Design and impact analysis of car door

[1]PremKumar.D, [2]Dr. V. Balaji, [3]Mohamed Muzammil Sherief, [4]Chinnarasu.M, [5]Hariharan.S.B.
[1]Assistant Professor, [2]Associate Professor
Department of Mechanical Engineering,
Prathyusha Engineering College, Tiruvallur.

Abstract: *Car door is one of the main parts which are used as protection for passengers from slide collisions. Side impact collision of vehicle is one of the terribly hazardous crashes causing injuries and death annually around the word. In this paper, the most important parameters including material, geometry and beam arrangement were studied to improve the crashworthiness during vehicle-to-vehicle side collision. In the side impact, the side door beam is responsible to absorb the most possible kinetic energy. We designed side impact beam of different cross sections. Presently steel is used for car doors construction. The aim of the paper is to analyse the car door and its structure with currently used material by replacing with composite materials like aluminium, s-glass epoxy, e-glass epoxy. The design of car door is designed using CATIA. Impact analysis is conducted on door with transient structural analysis using ANSYS software by varying the materials.*

Index Terms- *car door, Finite element Analysis, Structure, side impact beam, transient structural analysis.*

1. Introduction

Doors are one of the major components in a car which provide easy access for passengers into the car. With the growing demand on car styling, comfort, safety and other systems integration (window regulator, latch, speaker, motor and electronics) in the door, designing this system is a great challenge to engineers. Nowadays more research are going to design vehicle which uses fuel economically, by light weight engineering using low density material and with advance manufacturing and joining technology and thereby reducing the weight of vehicle. Crashworthiness is the ability of the vehicle structure to sustain impact loading and to prevent the occupant injuries at the time of accidents. Side impact crash is generally dangerous, since there is no room for large deformation of the vehicle structures. The side impacts is the second most common type of vehicle impacts after frontal impact that results in injuries to occupants which account to 25 percent of fatalities due to impacts between passenger cars and light trucks and approximately 30 percent between passenger car crashes. The fuel efficiency and gas emission regulation of the passenger are also very important in the contemporary world.

1.1 Car door

Car Doors are physically hinged but sometimes attached by other mechanisms in the front opening which is used for entering and exiting a vehicle. Door system mainly consists of window glass, window regulator assembly, door latch, sealing and structural components of the door assembly. Traditionally these parts were designed, manufactured and procured separately. The window regulator, speaker, and other wire harnesses are mounted on the carrier plate using bolts, rivets, and clips. The window regulator consists of a motor assembly, one or two rails to guide the glass motion, cursor or glass clamps to support the glass, and mechanisms to move the glass up and down. On the other hand, the vehicle door's interior side is typically made up of a variety of materials, sometimes vinyl and leather, other time’s cloth and fabric.

Fig-1: car door

2. Design of car door and beam

2.1 Design Parameters

The design parameters were selected from reference papers and OEM's. Some modifications are carried out by varying the thickness and geometrical dimensions. All these dimensions are made with respect to the car door and beam. The existing side impact beam is modified by introducing different cross sections and also evaluating the model using three materials namely Aluminium Alloy, E-Glass Epoxy, S-Glass Epoxy thus reducing the material usage and also the weight of the car door.

Table-1 Specification of materials

Property	Aluminium alloy	e-glass epoxy	s-glass epoxy
Modulus of Elasticity (GPa)	71	80	89
Poisson's Ratio	0.33	0.3	0.3
Tensile Yield Strength(MPa)	280	nil	nil
Tensile Ultimate Strength(MPa)	310	nil	nil
Mass Density(g/cm^3)	2.77	2.55	2.49

2.2 Design of car door using CATIA

The geometric model of the car door (circular section beam) is done using CATIA Software. The Three-Dimensional model of the car door frame is shown in Fig. 2.

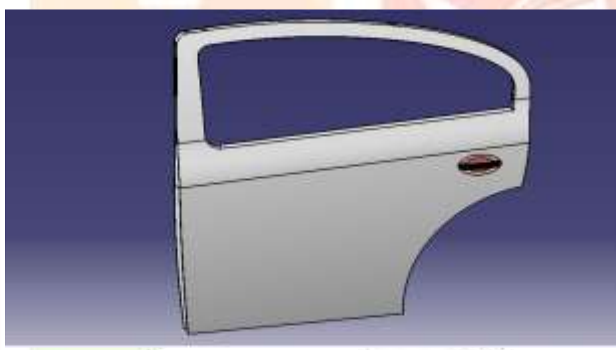

Fig-2: CATIA Model of car door

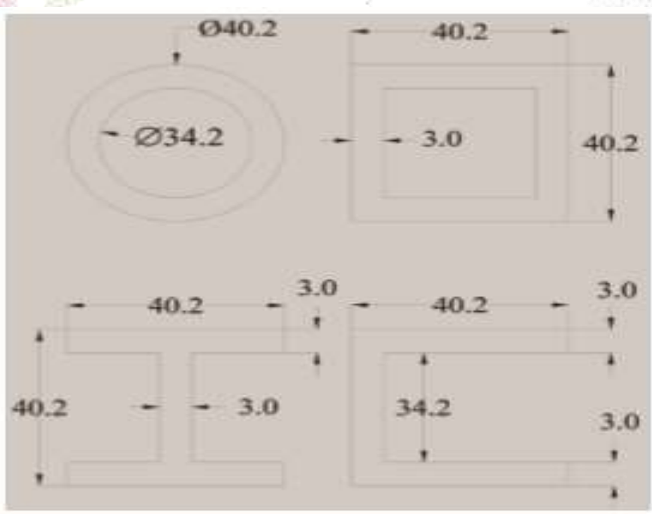

Fig-3 Cross Sections Used

Table-2 Force acting on the car door

S. No	Location	Load (Kg)	Load (N)
1	Door top	303	3000
2	Centre	810	8000
3	Door bottom	1110	11000

3. Analysis of car door

After the creation of the model using the design software, the geometric model is converted into STEP format in order to avoid data losses occurring due to importation of the geometric design file. There are three main steps involved in the analysis software, namely: pre-processing, solution and post processing. In the pre-processing stage, the geometric domain of the model is imported along with its material properties and boundary constraints. Further the geometric is meshed in several nodes and elements for accurate evaluation of the problem.

In the solution phase, the governing algebraic equations are formed and the unknown values are evaluated. The computed results are again utilized by back substitution method to determine the other additional variables and required information. In the post processing phase, the analysed results are evaluated and displayed.

3.1 Finite Element Analysis of car door using ANSYS Workbench

The model of the chassis is saved in STEP format which is imported into ANSYS Workbench. The imported model is shown in Fig-4.

Fig-4: Imported model in ANSYS Workbench

3.2 Meshing and Boundary Conditions

The model of the car door is meshed by using ANSYS WORKBENCH software.

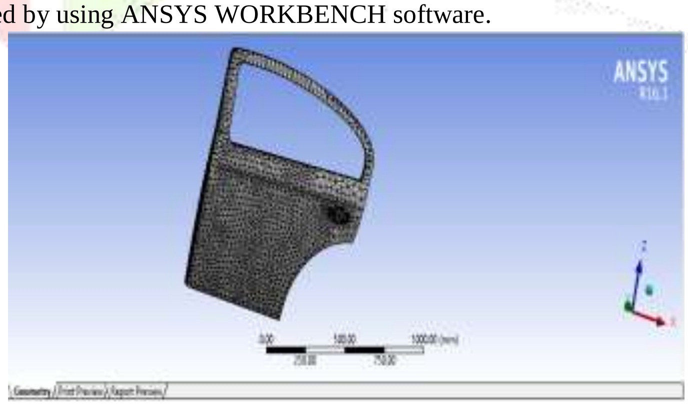

Fig-5: Meshed model of Car door

The car door is provided with necessary working loading which is considered to be uniformly distributed throughout the car door. The maximum impact load acting on the door is considered to be 8000 N and the passengers inside the car is weighted to 50kg at the impact in 3s. The finite element model of the car door provided with necessary boundary constraints are shown in the Fig 5.

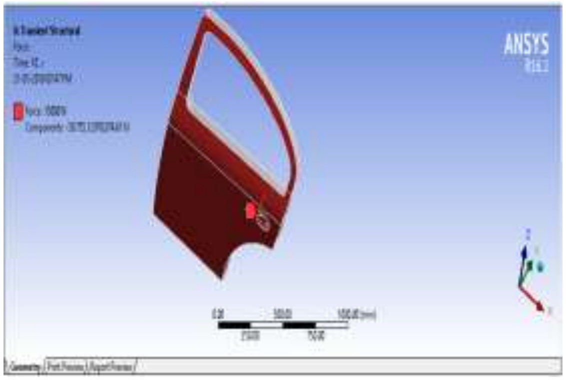

Fig-6: Load acting on outer body

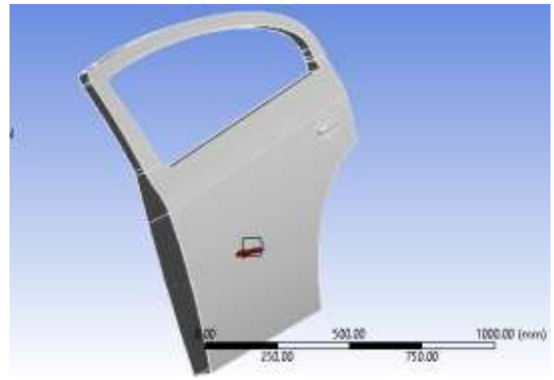

Fig-7: Load Conditions

3.3. Transient Structural Analysis of car door

The Finite element transient structural analysis of bus chassis model is experimented using three different materials – structural Steel, in the beam with three different materials with four different cross section mentioned above in the figure. The three different materials are aluminium alloy, epoxy-s glass UD, epoxy-e glass UD. The contour plots of all the three materials comprising the Von Mises stress distribution, Deformation and Normal Stress are shown in Fig-8 to Fig 16.

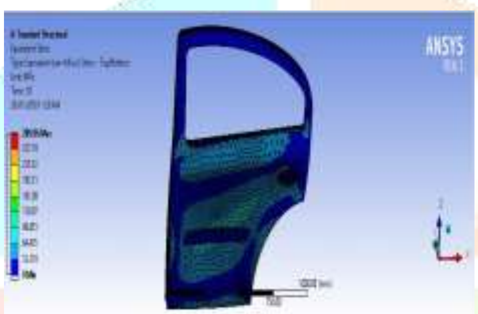

Fig-8 Von Mises Stress of Al-alloy box section

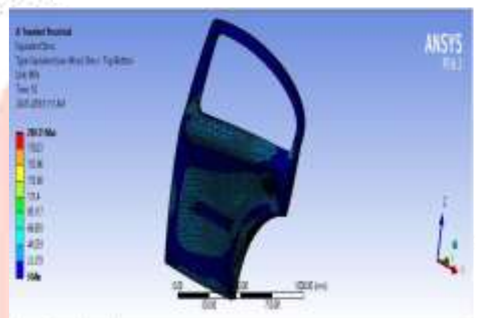

Fig-9 Von Mises Stress of S-Glass box section

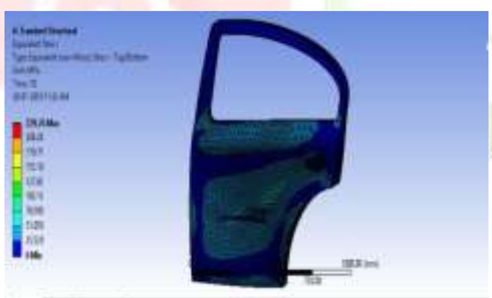

Fig-10 Von Mises Stress of E-Glass box section

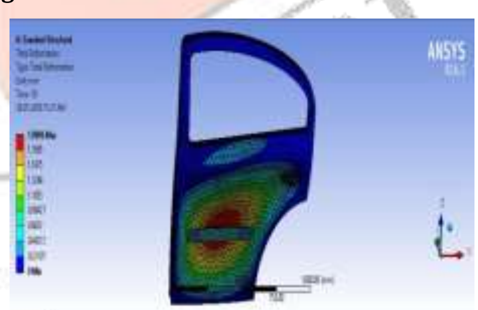

Fig-11 Total Deformation of Al-alloy box

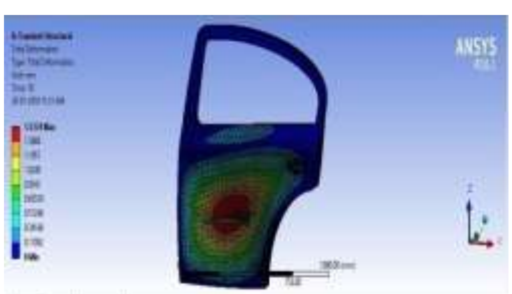

Fig-12 Total Deformation of E-glass -box

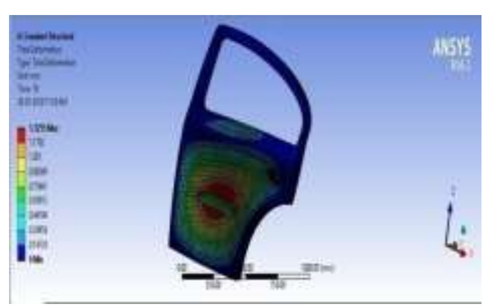

Fig-13 Total Deformation of S-Glass-Box

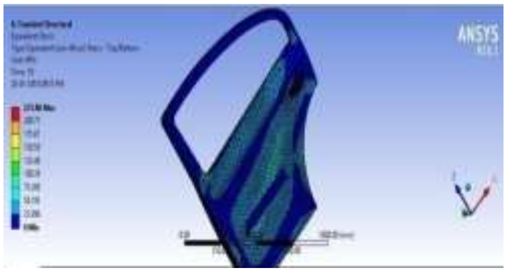

Fig-14 Von Mises Stress of Al Alloy-C section

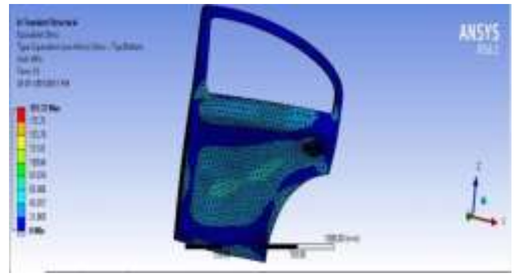

Fig-15 Von Mises Stress of S-Glass Epoxy-C section

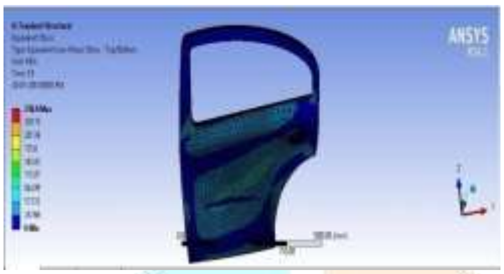

Fig-16 Von Mises Stress of E-Glass Epoxy-C section

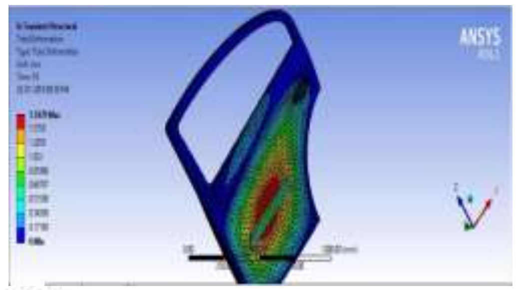

Fig-17 Total Deformation of Al Alloy – C section

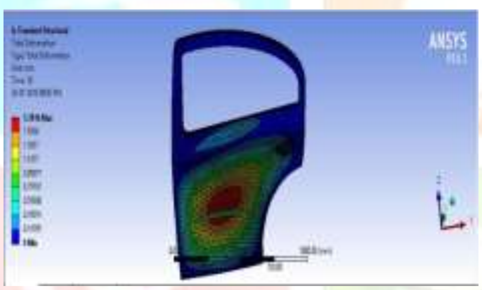

Fig-18 Total deformation of E-glass-C section

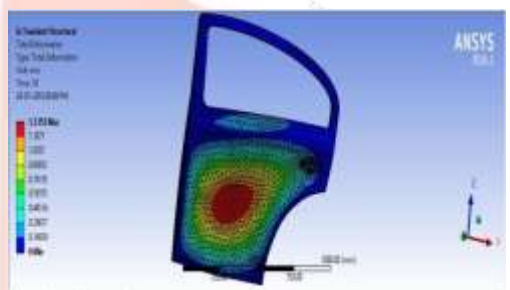

Fig-19 Total Deformation of S-glass – C section

4. Results

Since the problem given is a complex structure, the theoretical method cannot be used to determine accurate values and hence FEA results are taken into consideration. By using ANSYS, the results are tabulated in the Table-4.

Table-4 Results

Material	Aluminium alloy	e-glass epoxy	s-glass epoxy
Von Mises Stress (MPa)in box	289.96	229.76	200.51
Deformation(mm)in box	1.9896	1.5374	1.3255
Von Mises Stress (MPa)in box	225.86	258.9	215.72
Deformation in c section	1.5479	1.7816	1.3355

The graphical representation of the data evaluated using ANSYS software is shown in the Fig- 17 and Fig 18. The Fig-17 displays the comparison between the Von Mises Stress Developed in each material while the Fig. 18 displays the comparison of the deflection attained by the three different materials due to application of the loads.

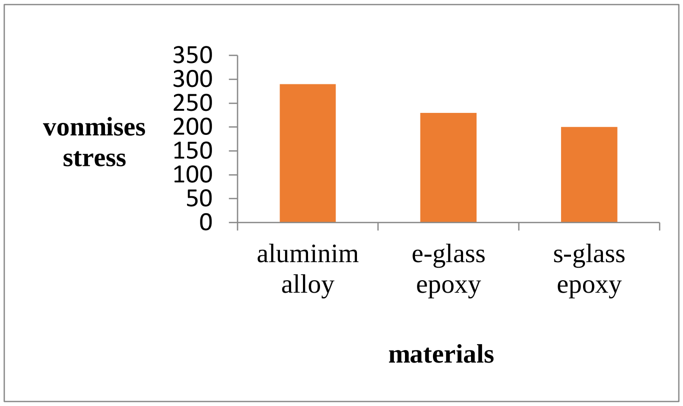

Fig-20 Bar Chart of Von Mises Stress in box section

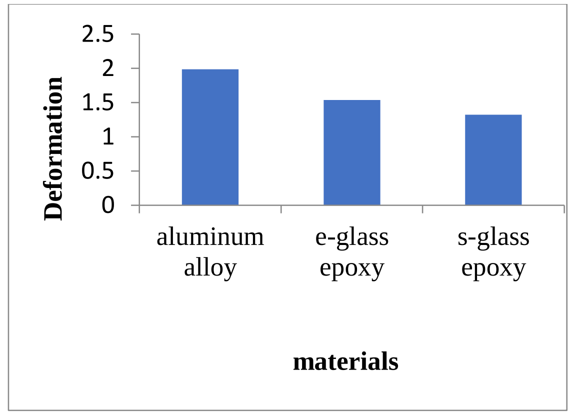

Fig-21 Bar Chart of Deformation in mm box section

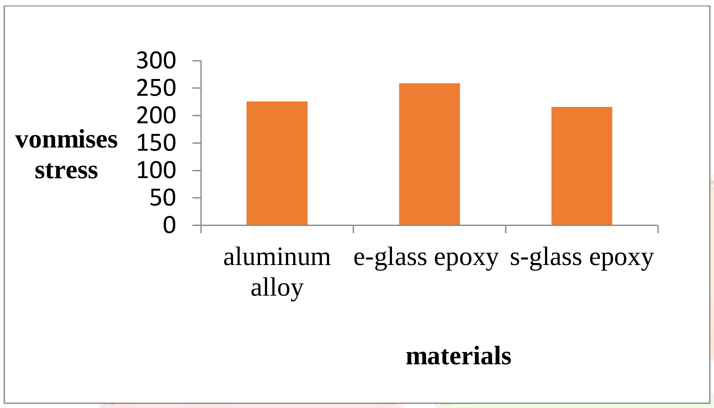

Fig-20 Bar Chart of Von Mises Stress in C- section

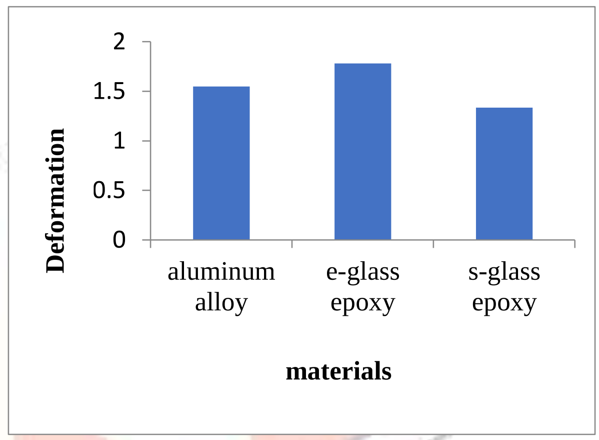

Fig-22 Bar Chart of Deformation in mm-C section

5. Conclusion

This paper focuses on improving the crashworthiness of the car door by analysing two different cross sections with three different materials such as ALUMINIUM ALLOY, E-GLASS epoxy UD and S-GLASS epoxy UD. By comparison with three materials improved crashworthiness is suitable for S-GLASS EPOXY UD when compared with another two materials. By applying these materials in practical application ALUMINIUM ALLOY consuming more weight than the S-GLASS EPOXY and it also preferable for improved crashworthiness than the E-GLASS epoxy material.

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