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Vehicle Compartment Heat Control Using Phase Change Materials

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Abstract-- The Phase change materials (PCM) are those have the ability to observe a huge amount of heat during its phase change from solid to liquid. The ability of PCMs is utilized in heat storing, heat removal applications. Temperature shoot up in cars during parking particularly in summer plays an important role in thermal comfort of car-cabin. As the vehicle is not in motion, and the air conditioner is off solar radiation heats up almost the entire cabin, particularly due to the fact that heat transfer co-efficient reduces too minimal as the car is parked. This project is to utilize the heat removal capability of PCM to remove the heat generated due to solar radiation. A thin layer of PCM coating over the car outer surface, particularly on the top and on the wind-shield has been made. CFD is found to be a better alternate in modern industries and has the ability of solving such complex problems. In this project with the help of CFD, a comparative analysis are executed to study the cases such as base car surface with AC off without PCM, base car surface with AC on without PCM, PCM coated where AC off. The comparative temperature pattern inside the cabin is used to understand the thermal comfort in the cabin and advantages of using PCM.

Keywords-- phase change materials, heat removal, wind shield, thermal comfort.

I. INTRODUCTION

A brake Climate control in automobile is becoming a critical factor for modern day automobile engineers. Application of HVAC is found to be the available methodology till date while some may believe aerodynamic cooling just by keeping the windows open would be an alternate choice in fact driving by keeping window open not only increases the aerodynamic drag, keep the domain noise level undesirable and the inner environment cannot be assured to be clean while HVAC technique is used, it consumes too much of energy that make the vehicle fuel in efficient.

In this project CFD analysis is utilised to compare three cases.

Cabin temperature distribution when HVAC is in OFF mode and no PCM is coated
Cabin temperature distribution when HVAC is in ON mode and no PCM is coated
Cabin temperature distribution when HVAC is in OFF mode and PCM is coated

These temperature distribution is used understand the underlying physics of each cases and to predict the appropriate methodology.

A. Heating Ventilation and Air Conditioning (HVAC)

HVAC is the technology of indoor and vehicular environmental comfort. HVAC system design is a sub discipline of mechanical engineering, based on the principles of thermodynamics, fluid mechanics, and heat transfer

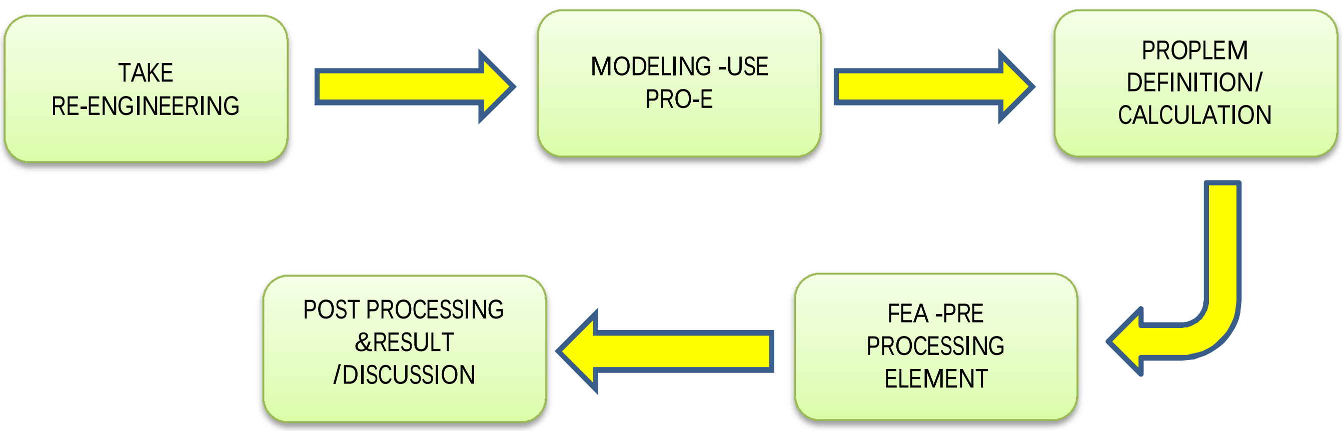
B. HVAC in Automobiles

Automobile air conditioning systems cool the occupants of a vehicle in hot weather, and have come into wide use from the late twentieth century. Air conditioners use significant power; on the other hand the drag of a car with closed windows is less than if the windows are open to cool the occupants evaporative. There has been much debate on the effect of air conditioning on the fuel efficiency of a vehicle. Factors such as wind resistance, aerodynamics and engine power and weight have to be factored into finding the true variance between using the air conditioning system and not using it when estimating the actual fuel mileage.

C. Phase change Materials

A phase-change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa; thus, PCMs are classified as latent heat storage (LHS) unit.

II. METHODOLOGY



III. COMPUTATIONAL FLUID DYNAMICS

Fluid dynamics is a field of science which studies the physical laws governing the flow of fluids under various conditions. Great effort has gone into understanding the governing loss and the nature of fluids themselves, resulting in a complex yet theoretically strong field of research. Fluid (gas and liquid) motions are governed by partial differential equations which represent the basic conservation laws for the mass, momentum, and energy. Computational Fluid Dynamics (CFD) is the art of replacing such PDE systems by a set of algebraic equations which can be solved using digital computers. Such complex sets of partial differential equation of solved on in geometrical domain divided into small volumes, commonly known as a mesh (or grid). CFD deals with predicting fluid flow, heat transfer, mass transfer, chemical reactions, and related phenomena.

A. Governing Equations

Rate of increase of mass in fluid element equals the net rate of mass flow into the element.

$$\frac{\partial \rho}{\partial t}+\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0$$

IV. DESIGN CALCULATIONS

A. Heat Transfer Co-Efficient Calculation

The convective heat transfer co-efficient has been calculated from the below expression with respect to the wind velocity at various time periods,

$$h = 18.63 * V \wedge (0.605)$$

V= 0.25*v if v >2m/sec

V= 0.5*v if v <2m/sec

Where,

v- Wind velocity m/s

V-calculated velocity m/s

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Time period (12 PM-12.30 PM) minutes	5	10	15	20	25	30
Wind velocity (v) m/s	4.10	4.15	4.20	4.36	4.65	4.65
Heat transfer co-efficient (h) W/m-K	43.74	44.06	44.70	45.40	47.21	47.21

TABLE 4.1 Observation Details

B. *Effective Temperature Calculation*

$$T_{eff} = T_{amb} + \frac{I*\alpha}{h}$$

Where,
T_{eff} = Effective temperature (k)
T_{amb} = Ambient temperature (k)
I = Solar intensity
α = External emissivity
h = Heat transfer co-efficient (W/m-K)

Time period=5Min
Heat transfer co-efficient (h) = 43.74 W/m-K
Ambient temperature (T_{amb}) = 312.50K
Solar intensity (I) = 1130 W/m2
External emissivity (α)= 0.6
Effective temperature (T_{eff}) = 328 K

V. CAD MODEL DEVELOPMENT AND CFD MODELING

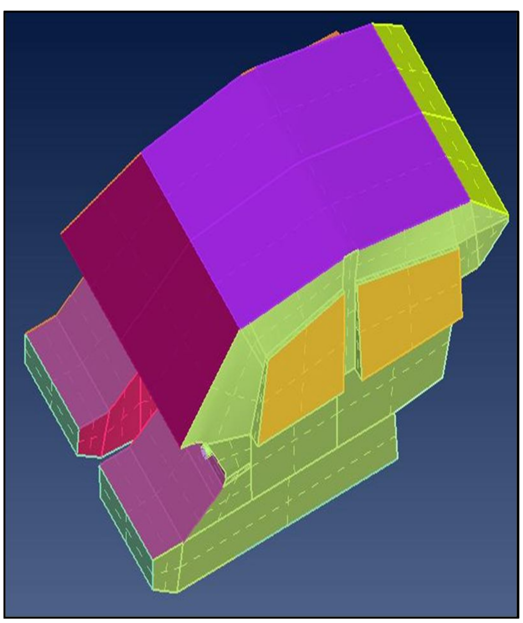
Fig 5.1.Interior of a car

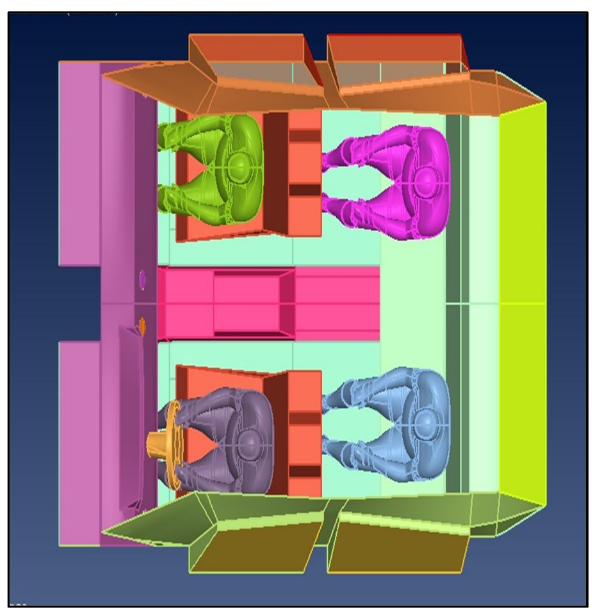
Fig.5.2.Top view of the car interior

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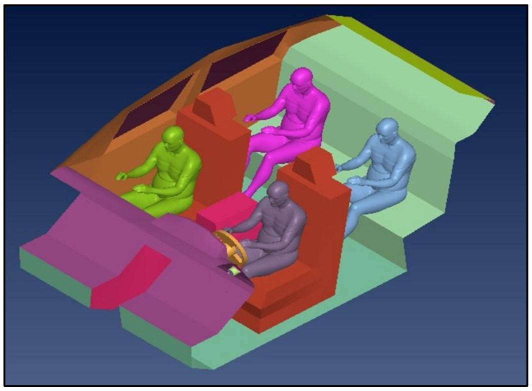

Fig5.3.Inside view

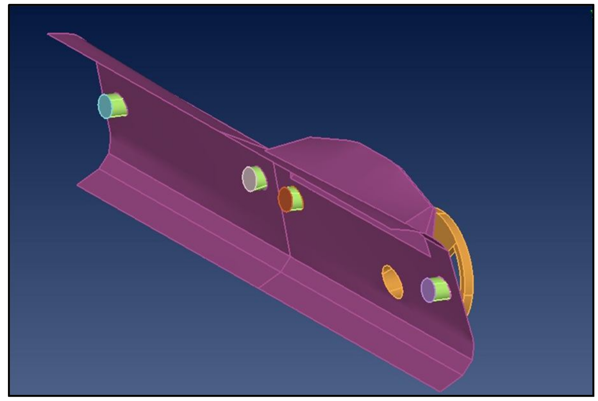

Fig5.4.Dash board and ac ducts

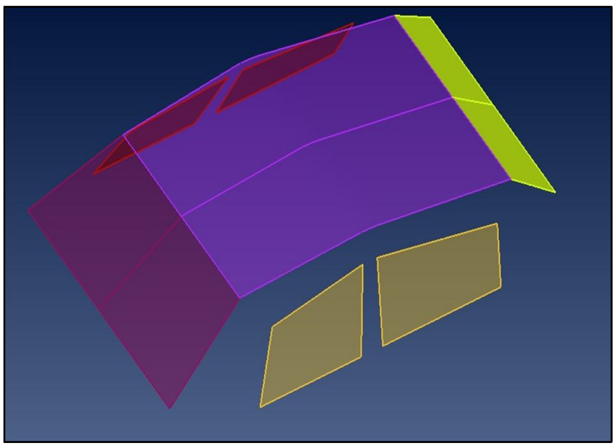

Fig 5.5.Wind screen details

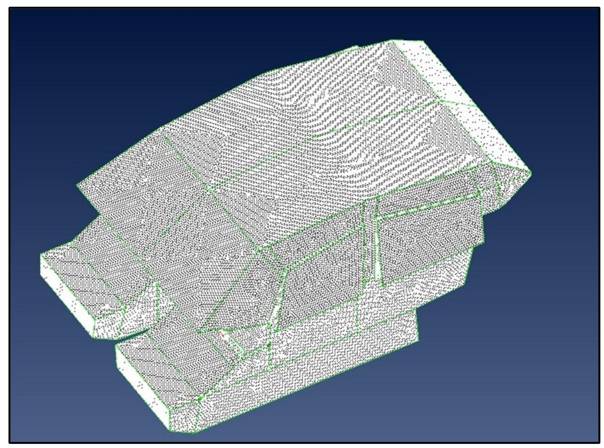

Fig 5.6.Over the interior

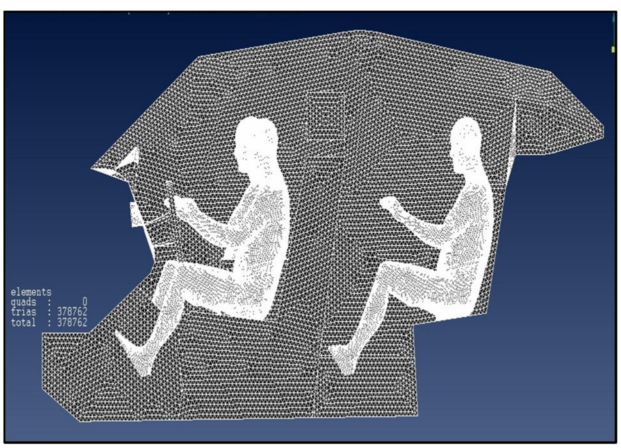

Fig 5.7.Surface mesh on passengers

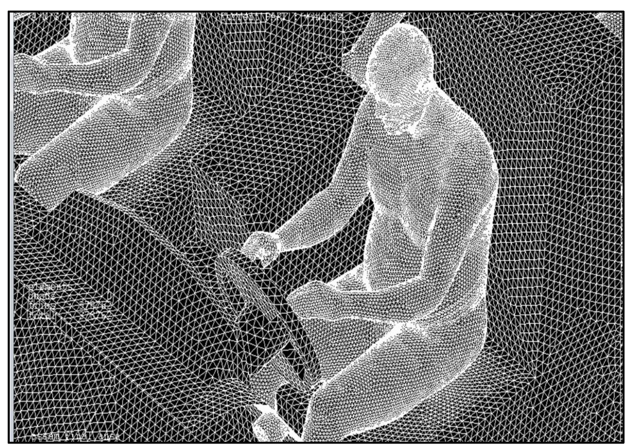

Fig 5.8.Surface mesh near to the driver cabin

VI. CONCLUSION

Thus a novel approach using Computational Fluid dynamics technique is attempt to compare the advantages of PCM over the car's outer surface. The findings are listed below,

A. Max temperature Cabin temperature when HVAC is in OFF mode and no PCM is coated = 314 K
B. Max Cabin temperature when HVAC is in ON mode and no PCM is coated= 307 K

C. Max Cabin temperature when HVAC is in OFF mode and PCM is coated = 301 K

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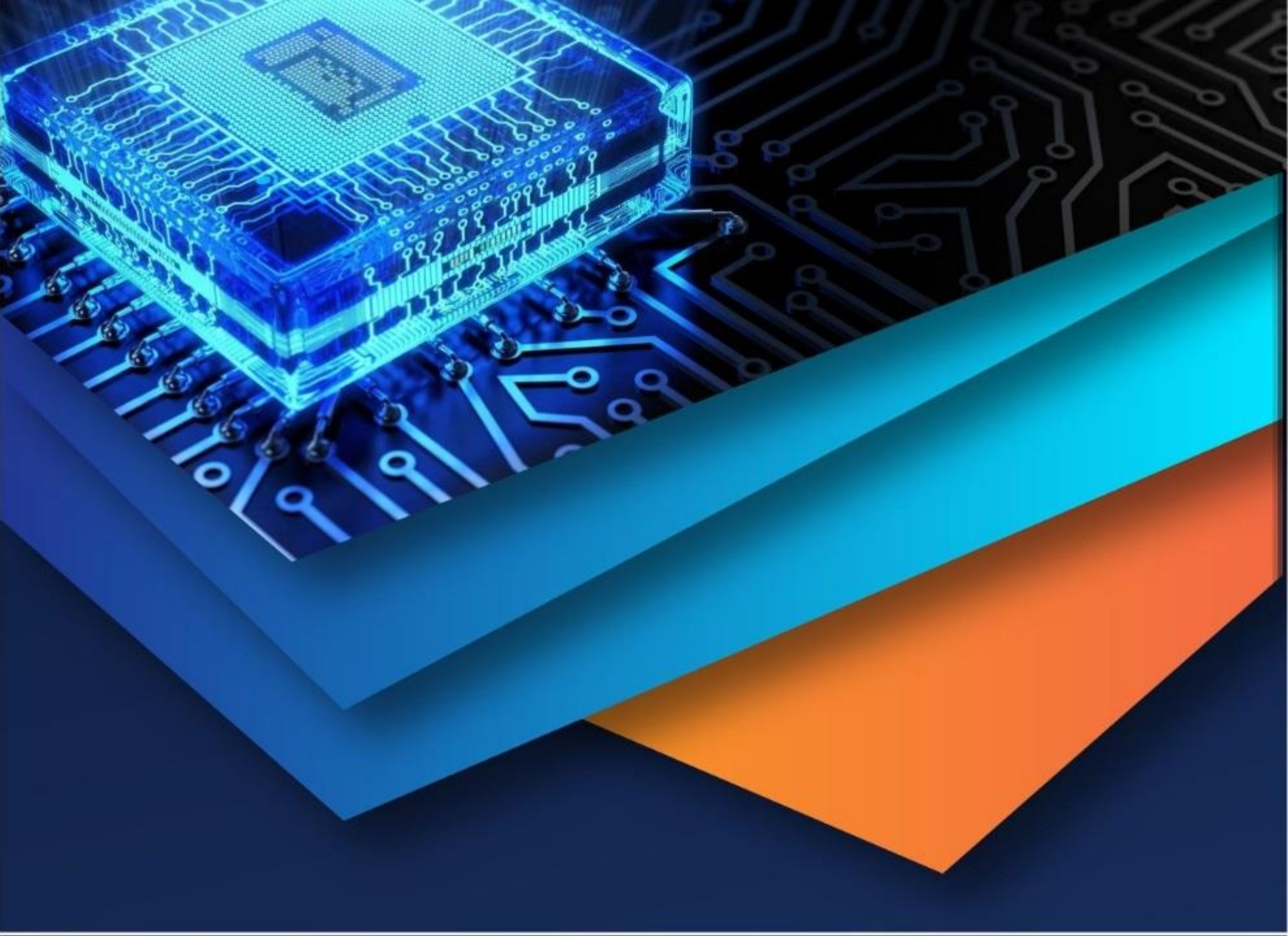

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