Paper ID 640

# Controlling Parked Vehicle Interior Temperature Using Renewable Energy

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**Abstract:** A parked vehicle cabin can be treated as a nearly closed volume. So, when an automobile is parked under sunlight the solar radiation heats the interior to extensive temperatures of above 60°C. These extreme temperatures reduce the cabin thermal comfort of the occupants, especially until the automobile's in-built cooling system brings the temperature to a comfortable level. The extreme temperatures in the cabin have also led to several heatstroke victims and even deaths of occupants in parked automobiles. These extreme conditions also degrade cabin materials. This research focuses on developing partly portable cooling equipment based on the vapor compression refrigerant cycle that is powered by solar energy for a car cabin.

The equipment was sized for a Suzuki Wagon R – 2015 automobile, based on the local heat loads that were gained in this research. Also, two Computer simulations were done to determine the cabin conditions with and without the designed equipment. Further verifications of these results were done by testing a prototype of the design.

The results from computer simulations and test results both confirm the reduction in cabin temperature to below 44°C. Further developments are necessary for this model to make the parked car cabin completely safe for occupants. With the current results gained using the prototype developed, the car cabin thermal comfort has increased by a huge margin, where the temperature has reduced from above 60°C to below 44°C. This paper focuses on the simulation segment of the research conducted.

**Keywords**: Heat distribution, Cabin cooling, Simulation

## Introduction

Automobiles are an essential part of human lives in the modern civilization. It is estimated that there are more than a billion passenger cars worldwide [1]. When these automobiles are parked outdoors thermal accumulation leads to several issues, out of which some are minor, and some major problems such as human deaths due to heat strokes while being in a parked car needs necessary attention of researchers to find proper solutions.

A parked automobile with all windows closed is nearly a closed volume. When such an automobile is parked outdoors, the solar radiation accumulates inside the cabin and the cabin temperature rises to extreme temperatures. The solar radiation reaches the cabin by direct and diffused solar radiation through windows and by the conduction of the absorbed heat by the automobile roof into the car cabin. Earlier researches as well as this research shows that the cabin temperature can reach to temperatures high as 65° C [2]. The heat accumulation inside such a car cabin can be so extreme that it has a possibility of leading to heat strokes of passengers [ 4].

The temperature increment is also extremely discomfort able for a passenger returning to a closed car cabin. The automobile's in-built air conditioner usually takes a few minutes to reduce the cabin temperature to comfort conditions recommended [6]. This is a minor problem that arises due to the heat accumulation in a closed car cabin. The major problem is the fact that the heat accumulation can lead to heat strokes, if a passenger is left inside a closed car cabin which is parked [5]. According to Llama et al, [6] When a human body is exposed to high temperatures or extreme heat the body first reaches heat exhaustion. Heat exhaustion is caused by loss of water and electrolytes due to sweat. If unattended this condition could lead to a heat stroke [ 3].

## Research problem

The increment of temperature due to accumulation of heat in a parked closed automobile cabin.

## Problem Solution

The proposed solution is to run a solar powered partly portable air conditioning unit to cool the car cabin when it is parked, and engine switched off. The air conditioning unit is a portable equipment, with flexible ducts and window mounted duct end parts. The refrigeration cycle is based on the vapor compression cycle and R132-A is being used as the refrigerant.

One of the duct-end parts, mounted to the windows is to admit fresh air from the outside ambient air around the car. The air is circulated through the condenser and compressor and in to the second duct-end which expels the heated air to the outside. This is the cycle used to cool the condenser of the refrigeration cycle and to cool the compressor. The second air side cycle is in the evaporator side. Return air from the cabin is admitted into the evaporator chamber which is separated in the unit. Then the return air is passed through the evaporator into the car cabin. The return air in turn is cooled. Both these air side cycles of condenser cooling with ambient outside air and cabin air cooling with the evaporator are completed with 2 circulation fans on each cycle. During a power surge or if the temperature rise in the equipment is too high, the refrigeration cycle stops and dampers are used to open the return airline to the outdoors, and the fresh air into the cabin to control the heating. Once the equipment cools down or enough charging is achieved by the batteries the refrigeration cycle powers back.

## Methodology

A. Evaluation of heat distribution of the automobile cabin

Temperature data will be collected of the outside surface temperatures and the inside air temperature of the cabin. Then by using the outside air temperature readings a CFD simulation model of the car cabin for the worst scenario, which is where the temperatures gathered are the highest. The simulation is done in this case to determine the temperature pattern of the air inside the cabin

B. Simulation of cabin interior using Computational fluid dynamics (CFD)

The temperatures we obtained in the data collection stage was utilized to lay the basis for the CFD simulation. A sketch was generated that resembled the geometry of the cabin that we chose for testing. The necessary boundary conditions were assigned to the surfaces to accurately simulate a real-world environment.

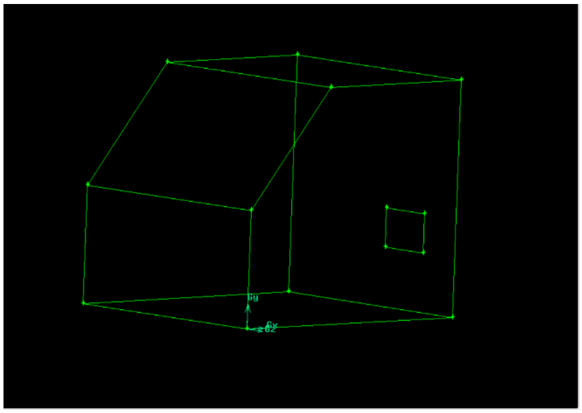

Figure 15: Geometry of cabin completed with GAMBIT

C. CFD simulations of the car cabin with the designed system

The next step to be followed is to simulate the conditions in the cabin after the air conditioning unit has been placed in the cabin. The unit will be placed in the rear passenger seat with an opening at the window to transport air to and from the condenser. After the completion of the simulation by using results from the post processing the areas with highest temperatures will be identified and the unit will undergo changes to both its physical and software components. In order to determine the changes, the air inside the cabin would undergo we decided to run simulations with the prototype positioned inside the car cabin. The basic settings from the previous iteration was carried into the new simulation and the car cabin geometry was subjected to changes to accommodate the prototype. The first change was to insert the velocity inlet to the cabin. This was done by making a diffuser that has a similar flow rate to that of the real-world example. The inlet was placed in the rear boundary condition and it was positioned close to the underbody of the car.

The heat load due to solar radiation is main contributor to the temperature rise in the car cabin. Therefore, it is of great importance that we employ a practical methodology to determine the heat gained due to solar radiation. The solution for this issue can be addressed using one of them mathematical models that is present within the Fluent software. The radiation can be virtually simulated using one of the models available in the selection menu. Rosseland, P1, Discrete transfer model, Surface to surface and discrete ordinates are the list of solar radiation models that can be applied for solar radiation problems. The model we chose was Discrete Ordinates (DO) radiation model. It is a model that is well suited for

- Automotive climate control applications
- Thermal comfort modelling scenarios in buildings

**Simulation Results**

A. Heat distribution without prototype

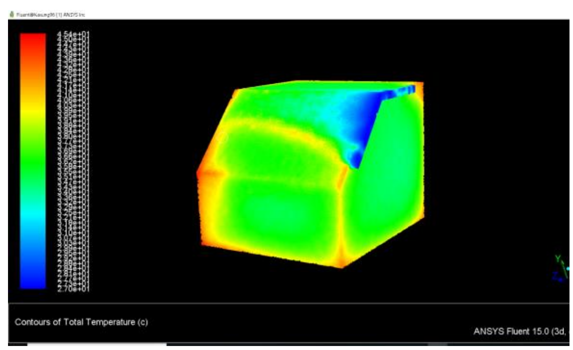


Figure 16: Isometric view, Heat distribution without prototype

The above figure is the representation the temperature distribution of the parked car cabin. The maximum temperature observed in this test result is 45° C. The edges of the car cabin seem to have accumulated more heat than the rest of the surfaces. The mean temperature of the surfaces was between 35 to 38 ° C. The roof, left and right panels showed a similar amount of heat gain and therefore had similar temperature ranges. The rear panel also showed similar thermal characteristics to other panels, but the centre portion of the surface shows a region which is transitioning to the yellow region which indicates that the temperature in that area is steadily increasing. A change in temperature is observed at the windshield which shows a mixture of temperatures. The temperature of the inner region has remained fairly constant at 32° C. The top right corner has received

some degree of solar irradiation as the pointed edge has a temperature higher which belongs to the yellow region which is analogues to a temperature range of 38 to 42° C. According to the result produced results we can see that the green region has formed a shape that has almost surrounded the lower temperature zone at the centre of the passenger compartment. The light blue region according to the settings that have been applied shows a temperature range that spans from 31 to 34 ° C. A green band which is the colour that represents temperature values 34 to 38° C has originated from the underbody and travels all the up to the midpoint of the windshield.

B. Heat distribution with the prototype inside the cabin

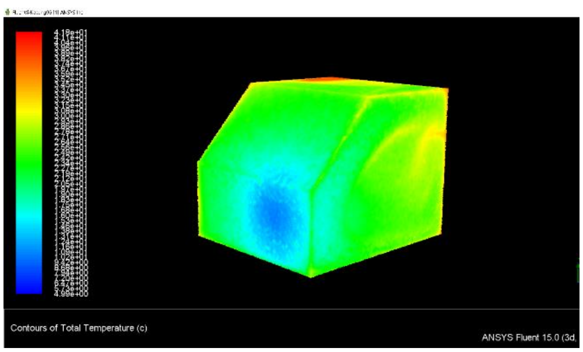


Figure 17 : Isometric View, Second iteration

The second iterations according to the figure shows a maximum temperature value of 42° C. The maximum temperature was obtained at the rear and a side panel surface. The whole volume is mostly covered in green which represents the temperature band from 21 to 26° C. The front panel has a large light blue patch that corresponds to temperatures between 13 and 20° C is due to the heat transfer that occurs between the cabin body panel and the chilled air supplied by the prototype. The interior temperature however is largely dominated by the green region which shows that the temperature inside the cabin has been reduced by the placement of the prototype. Before the simulation was started the interior was initialized at a temperature of 32° C. The prototype according to the simulations has reduced the interior temperature by about 3° C.

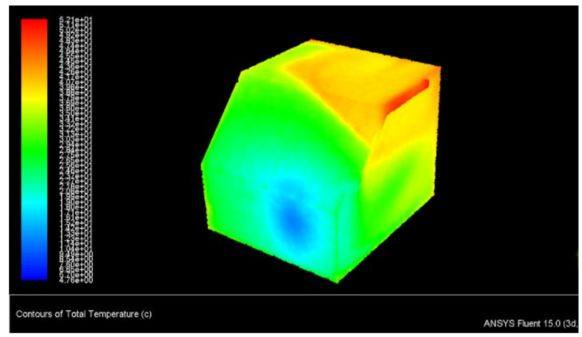


Figure 18 : Isometric View, Third iteration

The final iteration of the simulations was done with a window duct in place which acts as an outlet for the air inside the system. The window is placed close to the top edge of the car cabin and run a length that is equivalent to the length of the window in the real-world example.

As demonstrated below the mesh was oriented in a such a way that the sun`s radiation would fall on to the roof of the car cabin. The maximum temperature observed in this exercise was 52° C. The edge of the roof that is joint with the left body panel has the maximum temperature level according to this figure. A considerable portion of the roof and the left body panel is in a temperature range of 40 to 50° C. The interior of the car was set at 32° C before the simulation was commenced. As per the below figure the region that that falls under the region of 26 to 33° C temperature band has reduced dramatically. The effect is clearly visible as the temperature in the region as the 32° C temperature has been reduced to values in between 25 and 16° C.The light blue region also extends along the length of the left body panel and the temperature has made quick transition to the

30 ° C range and continued its increase towards the upper most limits of .The windshield region expresses a range of temperature levels from the lowest to the highest. According to the below figure the lower end of the windshield is belongs to an 18-26° C temperature band. The temperature then makes its way towards higher temperatures mainly due to the solar irradiation and the total temperature reaches its highest value in the left corner of the windshield. The roof region has no temperature level that falls within the temperatures lower than 26° C.

## Conclusion

The simulations we conducted showed us the amount of solar irradiation on a car parked under the direct sunlight. The cabin interior temperatures rose to 42° C and the thermal comfort within the cabin was at a lower level. The placement of the prototype helped to reduce the cabin temperature by 3 ° C when solar radiation is at its peak and by 13° C when it is moderate levels. The placement of the ducts on the windows together with the unit helped further reduce the cabin temperature.

## References

Al-Kayiem, Hussain & Sidik, M. & Munusammy, Yuganthira. (2010). Study on the Thermal Accumulation and Distribution Inside a Parked Car Cabin. American Journal of Applied Sciences. 7.

Hodder, S. and Parsons, K. (2006). The effects of solar radiation on thermal comfort. International Journal of Biometeorology, 51(3), pp.233-250.

K. Arbogast, A. Belwadi and M. Allison, " Reducing the Potential for Heat Stroke to Children in Parked Motor Vehicles: Evaluation of Reminder Technology"

Karaman, A., Tan, A. and Li, B. (2019). ThermSafe: Child Heat Injury Prevention in Heated Locked Cars. [online] Www2.ee.ic.ac.uk. Available at: http://www2.ee.ic.ac.uk/yikuan.yao11/yr2proj/ReportFinal.pdf [Accessed 8 Nov. 2019].

R. Kumar, "Computational analysis of air flow and temperature distribution in an air-conditioned car: A Review", International Journal of Advance Engineering and Research Development, vol. 2, no. 04, 2015. Available: 10.21090/ijaerd.020473.

Photovoltaic Systems, 2012, James P. Dunlop, NJATC,2012