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Research Article

Opportunities in Optimizing Car Door Weight

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Abstract: Car door is an important part that is used for the protection of passengers from side collisions and also for the comfort of entering and leaving the car. Car doors weigh around 2% of total car weight. Conventional car doors are made from steel as it is sturdy. But it also contributes to the increment of the car weight. As scientific researchers are getting more advanced, finding out new materials as a substitute for conventionally used steel becomes more evident. Advancement in manufacturing and joining technologies pave the way to encouraging us to search for new improvement opportunities in car door weight optimization. Side impact collision of a car is the most hazardous as it directly hits the driver which causes injuries or death all over the world. Vehicle is one the medium of the terribly hazardous crashes causing injuries and death annually around the word. In this research paper, the most important parameters including materials, loads, stresses and deformation were studied to find out opportunities of car door weight optimization. Reduction in car weight means less fuel consumption which enables automobile industries to reduce carbon emission levels of a car. But the safety of passengers is the main priority which demands a light-weight as well as strong material that can sustain collision impact. The aim of the report is to compare the structure of different materials used in car door with currently used material. The designing of the car door is done using computer-aided three-dimensional interactive application (CATIA) software. Impact analysis is conducted on the door using ANSYS Workbench software by varying the materials. S-glass epoxy UD alloys become promising substitutes because of their satisfactory mechanical properties and specific strength.

***Keywords*:** vehicle door, weight optimization, finate element analysis (FEA), alternative materials, structural analysis

1. Introduction

A vehicle entryway (door) is generally pivoted. However, it might be supported by different systems, for example, tracks, near the passage which is utilized for entering and leaving a vehicle. A vehicle entryway can be opened to empower us to enter the vehicle, or shut to secure the passenger. Presently vehicle entryways can be opened physically, or controlled electronically. Battery powered entryways are generally found on smaller vans, good quality vehicles, or altered vehicles. In contrast to different kinds of entryways, the outer side of the vehicle entryway different from its inside side (the inside side is otherwise called the vehicle door panel). The outside side of the entryway is structured using steel along with the remainder of the vehicle's exterior structure. The focal design of the door is proposed to coordinate with the remainder of the vehicle's exterior appearance. The vehicle door's inner side is commonly comprised of an assortment of materials and textures including vinyl. The material selection relies upon the styles

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utilized in the vehicle's internal body like the dashboard, cover, seats, and so forth. Unlike the material utilized on the outer side of the vehicle entryway, the material on the inside side fills a more noteworthy need other than the simply stylish look. The materials that make up the inner side are expected to add to the general purposes along with comfort and solace. This is to state, a vehicle entryway board has inside parts that add to the general usefulness and ergonomics of the ride, for example, armrests; different switches; lights; electronic frameworks like the window controls and bolting component; and so forth.

Since material replacement and topology advancement strategies have been main aim for making light weighting car parts, there are a few examinations in the writing. Kim et al. [1] structured suspension lower arm by using finite element analysis (FEA) with changes in design. They expressed that the new lower arm is stiffer in comparison with the traditional steel lower arm while having half the weight. Polavarapu et al. [2] utilized topology changes joined with free-size enhancement for a lightweight plan of die cast car seat outline. Hirsch [3] demonstrated the light weight possibilities and focus of the automobile sector. He expressed that 50% weight savings in vehicle parts can be accomplished with the assistance of aluminum while keeping up security and execution of the vehicle. Lau et al. [4] stated that 18% of the road accident related injuries involves side impact incidents, of which 35% of the injuries are fatal. It should be noted that it is more difficult to protect the occupants against side impact collisions, as there is less space for the vehicle structure to deform and crumple to absorb impact energy. During a side impact, the key component to protect the occupants of a vehicle is the door. Zini et al. [5] indicated that some feasible innovations that may lead to a better side impact protection, pointing out some aspects that can be developed thoroughly within the corresponding settings and using the appropriate resources. Ghadianlou et al. [6] developed the side-door impact beam for passenger cars using glass-fibre-reinforced composite.

2. Weight reduction opportunities

The decrement of the vehicle weight is an effective way to deal with the developing worries about ozone depleting and fuel consumption by traveller vehicles. It is found that for each 15% decrement of the vehicle weight, the fuel usage is reduced by about 7%. In present times, vehicle weight reduction is basic for meeting future, more severe fuel efficiency measures. It is a must for the new vehicles to get lighter, give better kilowatt enhancements, and utilize more eco-friendly power trains, for example, half mechanical and half electric drives. We can reduce weight by replacing a portion of the iron and steel utilized in vehicles with lighter-weight high-quality steel or aluminium by making modifications to the design or size of the vehicle. By using these techniques, we can accomplish up to 40% (690 kg) vehicle weight decrease [7]. The expense related with assembling light weighted vehicles isn't justified, despite any potential benefits. Moreover, the properties of materials, effect of utilizing other lightweight materials, which can be more harmful for the environment to create and handle, should be thought of. Materials that are lightweight and strong but harmful for nature cannot be used.

As a basic vehicle part, the hinges on the door help join the vehicle body to the entryway. Their function is to bolt or open the vehicle entryway. The other function is to secure body-entryway association, particularly during a collision. The regular entryway hinges comprise of four sections, a fixed part of the pivot on the vehicle body, a portable piece of pivot on an entryway, a pin to hold fixed and moving parts, and a plastic plug to diminish the sound of opening and closing the entryway. Generally, these parts are created from structured steel made by the procedure of forging. In Figure 1, the parts of entryway for the business vehicle are shown.

3. Material properties

The design parameters were selected from reference papers and original equipment manufacturer (OEM)'s. Some modifications were carried out by varying the thickness and geometrical dimensions. All these dimensions were made with respect to the car door and beam. Three materials namely aluminum alloy, E-glass epoxy, and S-glass epoxy were considered for reducing the material usage and also the weight of the car door (Table 1).

Table 1. Properties 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

4. Modelling and boundary conditions

4.1 *Door modelling:*

The geometric model of the car door (circular section beam) was done using CATIA Software. The three-dimensional model of the car door frame is shown in Figure 1.

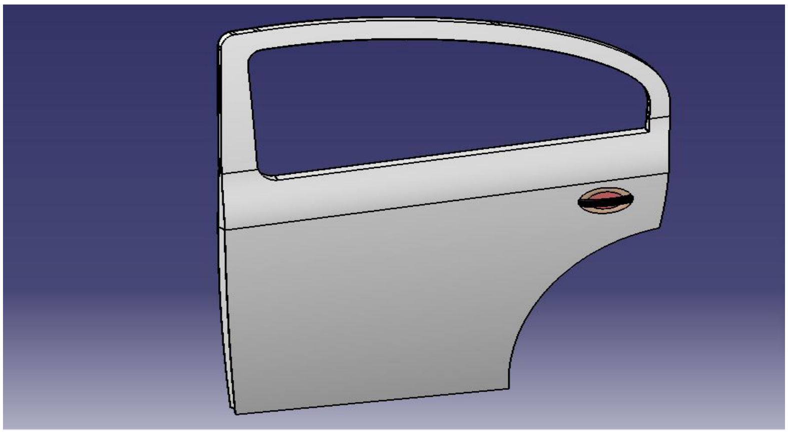

Figure 1. Car door CAD model

4.2 *Mesh modelling:*

After the creation of the model using the design software, the geometric model was converted into Standard for the Exchange of Product Data (STEP) format (Figure 2) 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 was imported along with its material properties and boundary constraints. Further the geometric was meshed in several nodes and elements for accurate evaluation of the problem.

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

The car door was provided with the necessary working load (Table 2) which was considered to be uniformly distributed throughout the car door. The maximum impact load acting on the door was considered to be 8000 N and the passengers inside the car were weighted to 50 kg at the impact after 3s. The finite element model of the car door was provided with necessary boundary constraints.

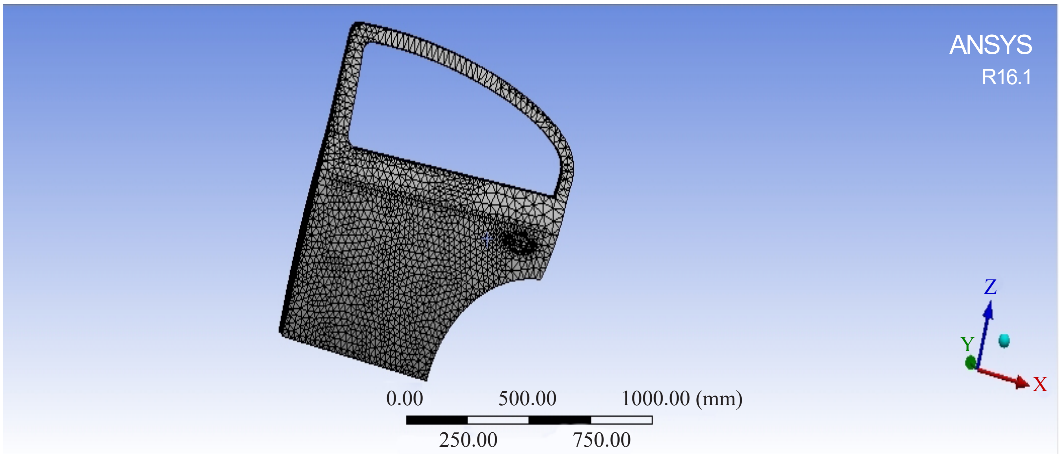

Figure 2. Car door meshed model

Table 2. Loading conditions

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

5. Transient structural analysis

The finite element transient structural analysis of bus chassis model was experimented using three different materials-structural steel, in the beam with three different materials with four different cross sections mentioned above in Figure 3 to 8. The three different materials are aluminum alloy, epoxy-s glass UD, and 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 Figure 3 to 8.

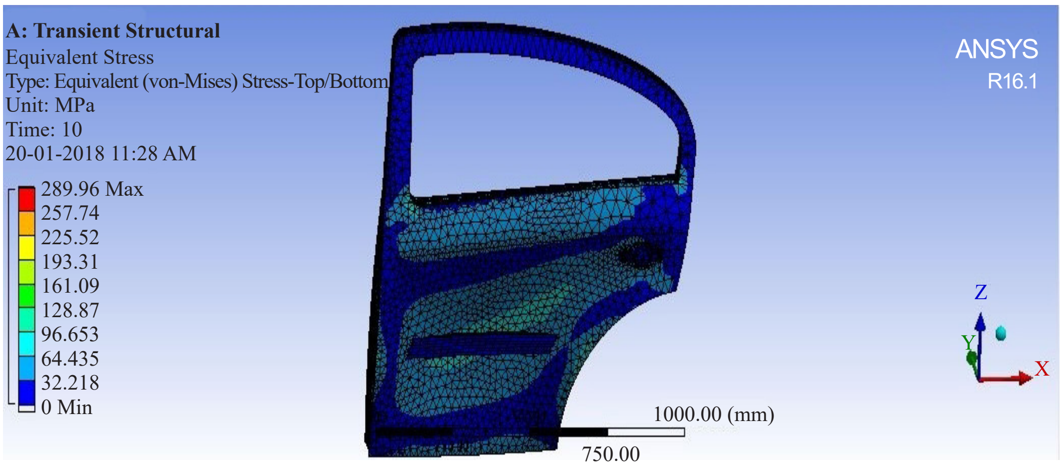

Figure 3. Von Mises stress of Al-alloy box section

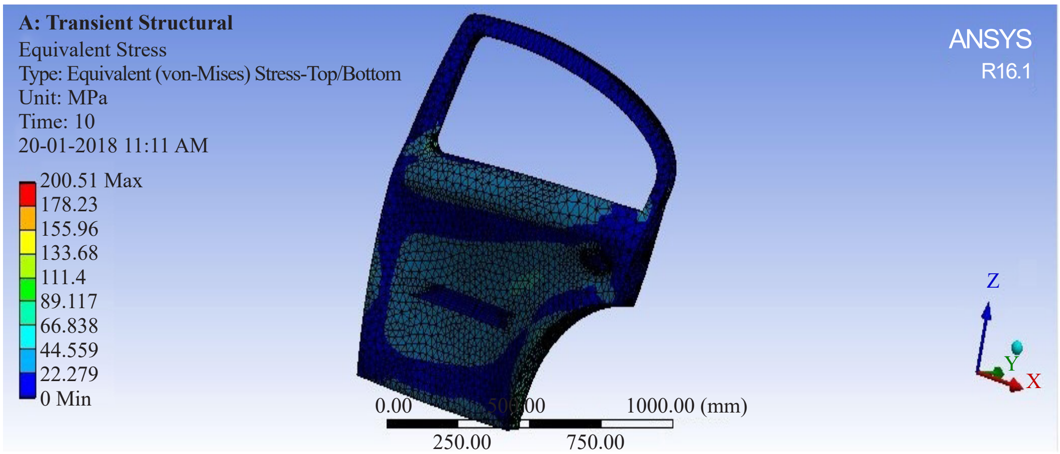

Figure 4. Von Mises stress of S-glass box section

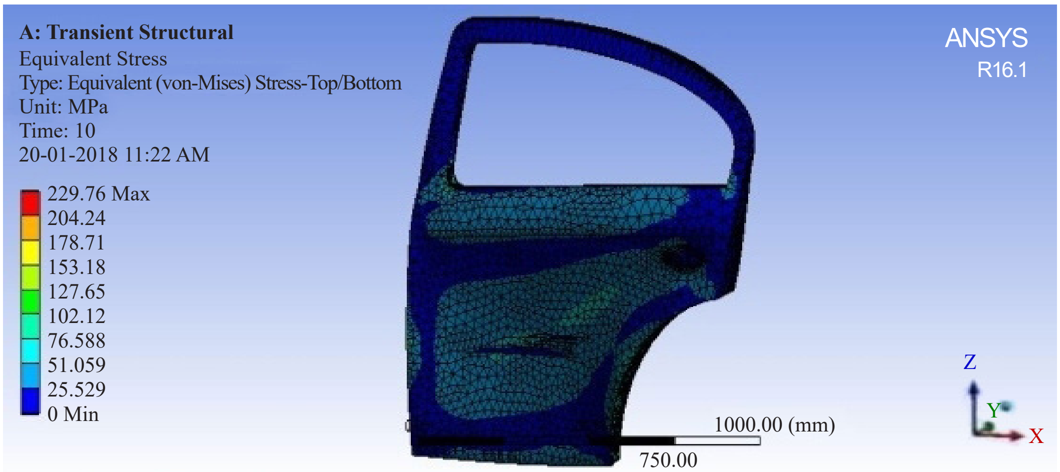

Figure 5. Von Mises stress of E-glass box section

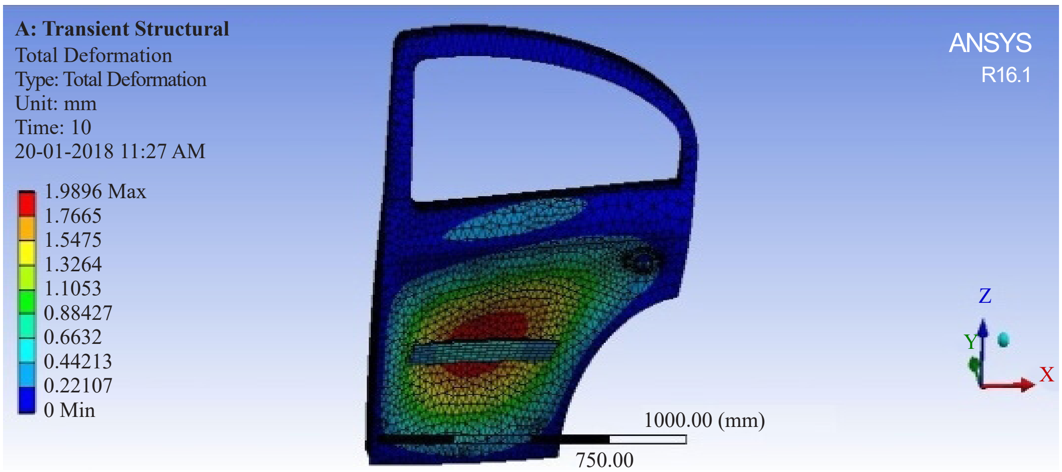

Figure 6. Total deformation of Al-alloy box section

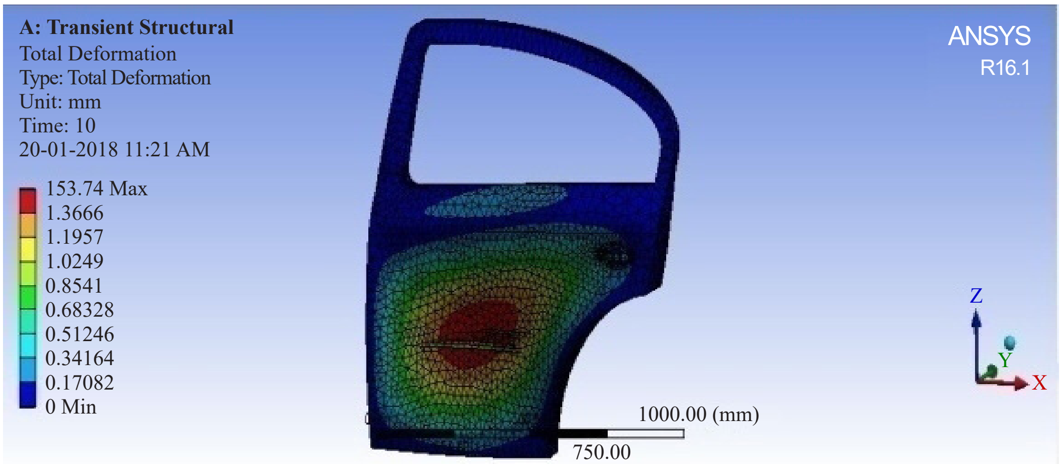

Figure 7. Total deformation of E-glass-box section

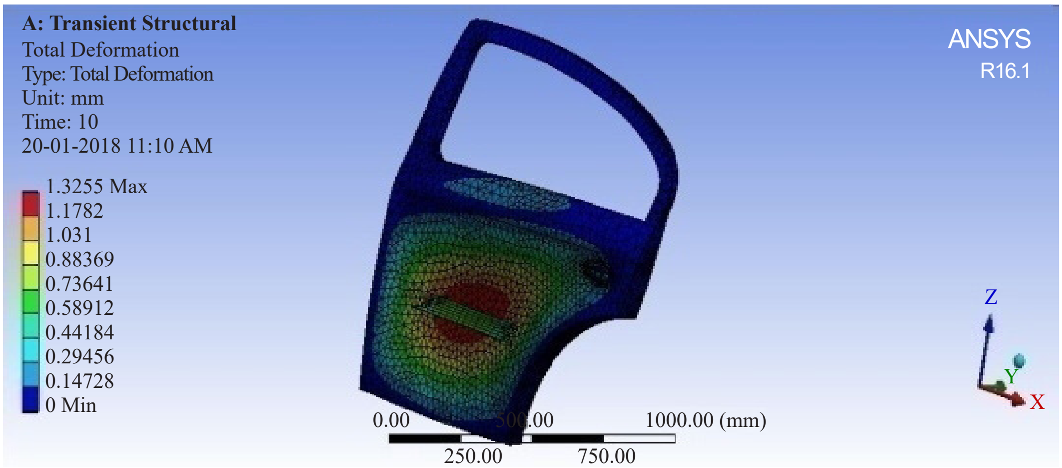

Figure 8. Total deformation of S-glass-box section

Since the problem involved 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 Table 3.

Table 3. Result data for three cases

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 c section	225.86	258.9	215.72
Deformation (mm) in c section	1.5479	1.7816	1.3355

The graphical representation of the data evaluated using ANSYS software is shown in Figure 9 and 10. Figure 9 displays the comparison between the Von Mises Stress developed in each material while Figure 10 displays the comparison of the deflection attained by the three different materials due to application of the loads.

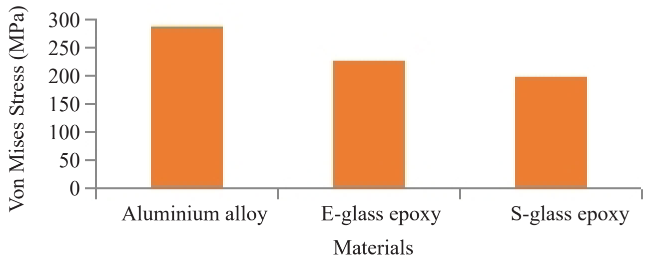

Figure 9. Graph of Von Mises Stress in box section

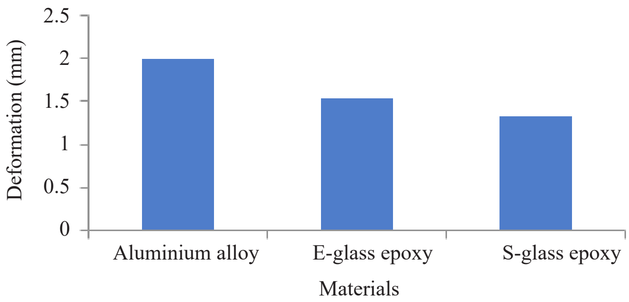

Figure 10. Graph of deformation in mm for box section

After studying these three cases, we can summarize the results as:

• The quality of the vehicle entryway is enhanced alongside weight reduction by changing material from steel to E-glass epoxy and S-glass epoxy.

• The cost of the door rises by utilizing the composite materials for the fabrication. However, this could help reducing the hazard from the crashes.

• Since FEA results match with the hypothetical calculations most of the time, it can be considered as a decent instrument to decrease the tedious hypothetical work.

6. Conclusion

This paper focuses on exploring the opportunities in car door weight optimization by analysing box cross section with three different materials such as aluminium alloy, E-glass epoxy UD and S-glass epoxy UD. The S-glass epoxy UD material shows better optimization on the car door weight when compared with the other materials. This is because the practical application of aluminium alloy is consuming more weight than the S-glass epoxy. When compared with the E-glass epoxy material, S-glass epoxy is more preferable for its ability to improve strength and reduced weight.

Conflict of interest

The authors declare no conflict of interest.

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