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CFD EVALUATION ON EFFECT OF DOUBLE GLAZING OVER SINGLE GLAZING IN A SMALL UTILITY VEHICLE

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ABSTRACT

Double glazing glass provides nearly twice the insulation as single glazing. Double glazing insulates you against extremes of temperature, trapping some of the summer sun rays and minimizing the heat which enters through your windows on hot sunny days. Due to this advantage single glazing glass is replaced by double glazing glass. And double glazing glass is also used in energy efficient building. Solar radiation enters in to the automotive SUV vehicle through the glass window. This solar radiation contributes about 47% of overall cooling load in automobile. Therefore fuel consumption is also increased. In order to reduce this solar radiation entering in to the automobile, the single glazed glass window is replaced by double glazed glass window. The theoretical calculation results in 22% improvement in using double glazed glass over single glazed glass. This paper also provides CFD analysis of effect of double glazing glass over single glazed glass.

Keywords: Automobile SUV, Solar radiation, Car cabin, Double glazed glass, CFD

1. INTRODUCTION

Double glazing insulates you against extremes of temperature, trapping some of the summer sun rays and minimizing the heat which enters through your windows on hot sunny days. Double glazed windows consist of two layers of glass with layer of inert gas sealed between them. This creates nearly twice the insulation as single glazed glass. Double glazing insulates your home against extremes of temperature, trapping some of the summer sun's rays and minimizing the heat which burns through your windows on hot, sunny days. This is the main reason why double glazing glass is preferred to replace the single glazed glass. We remember to insulate our ceilings and sometimes our walls, but windows act as a large hole in the wall for heat to move through. Double glazing can stop around 35% of heat loss in winter and around 10% of heat gain in summer, compared to a normal single glazed window. Glass doesn't stop most heat transfer on its own, it's not an insulating material. Most of the (very small) insulation value provided by a normal window comes from the very thin layer of inert gas that sits next to the glass on either side. Inert gas is a very good insulator. Double glazing is a good way to reduce heat transfer through windows. Some types of glass are designed to

block high percentages of incoming heat energy while only reducing the visible light by a small amount. These glasses are useful on any windows that are exposed to regular sunlight but are hard to shade. In automobile various load act on it and contribute to cooling load. But solar radiation contributes about 47% of overall cooling load. The solar radiation enters in to the automobile only through the glass window. The glass window used in the automobile is single glazed glass. On a sunny day, a closed car is a solar collector. Solar energy passes through the glass, hits the inside of the car and changes in to thermal energy, which gets trapped inside. This results in developing a green house effect inside the car cabin. Therefore in this paper, the normal single glazing glass window is replaced by double glazing glass window. Direct and diffuse solar load mathematical formulae is used to obtain the theoretical results of using single glazed glass and double glazed glass. Computerized fluid dynamics is also used to compare the double glazed glass over single glazed glass. In CFD solar radiation load is applied in specific period of time and results are obtained.

2. THEORITICAL COMPARISION OF DOUBLE GLAZED OVER SINGLE GLAZED GLASS

2.1 SOLAR RADIATION LOAD

Direct radiation is that part of the incident solar radiation which directly strikes a surface of the vehicle body, which is calculated from

$$\dot{Q}_{Dir} = \sum_{Surfaces} S\tau \dot{I}_{Dir} \cos\theta$$

$$\dot{I}_{Dir} = \frac{A}{\exp\left(\frac{B}{\sin\beta}\right)}$$

Diffuse radiation is the part of solar radiation which results from indirect radiation of daylight on the surface. During a cloudy day, most of the solar radiation is received from this diffuse radiation. The diffuse radiation heat gain is found by

$$\dot{Q}_{Dif} = \sum_{Surfaces} S\tau \dot{I}_{Dif}$$

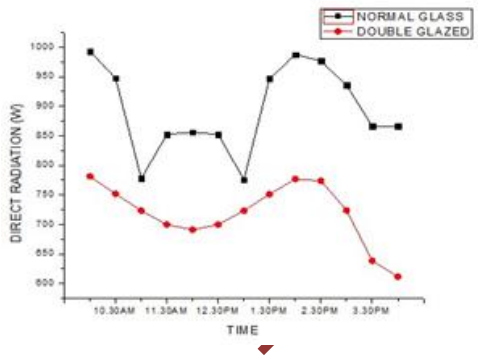
$$\dot{I}_{Dif} = C\dot{I}_{Dir} \frac{1+\cos\Sigma}{2}$$

Ɵ is the sun incident angle on the glass. The direct loads have a greater contribution than diffuse or reflected load. The direct and diffuse radiation load increases due to the increase in the sun altitude angle. The table below gives the overall solar load acting on the vehicle cabin.

	Time	Overall Q direct	Overall Q(diffuse)	Overall Solar Radiation		Time	Overall Q direct	Overall Q(diffuse)	Overall Solar Radiation
Normal Glass window	10.00AM	992.9155	140.5926	1133.508	Double Glazed Glass Window	10.00AM	781.2052	103.2198	884.4251
	10.30AM	947.1513	141.7585	1088.905		10.30AM	751.6103	104.0722	855.6825
	11.00AM	777.7228	142.6962	920.419		11.00AM	723.1737	104.7643	827.938
	11.30AM	852.3522	143.2917	995.644		11.30AM	699.5119	105.2015	804.7135
	12.00PM	855.8611	143.4114	999.2725		12.00PM	690.8758	105.2894	796.1652
	12.30PM	852.3522	143.2917	995.644		12.30PM	699.5119	105.2015	804.7135
	13.00PM	775.6782	142.6962	918.3744		13.00PM	723.1737	104.7643	827.938
	13.30PM	946.3698	141.6366	1088.006		13.30PM	750.9902	103.9863	854.9765
	14.00PM	987.2556	139.7911	1127.047		14.00PM	776.7521	102.6315	879.3836
	14.30PM	976.6249	137.5509	1114.176		14.30PM	773.6104	100.9867	874.5971
	15.00PM	935.4623	134.0074	1069.47		15.00PM	723.9138	98.38519	822.299
	15.30PM	866.2196	129.3621	995.5817		15.30PM	638.4112	94.97471	733.3859
	16.00PM	866.1374	143.7718	1009.909		16.00PM	611.3577	105.554	716.9116

22% reduction

From the above table it is clear that there is 22% of reduction in overall radiation load by using double glazed glass. The theoretical calculation is calculated from the time period of 10.00AM to 16.00PM. The overall solar radiation is the sum of direct solar radiation and diffuse radiation load. The transmisivity of glass is calculated for each time period for obtaining exact value of solar radiation entering inside the car cabin through the glass window. By using double glazing glass the transmisivity decreases since it reduces the transmisivity obtained by considering reflection, refraction and absorption.



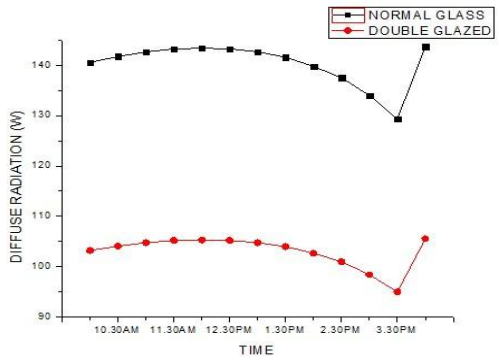


Figure 1: Comparisons of direct solar radiation load **Figure 2**: Comparisons of diffuse solar radiation load

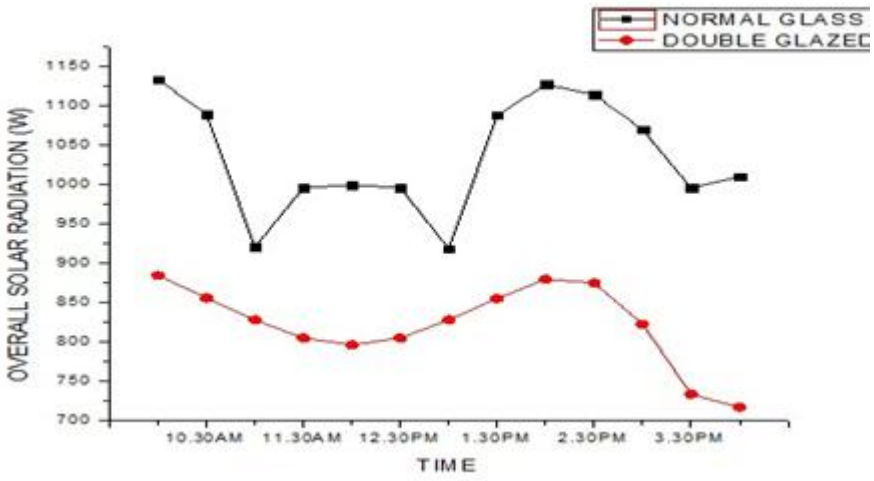


Figure 3: Comparisons of overall solar radiation

Figure 1 represents the graph drawn between direct solar radiation with time of normal glass and double glazed glass. Figure 2 represents the graph drawn between diffuse solar radiation with time of normal glass and double glazed glass. Figure 3 represents the graph drawn between overall solar radiation with time of normal glass and double glazed glass.

From the above graph and table it is clear that there is a considerable reduction of solar radiation entering through the glass window of an automobile. Therefore it is better to replace the normal single glazed glass by double glazed glass.

3. CABIN GEOMENTRY

In order to perform the energy simulation in computational fluid dynamics geometry has to be created. An approximate dimension of a small utility vehicle is assumed. The geometry is created in creo software which is later analyzed by CFD. The created geometry is given below on figure 4.

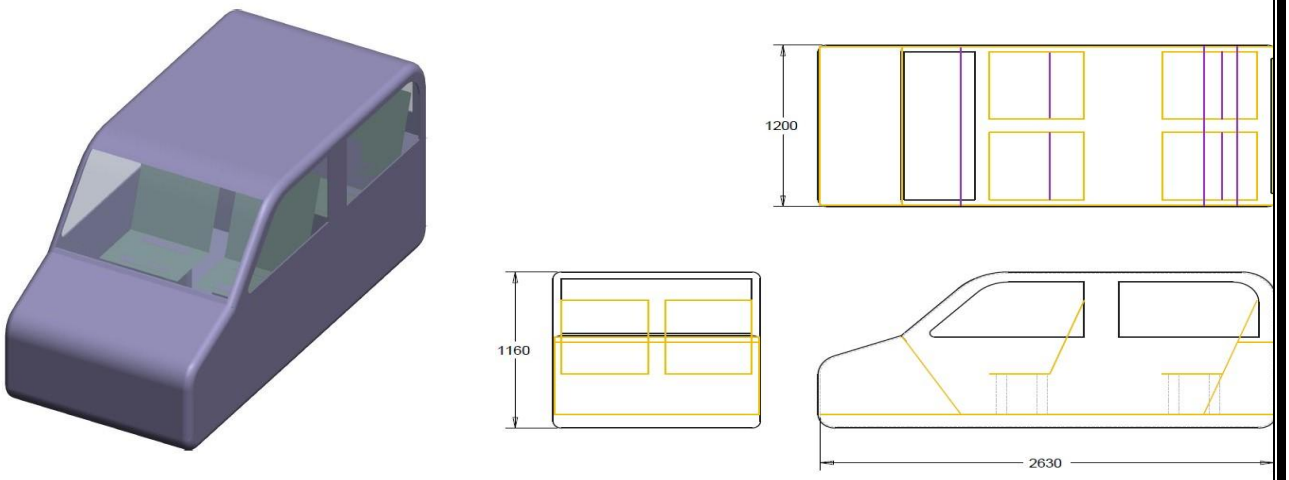


Figure 4: Cabin geomentry

4. CFD ANALYSIS

Solar radiation simulation in done in fluid flow fluent in ansys workbwench. In fluent radiation model is switched on. In radiation model, discrete ordinates (DO) is selected. Solar ray tracing is switched on and respected value of sun loacation is given. The longitude value is 77.7 degree, latitude is 8.73 degree. The time zone is +5.30 GMT. Day of the year is 15th may since it is used in theoritical calculation. The direct and diffuse solar irradiation is also given. The boundry condition is given such a way that the car body except glass are kept as wall. Only the glass properties are given since we are analyzing solar radiation load only entering inside the car cabin. Other loads are not considered. Therfore analyzing is done in way that the solar radiation load only enter into the car cabin only through the glass window. Inside the cabin air domain is available. The inside air domain temperature is considered as 25 degree celsius and one bar pressure. The thickness of the normal single glazed glass is 3 mm. The double glazed glass consits of two layer of glass and in between them a layer is filled by inert gas. Argon is the inert gas choosed in this analysis. Their respective value of thermal conductivity, specific heat and density is given as a input along with solar radiaiton. In fluid flow fluent 3 dimensional stedy flow is considered.

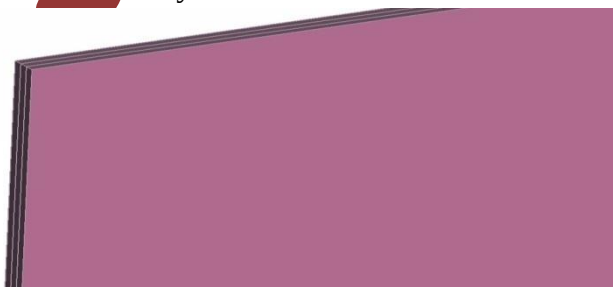


Figure 5 The above figure 5 is double glazed glass with inert gas in between.

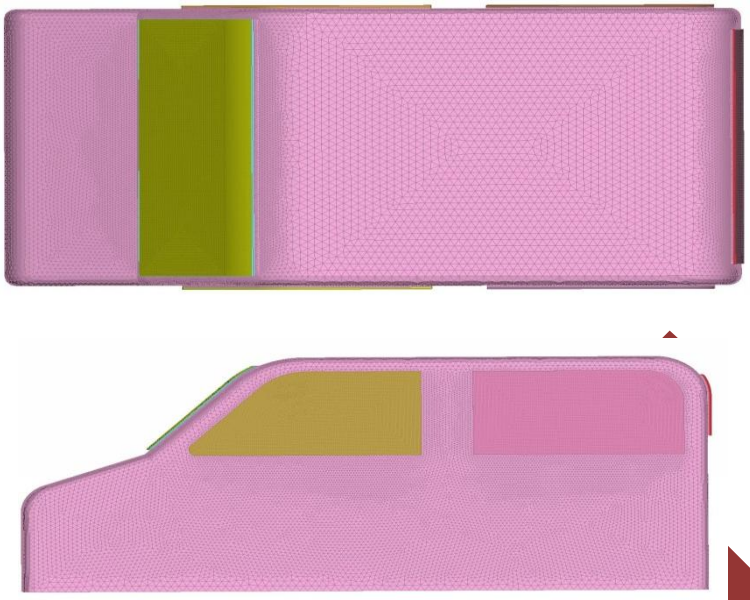


Figure 6 Meshing of car cabin

The above figure 6 represents the meshing of the car cabin. Tetrahedral mesh is applied here. After meshing 22 lakh element is obtained.

5. RESULTS AND DISCUSSION

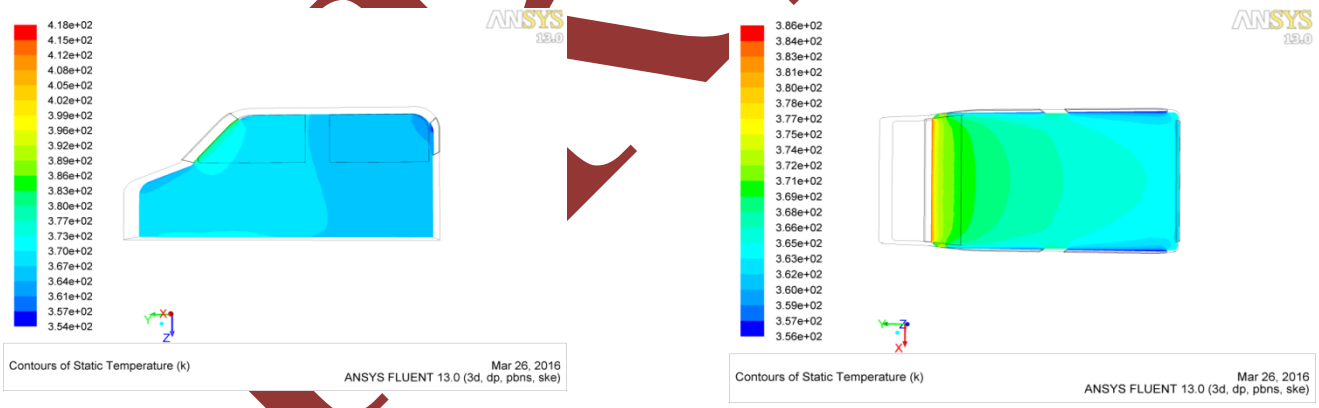


Figure 7: Contours of static temperature of single glazed glass

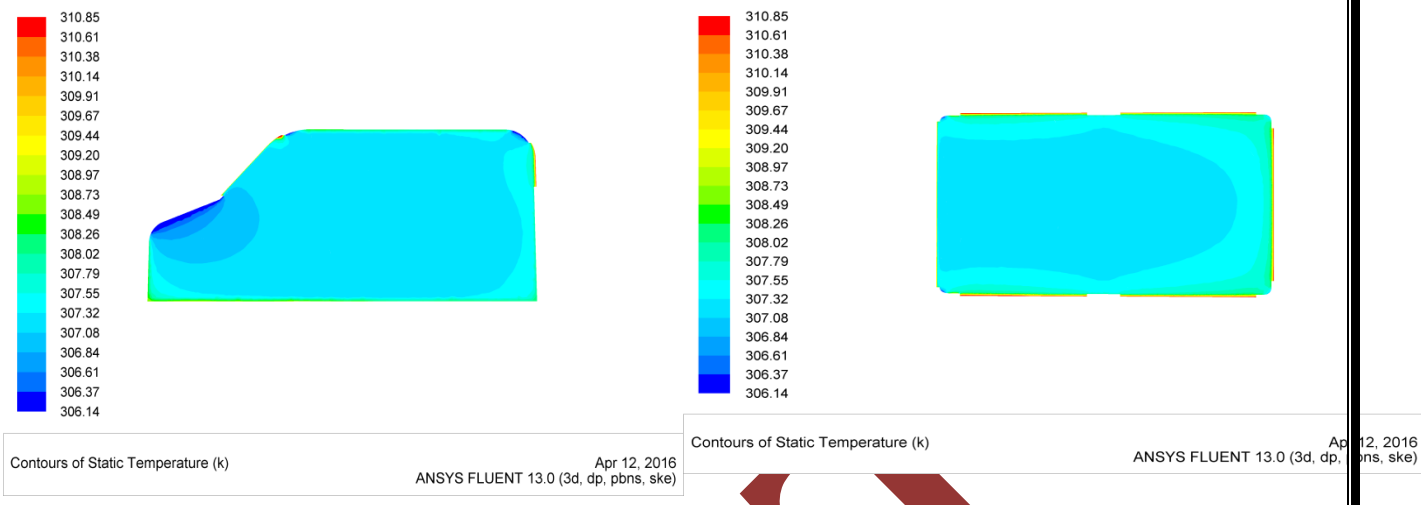


Figure 8: Contours of static temperature of double glazed glass

Figure 7 represent the temperature distribution due to the impact of solar radiation through single glazed glass. Figure 8 represent the temperature distribution due to the impact of solar radiation through double glazed glass. The temperature distribution of solar radiation through single glazed glass is more. It is due to the high transmissivity of solar radiation entering in to the cabin. But by using double glazed glass the transmissivity decreases and reduces the transmission due to reflection, refraction and absorption. Since double glazed glass has three layer to reduce the above transmission of light. The temperature distribution of solar radiation entering through the double glazed glass is reduced in a significant way. So by reducing the solar radiation it can also reduces the overall cooling load needed by the air conditioning system.

6. CONCLUSIONS

The computational modeling of automotive cabin with existing glass material and double glaze glass is performed using CFD simulations. Since the usage of glazing material is at infantry stage in the automotive industry, this study focused on the effect of glazing material in the passenger comfort inside the automotive cabin. Glazing material is used as sandwich with pack of two glasses and inert gas argon is placed in between these two glasses. This presence of inert gas offer significant temperature reduction inside the cabin.

This is a work which is the proof of concept for the implementation of double glazing material in automotive HVAC. This part of work focused only on simulation part to show cases the advantages in using glazing materials. However, the practical implementation of this glazing material without compromising on spacing on the windshield area needs to be studied further. We will take this as future scope of work and physical testing will be conducted to see the feasibility of work.

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