Thermal Management of Passenger Car Cabin Using Different Glazing Materials

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Abstract : In recent times the influence of aerodynamic design has made passenger vehicles more streamlined, compact and fuel efficient. The body design and styling has made the car more curvaceous in nature. The windscreen and windows have become more tangential for air flow exposing larger glass area for sun. Even though it was given for better visibility and efficient ventilation, it has adverse effect on vehicle thermal management. The larger glass area exposed to solar radiation increases the heat accumulation inside the car compartment. Research have been carried out on improving the thermal management of passenger vehicles by optimising the HVAC system, air flow management and redesign of passenger compartments. Automotive glazing material is another area of interest as the vehicle management is concerned. In this work an attempt is made to evaluate the thermal management of passenger car using different glazing materials and analyzing with CFD simulations.

The geometric model of a car with four passengers was modeled with all interiors including inlet and outlet vents using CATIA V5 software. The computational domain discretization was carried out using ICEM CFD tool. Steady state CFD simulation was carried out for Bangalore weather condition. The temperature distribution for interior has been evaluated. Different glass materials such as laminated glass, clear glass, heat absorbing glass and heat reflecting glass with different thermal properties and same climatic conditions were assessed for thermal management.

From the CFD simulations, the most appropriate material for windows and windshield with the improved thermal management is identified and suggested.

Keywords: thermal management, glazing material, temperature distribution.

I. Introduction

The passenger car has become important means of public transport. There is a need to increase the car performance. By installing the efficient engines and aerodynamically designed exterior shape it is possible to increase the performance. Global warming has created many problems due to the high temperature that will cause adverse effect including the car that we use every day. A car that's been exposed to direct sunlight for an extended period will develop a temperature inside, due to outside temperature of the car [2]. When the weather turned hot, most of the drivers simply put up with the discomfort. More even, the instrumental panel, leather seats and plastic accessories among other items age rapidly if exposed to these temperatures for a long period[2]. It also causes the rise in fuel consumption due to higher power of air conditioning needed to cool down the car cabin.

1.1 Motor vehicle rules in India

As per motor vehicle rules (rule 188) in India, black film usage in windshield and side windows is banned because of rise in accident and crime rate due to poor visibility. The glass of the wind screen and rear windows of every motor vehicle shall be maintained to a condition that the visual transmission of light should not be less than 70%[4]. The glass applied for the side windows are maintained such that visual transmission of light is not less than 50% and shall conform to Indian standard[4].

1.2 In cabin passenger thermal comfort

Human thermal comfort is defined by the " the American society of heating refrigeration and air conditioning engineers[ASHRAE] as the set of mind that express the satisfaction environment[1]. Glazing is the actual glass part of the window. In automobile it is referred to the windshield. Certain amount of solar energy has been reflected and absorbed by the exterior surface of the automobile including the roof and door. It has the potential to directly transmit the solar energy, absorb energy between the layer of glass or reflect the solar energy back in to atmosphere.

The present research work is analyzed for different glazing material for the better thermal comfort of passenger in the car cabin.

II. METHODOLOGY

2.1 Model construction

The geometric model of the Maruthi swift car was selected for current project work. The geometric model of car is shown in fig 1.

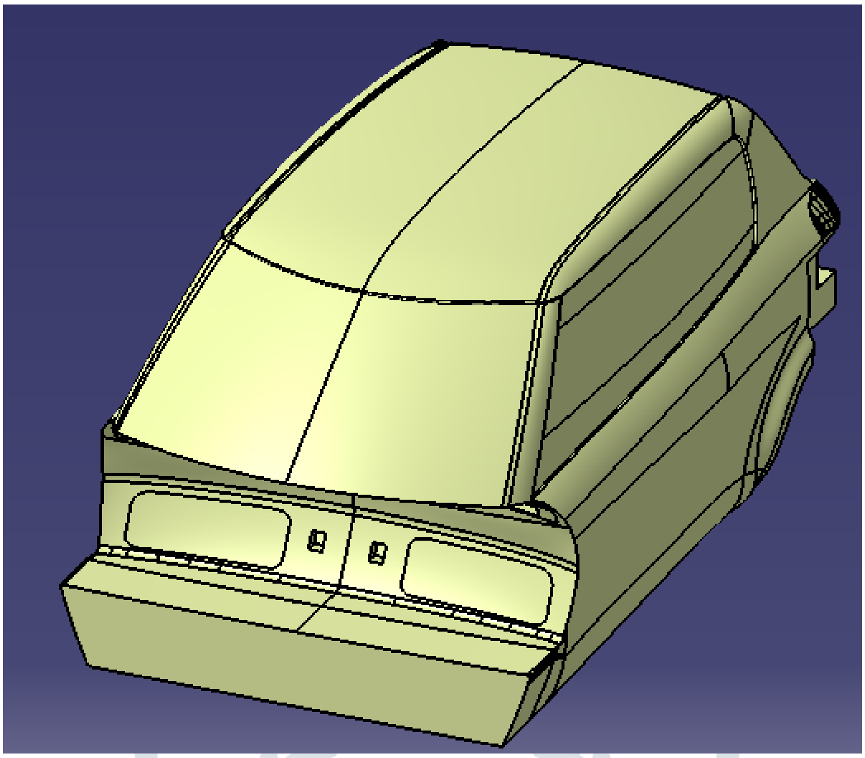


Fig 1: Geometric model of car

2.2 Discretization and pre-processing

The geometric model of the car with its interior was discretized using Ansys 15 ICEM CFD preprocessor software. The model was cleaned up for defect such as discontinuous and overlapping curves which were repaired. Inside the car cabin the fluid body was created which specify the fluid flow during the simulation.

For the mesh geometry the unstructured mesh is used and for the entire fluid domain the tetrahedral mesh was generated. Near inlet vent, outlet vent and at the driver and passenger section fine mesh was created.

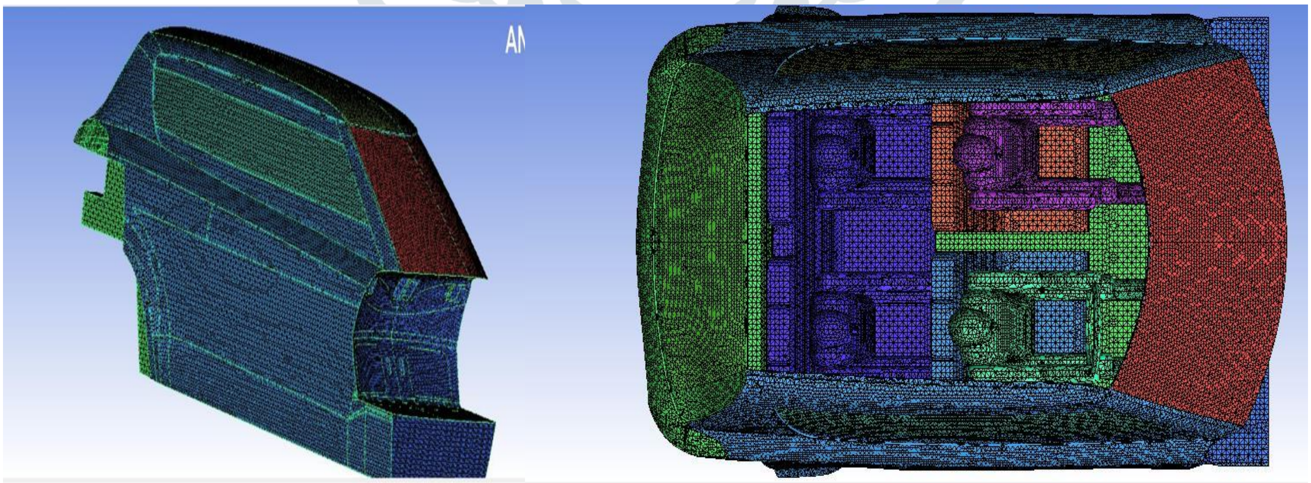


Fig 2: Discretization of model

III. BOUNDARY CONDITION

The boundary conditions are specified for the car body and the other parts created by ICEM CFD software.

Table 1: Boundary condition assigned to ICEM –CFD

Part	Boundary condition
Body	Fluid-air
Inlet vent	Velocity inlet
Exit vent	Pressure outlet
Windshield and windows, seat	Wall

To specify the direction of the sun relative to the passenger cabin of the car, a solar calculator available in the fluent is used and thereby calculated the direction and magnitude of diffused solar radiation for the given time, date and location. In this project the ambient condition in Bangalore (Long: 77.59^0 and Lat: 12.97^0) on 21^{st} June at 1 PM were selected for the analysis. The Indian zone of 5-30(+GMT) hours was specified in the input window of solar calculation.

Table 2: Solar irradiation computed from solar calculator

Direct normal solar irradiation (at earth's surface) (w/m^2)	944.289
Diffuse solar irradiation (vertical surface) (w/m^2)	60.95
Diffuse solar irradiation (vertical surface) (w/m^2)	91.59
Ground reflected solar irradiation (w/m^2)	101.118

3.1 Solver Setting

For analysis suitable solver setting is selected and is tabulated in the Table 3.

Table 3: Solver settings

Solver type	Pressure based
Space	3-D
Velocity	Absolute
Flow	Steady state
Viscosity model	turbulent(k-ε)

The boundary condition in the fluent software is applied as shown in the Table 4

Table 4: Boundary conditions

Zone name	Boundary condition
Car body	Stationary wall, no slip condition
Inlet	Velocity inlet
Outlet	Pressure outlet
Fluid material	Air
Windshield and windows, seat, passenger	Stationary

IV. RESULT AND DISCUSSION

The different automotive glazing material impact on passenger thermal comfort is acquired. To get the thermal comfort by best glazing material in the car, the outcomes of different glazing materials are reviewed and contrasted.

The assumed boundary conditions for the simulation are given below.

- Velocity- 2.5m/s
- Inlet vent temperature- 18°C
- Exit vent temperature- 23°C

Simulation to ascertain the temperature distribution and air flow condition around the passenger compartment with the above boundary condition at different location on the driver and on the rear passenger is formed in fluent software along with this temperature points are procured and tabulated in the table for different glazing material such as laminated glass, clear glass, heat absorbing glass and heat reflecting glass.

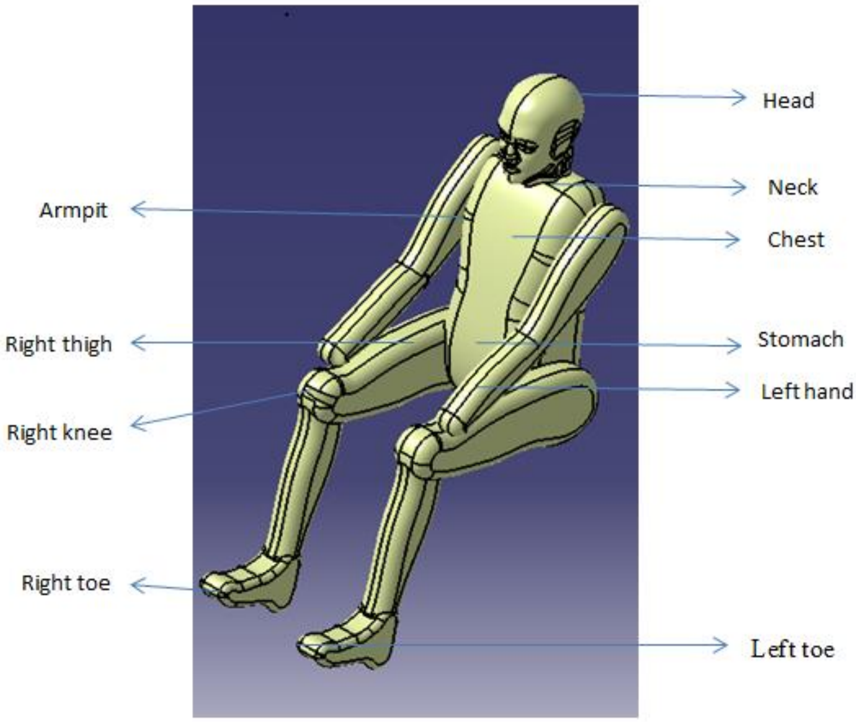
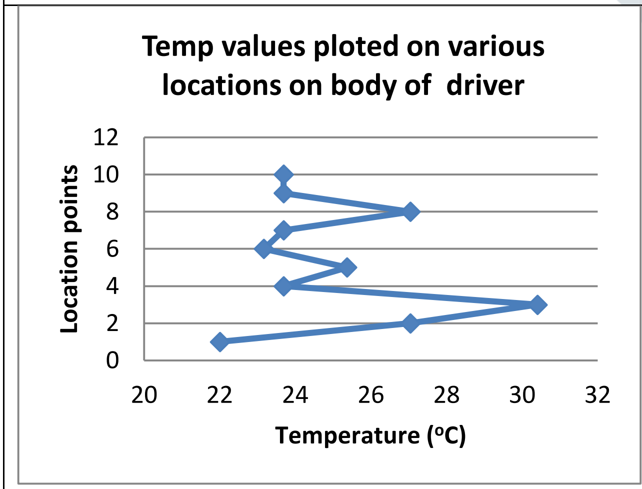
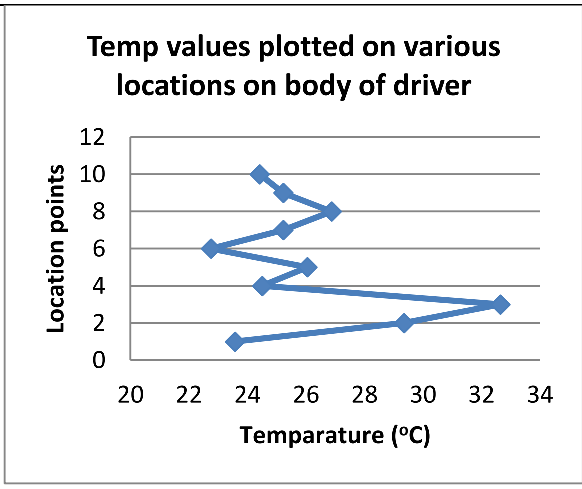


Fig 3: Point location on a seated passenger

The temperature distribution for the driver using different glazing materials is plotted in graph 1.

<table>
<tr><th>Laminated glass</th><th>Clear glass</th></tr>
<tr><td>
</td><td>
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<tr><td>Heat absorbing glass</td><td>Heat reflecting glass</td></tr>
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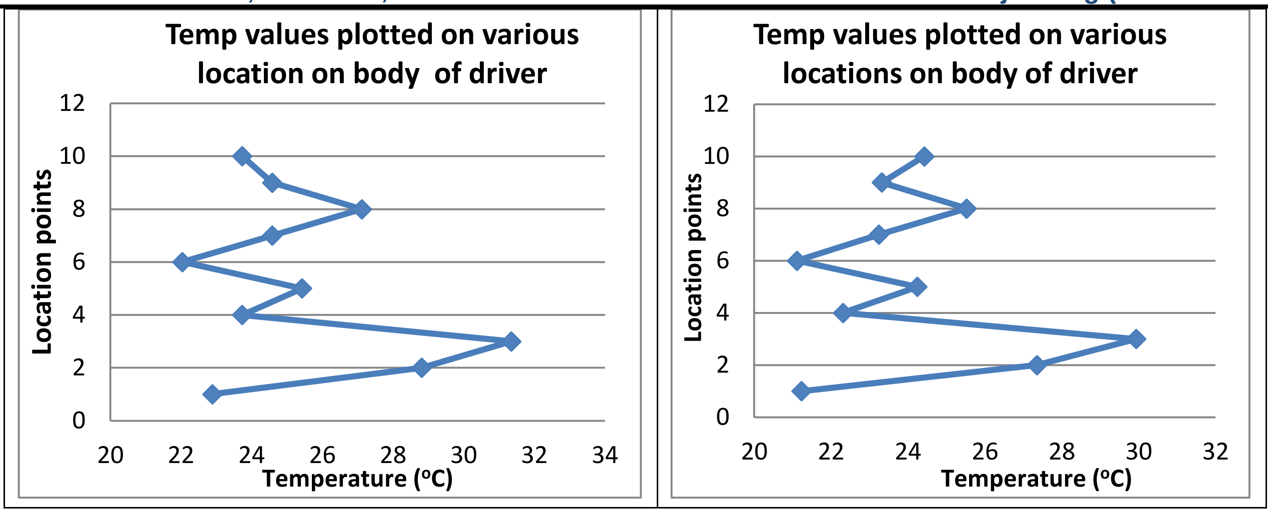
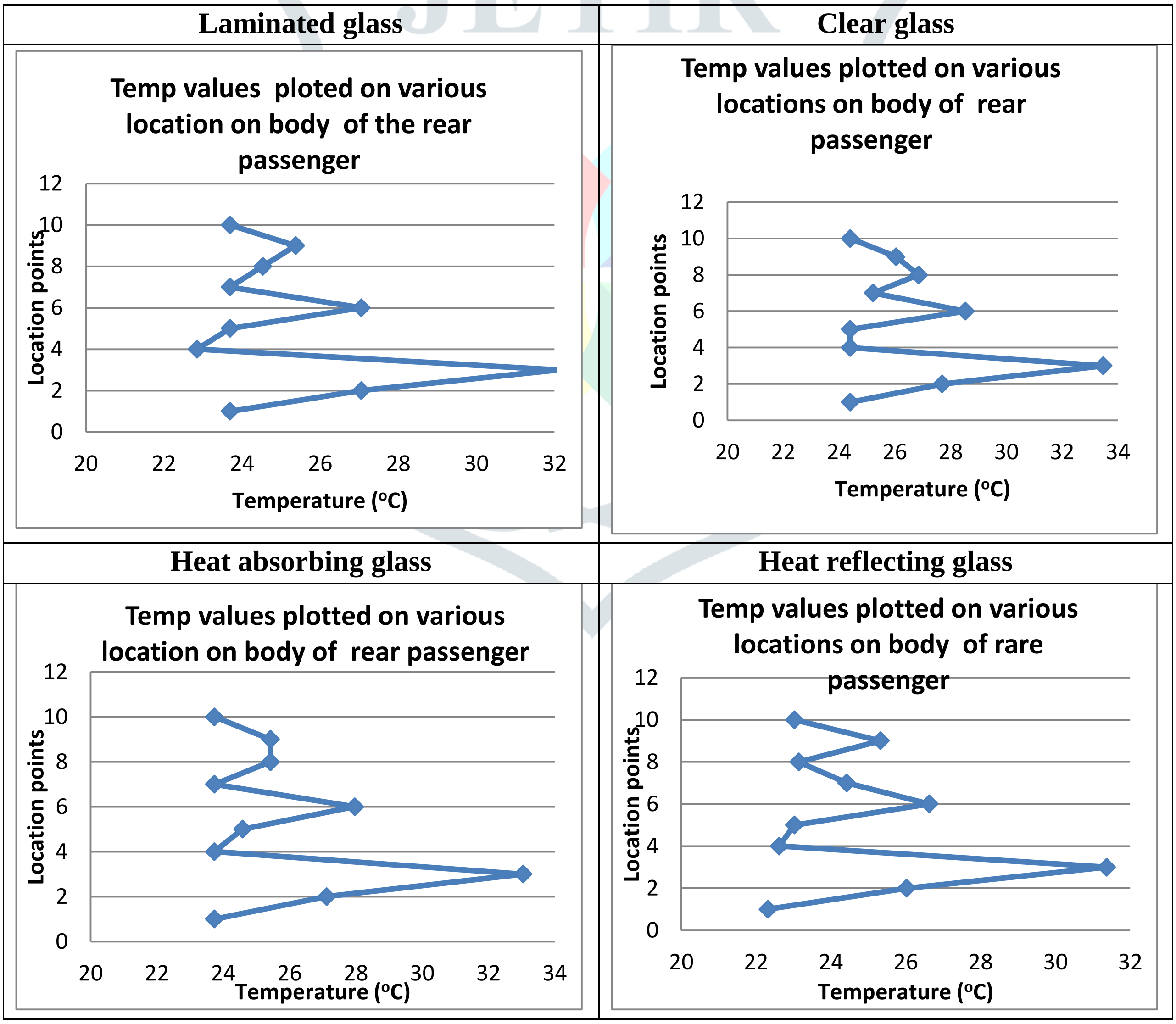


Graph 1: Temperature values plotted on various locations on driver body for different glazing materials

The graph 1 and 2 shows the temperature distribution of driver and rear passenger for the different glazing materials. It can be noticed that heat reflecting glass portrays that the temperature around the driver was lower than other glass material. The higher temperature is obtained in the clear glass when it is used in the windows and the windshield of the car. The maximum temperature obtained is at the armpit region.

The temperature distribution for the rear passenger using different glazing materials is plotted in graph 2.



Graph 2: Temperature values plotted on various locations on rare passenger body for different glazing material

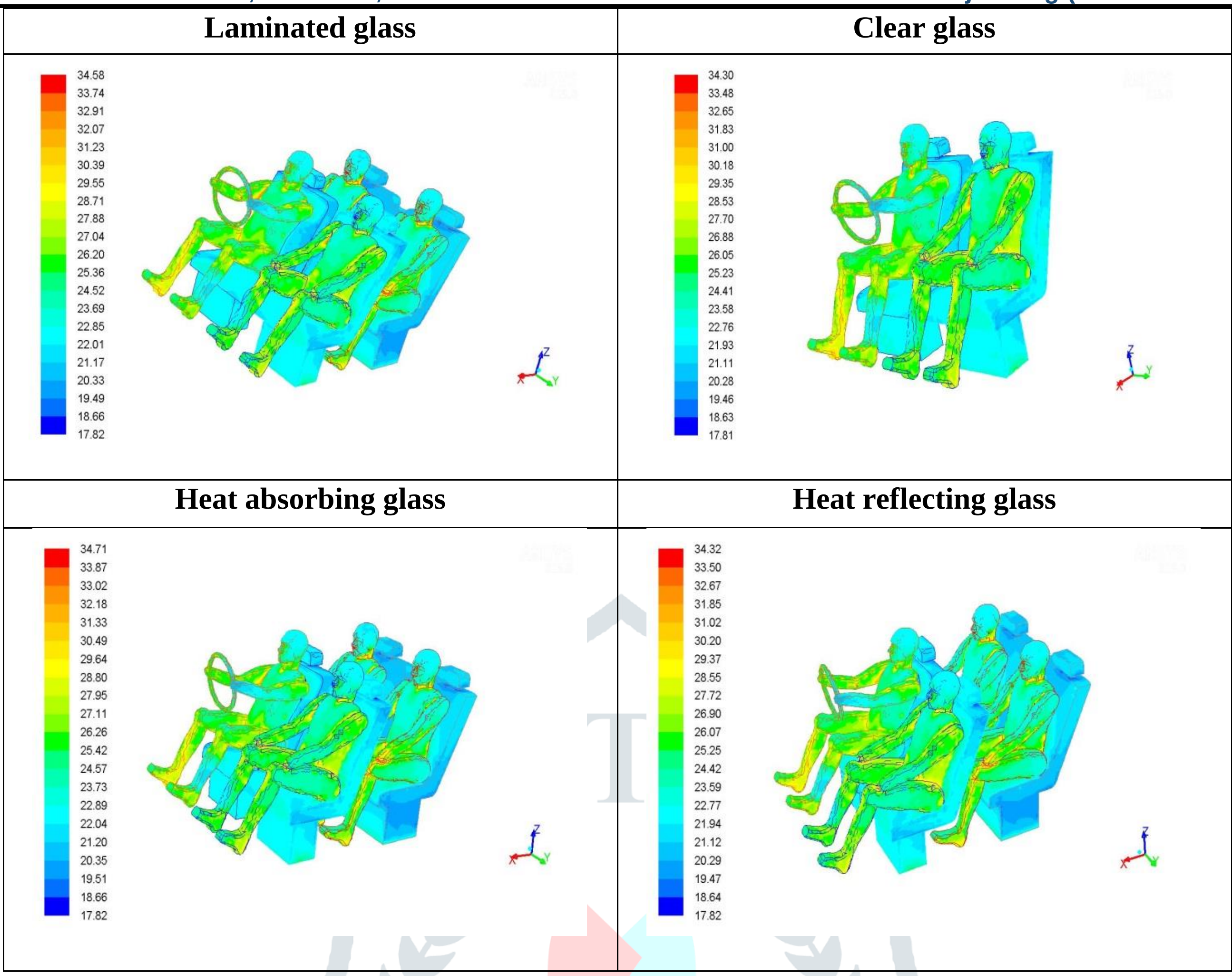


Fig 4: Temperature distribution for different glazing materials

The temperature distribution around the driver and passenger for the different glazing material is illustrated in fig 4. Although the temperature distribution is similar, the temperature at individual points is found to vary. The heat reflecting glass material shows least temperature distribution at different locations of passenger body, compared to other glass material. From the above fig it is noticed that the maximum temperature occurred in armpit region.

Table 5: Percentage of temperature decreased in driver section for absorbing glass and reflecting glass when compared to clear glass

Measured location	Clear glass material (°C)	Heat Absorbing glass (°C)	Percentage of temperature decreased in absorbing glass (%)	Heat reflecting glass (°C)	Percentage of temperature decreased in the reflecting glass (%)
Head	23.58	22.885	2.94	21.228	9.97
Neck	29.352	28.808	1.85	27.359	6.78
Armpit	32.65	31.347	3.99	29.934	8.31
Chest	24.504	23.732	3.15	22.31	8.95
Stomach	26.054	25.424	2.41	24.245	6.94
Left hand	22.756	22.039	3.15	21.115	7.21
Right thigh	25.23	24.578	2.58	23.243	7.87

Right knee	26.879	27.116	0.88	25.527	5
Left toe	25.23	24.578	2.58	23.32	7.57
Right toe	24.426	23.732	2.84	24.423	0.012

Table 6: Percentage of temperature decreased in rare passenger section for absorbing glass and reflecting glass when compared to clear glass

Measured location	Clear glass material (°C)	Heat Absorbing glass (°C)	Percentage of temperature decreased in absorbing glass (%)	Heat reflecting glass (°C)	Percentage of temperature decreased in the reflecting glass (%)
Head	24.405	23.732	2.75	22.32	8.54
Neck	27.703	27.116	2.11	26.027	6.04
Armpit	33.475	33.039	1.30	31.369	6.29
Chest	24.405	23.732	2.75	22.62	7.31
Stomach	24.405	24.576	0.7	23.023	5.66
Left hand	28.528	27.962	1.98	26.627	6.66
Right thigh	25.229	23.732	5.93	24.423	3.19
Right knee	26.854	25.424	5.32	23.139	13.83
Left toe	26.045	25.424	2.38	25.325	2.76
Right toe	24.405	23.732	2.75	23.023	5.66

Tables 5 and 6 show the temperature reduction with the heat absorbing glass and heat reflecting glass used for windshield and windows in the car as compared to clear glass. The heat reflecting glass gets much higher percentage of temperature reduction around the body of the driver and passenger.

V CONCLUSION

In the current project work numerical simulation on thermal management of passenger car was carried out to evaluate thermal comfort of passengers using different glazing materials and best possible material for automotive windshield and windows are suggested. The following points are concluded

- Different glazing materials like laminated glass, clear glass, heat absorbing glass and heat reflecting glass are used for simulation and the results of effect of temperature distribution around the driver and passenger are studied and compared for temperature distribution and heat transfer.
- The reduction in temperature obtained in reflecting glass measured at head level of driver is 9.97% and rear passenger is 8.54% in comparison with clear glass material.
- The reduction in temperature obtained in reflected glass measured at chest level of driver is 8.95% and rear passenger is 7.31% in comparison with clear glass material.
- The reduction in temperature obtained in reflected glass measured at foot level of driver is 7.57% and rear passenger is 2.76% in comparison with clear glass material
- There is no significant effect on air flow condition.
- Heat reflecting glass is suggested as an automotive glazing material because of its reduced temperature for the required thermal comfort condition.

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