the same time period. The high temperature prevailing inside the car parked under the sunlight is definitely unreceptive to the occupants when they arrive to take a drive. Although this intolerable car cabin conditions prevails for a relatively shorter period of time, but it cannot be ignored as it causes a serious health threat for children or pets left inside the car. It was consistently observed for the all the days of experiments maximum cabin air temperature was observed at 14.00 hours of the day. It was indeed observed that for most of the days the lower cabin temperature was recorded when car was parked with ventilation system turned on vis-à-vis to that of without ventilation system.

Fig. 6 depicts the cabin air temperature readings recorded at the front side of the car for 14.00hrs for consecutives days for the month of May 2013. It was seen that, the difference between maximum cabin air temperatures with ventilation and without ventilation systems was very much similar for all the days of the experiments. However it was interesting to note the average difference between car cabin temperature and ambient air temperature was consistently around 12°C when car was parked with ventilation system turned on. However, the average difference between the temperatures rose to 21.°C when the ventilation system was turned off. The ventilation

system developed was effective enough to bring an air exchange such that the temperature difference between ambient temperature and cabin air temperature was nearly reduced to nearly just over half compared to the temperature difference without the ventilation.

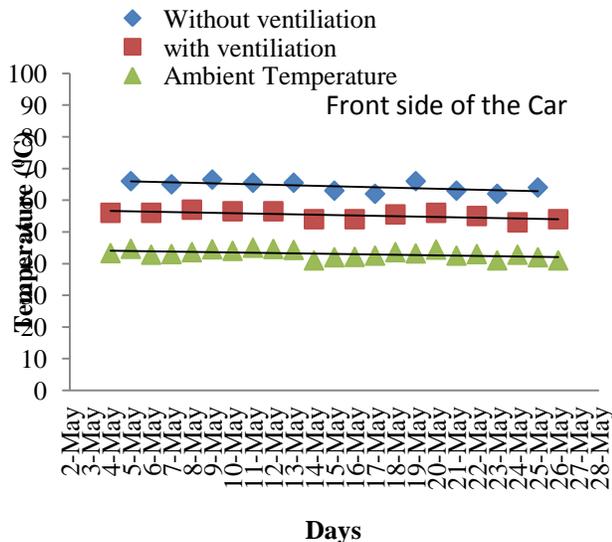


Fig. 6: Temperature measured at the front of car cabin at 14 hrs for consecutive days for the month of May

IV. CONCLUSION

From the above mentioned experimental investigation, it was evident that the solar PV powered ventilation system was successfully performed when tested for its intended application. Thus temperature time profile inside the car parked under the sunlight was studied and ventilation system developed to perform air exchange was successfully tested and the results show that the ventilation system was successful in mitigation of rise in cabin temperature. The results of test show that the rise car cabin temperature with ventilation system was lower compared to that without ventilation system. The peak cabin air temperature difference with reference to ambient air temperature was nearly halved with the aid of developed ventilation system. Besides that, cabin air temperature was found higher at the front end of the car cabin as the car windshield allows the larger quantum of radiation to enter the car cabin. Alas the cabin air temperature was found to be far away from the region of human thermal comfort and it calls for further study for mitigate the temperature rise. Although the developed ventilation system aid in reducing the cabin air temperature to certain extent, but much such effort is required to bring the temperature rise with in the acceptable level especially meeting the climatic condition of Oman.

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