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Finite Element Analysis of Internal Door Panel of a Car by Considering Bamboo Fiber Reinforced Epoxy Composite

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Abstract

In this paper work the dynamic structural Finite Element Analysis of internal door panel of a vehicle by considering bamboo fiber reinforced epoxy composite (BFREC) materials was conducted. The objective of the paper is to develop a suitable model of internal door panel for Toyota DX car, to conduct a transient dynamic structural analysis (stress and displacement analysis) of internal door panel by finite element method, to compare the performance of BFREC material with previously recommended materials of internal door panel. The door panel of Toyota Corolla DX model vehicle was used to develop the geometric model of the internal door panel by CATIA V5 R20 modeling software. This 3-D geometric model was imported to using ANSYS Workbench 15.0. The transient dynamic structural FEA was done after assigning loading and boundary conditions. The applied load considered for this analysis is the self-inertial weight of the panel due to the acceleration field produced while the door is closing. The equivalent stress and the displacement are noted and investigated to compare with the literatures revised. The result shows that, bamboo fiber reinforced epoxy composite panel has the smallest mass and equivalent stress values, as compared with the ligno-cellulosic composite and polypropylene one. Based on these realities, it is recommended that bamboo fiber reinforced with epoxy composite materials are suitable for internal structural automotive panel applications.

Keywords: Bamboo fiber; Epoxy; Composite; Door panel; Transient structural analysis; Equivalent stress; Displacement; Finite element analysis

Introduction

In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile designers and manufacturers in the present scenario. Weight reduction can be achieved primarily by the research of better material, design optimization and better manufacturing processes. Due to rise in demand of lightweight and more efficient vehicles and better mechanical performance of materials in automotive applications, different material combinations such as composites, plastic and light weight metals are implemented on different structural parts of vehicles. Applications of composite materials in automotive industries already include some structural parts, such as dashboard, roof, floor, front and back bumper, passenger safety cell, and door panels [1-5].

The internal door panel of an automobile is typically made of different materials. Unlike the materials used on the exterior side of the vehicle door, the material on the interior side serves a greater purpose other than just aesthetic appeal. The internal door panel of an automobile contributes to the overall functionality and ergonomics of the ride, such as: armrests, various switches, lights, electronic systems like the window controls and locking mechanism; etc. [6-9].

Composite materials made of natural fibers and polymer matrix provides synergistic properties, improving their strength and durability. These materials are suitable for achieving automotive interior components, where in addition totheir low weight have also high rigidity and good thermal and sound insulation. The most important internal vehicle elements include car internal door panels [10-13].

Materials and Methods

In this analysis, the bamboo fiber/epoxy composite materials with a considerable composition are used as the materials of internal door panel of an automotive.

During selecting the material, the characteristics of the composite, the ways of fiber extraction, the ease of the manufacturing process, the types of the matrix used for the composite and some other criteria are taken into consideration. In addition to this, the selection of the material for this specific research work is basically focusing on the Ethiopian bamboo fiber and the researches which have previously done on it. Based on these measures, the composite with 25% bamboo fiber and 75% epoxy resin was selected [14] (Table 1).

Modeling and Analysis

The following steps are used in the solution procedure using ANSYS Workbench software for transient structural Finite Element Analysis of a mechanical problem [15] (Figures 1 and 2).

1. Imported the geometry of the panel from modeling software to the ANSYS workbench.
2. The material type and its properties are specified.
3. Meshing the imported panel model.
4. The boundary conditions and external loads are applied.
5. The solution is generated based on these input parameters.
6. Finally, the solution can be displayed.

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Material Property	Values
Density (ρ)	1.12 g/cm³
Tensile Strength	187.73 MPa
Flexural Strength	190.32 MPa
Compressive Strength	114.13 MPa
Shear Strength	81.18 MPa
Young's Modulus	3852
Shear Modulus	1580

Table: 1: Mechanical properties of Bamboo fiber reinforced epoxy composite [10].

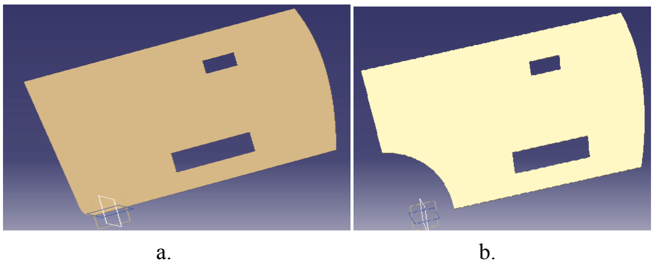

Figure 1: The 3D modelling of the internal door panel; a). Front left door panel; b). Rear left door panel.

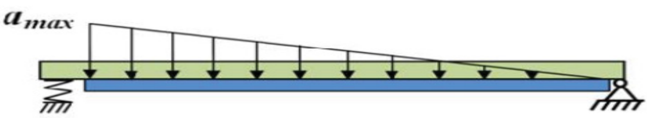

Figure 2: Acceleration field resulting from inertia forces due to its own weigh.

The internal door panel has several areas where constraints are applied as follows:

- Upper part rests on a metal door structure, thus blocking shifting on the y direction (U_2).
- In screw mounting areas shifting are blocked on all three directions (U_1, U2 and U3).
- On clips systems panel mounting metal structure areas, shifting are blocked on all the three directions (U_1, U_2 and U_3).

Where, U_1, U_2 and U_3 are the displacements in x, y and z directions, respectively.

Results and Discussion

The transient structural dynamic analysis determines characteristics of the stress and deformation of the structures (the panel) caused by the applied loading systems and boundary conditions (Figures 3-10).

Discussion

This transient structural dynamic analysis of the internal door panel of a vehicle using BFREC was performed for self-weight inertial load intensity of the shock produced while closing the door.

Comparing the results obtained by FEA of the BFREC panel with the panels of other previously recommended materials (ligno-cellulosic composite and polypropylene plastic composite materials) is important to see the improved achievement. The comparison is carried out by making everything the same, except the material properties; i.e. at the same acceleration field (350 m/s²) in the same model and the same method of FEM analysis (Figure 11).

Equivalent (Von-Mises) stress

The results of this analysis show that the equivalent (Von-Mises) stress of the BFREC panel is the smallest one as compared to that of the lignocellulosic composite and polypropylene panels. This implies that BFREC material is less stressed and thus, has a better performance.

Displacement

The maximum displacements of the BFREC panel are lower by about 34% than the lignocellulosic composite panel and 50% of the

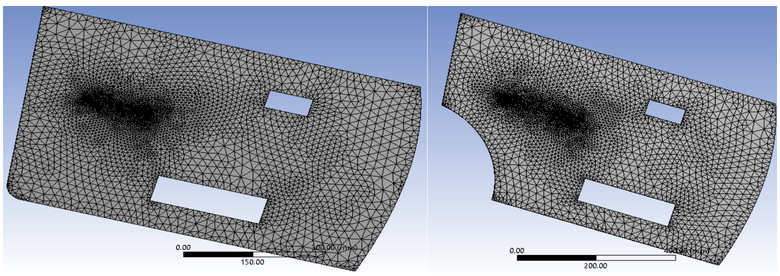

Figure 3: Geometric meshing of the model on ANSYS workbench.

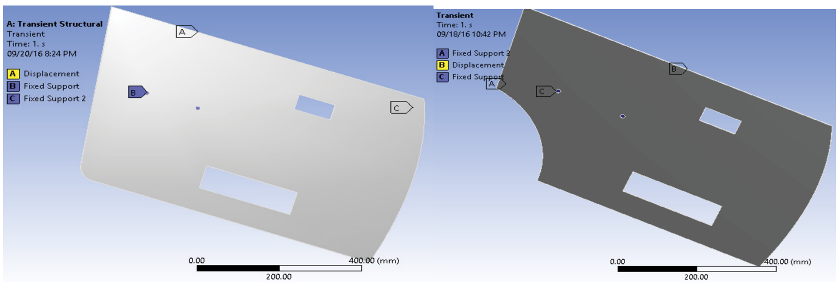

Figure 4: Applying boundary conditions on ANSYS workbench.

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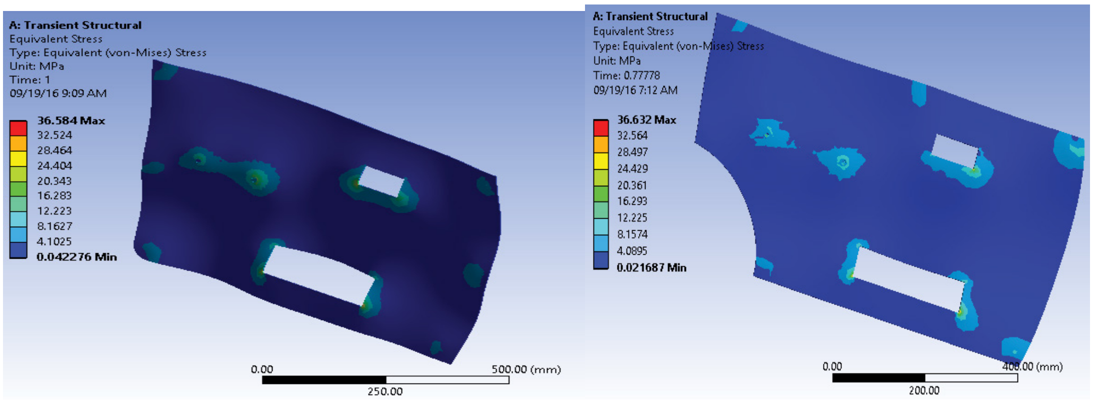

Figure 5: Equivalent (Von Mises) stress of BFREC door panel.

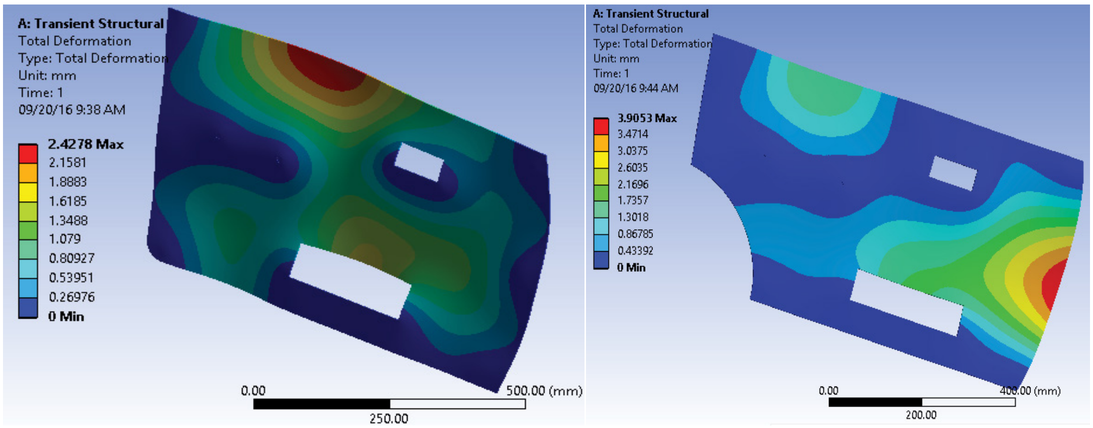

Figure 6: Total displacement of BFREC door panel.

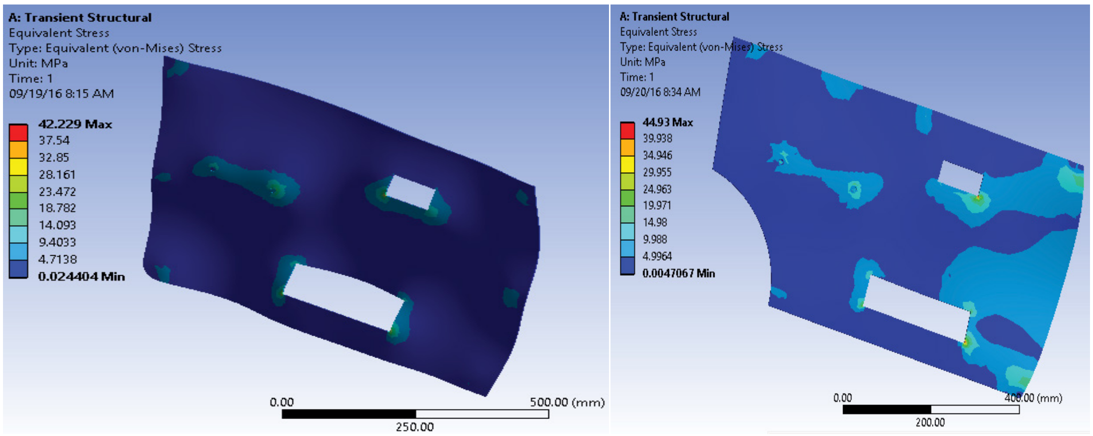

Figure 7: Equivalent stress of lingo-cellulosic composite panel.

polypropylene panel. This is due to the greater rigidity of BFREC material.

Moreover, the mass of BFREC panel is reduced by 6% and 8% than that of lignocellulosic composite and polypropylene materials respectively. The smaller mass of the BFREC panel helps to make the vehicle lightweight, so that the efficiency and fuel economy of the vehicle is improved by reducing its dead weight [16] (Tables 2 and 3).

Conclusion

In order to achieve the goal of this study, different tasks were performed and the following conclusions are drawn.

1. The transient structural dynamic analysis of the modeled panels was performed by ANSYS Workbench 15.0 analysis software.
2. Under the same applied load and boundary conditions, the

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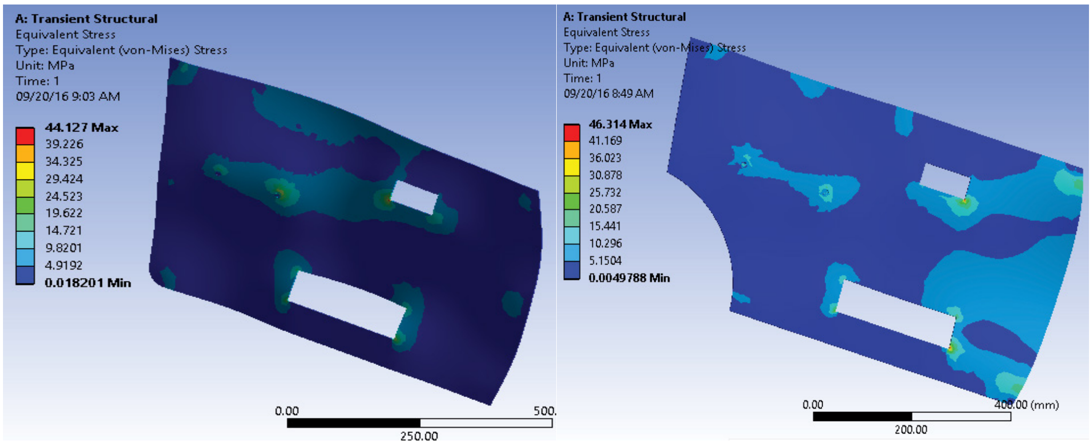


Figure 8: Equivalent stress of polypropylene composite panel.

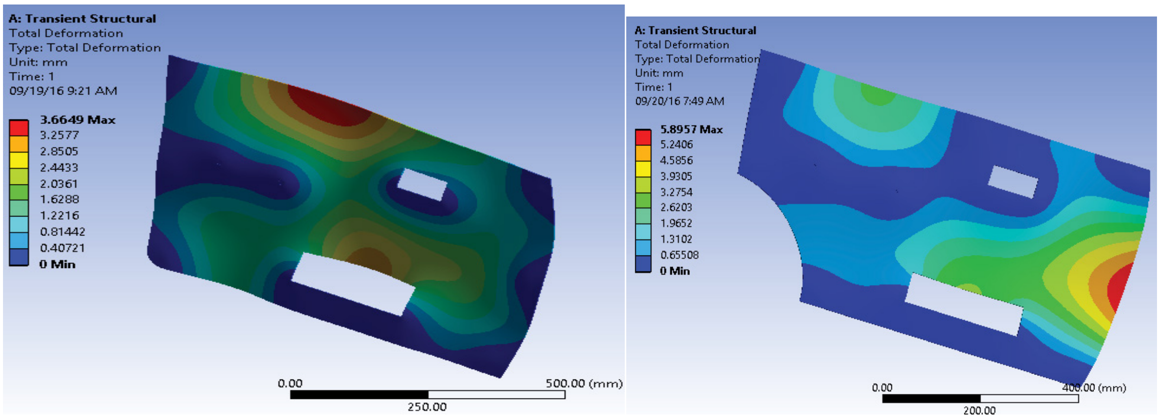


Figure 9: Total displacement of lingo-cellulosic composite panel.

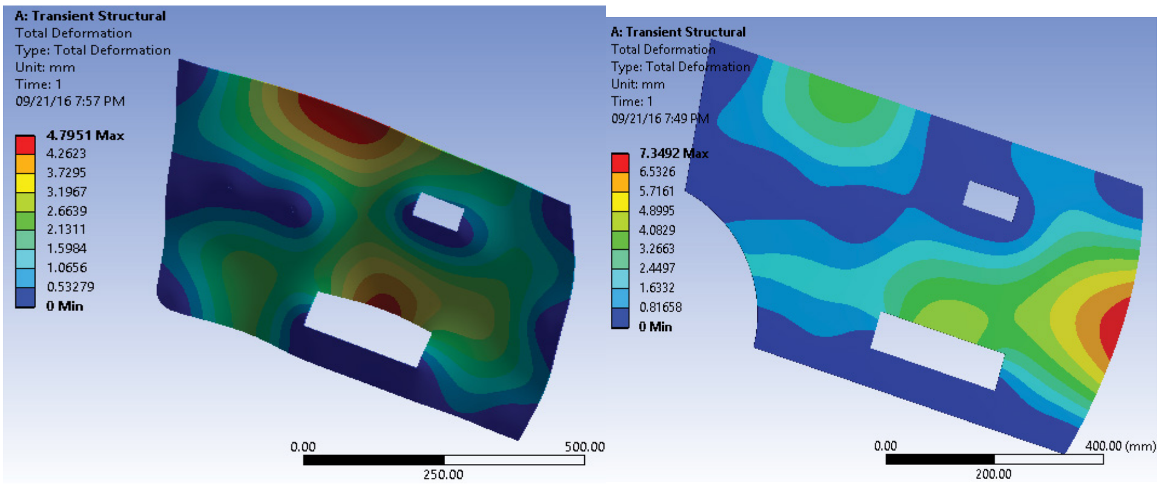
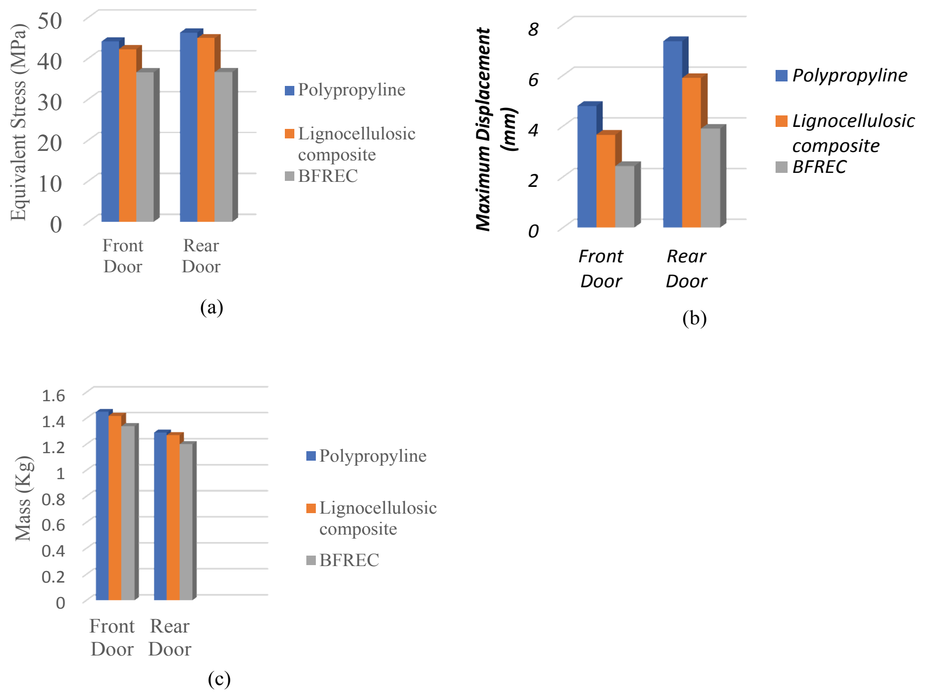


Figure 10: Total displacement of polypropylene plastic composite panel.

smallest equivalent (Von-Mises) stress is recorded on BFREC panel as compared to the ligno-cellulosic composite and polypropylene panels. Thus, BFREC panel performs in a better way at a given loading condition.

3. Displacements of BFREC materials internal door panel obtained by FEA are smaller by 34% and 50% than that of the ligno-cellulosic composite and polypropylene plastic materials respectively.



The charts plotted above will show the comparisons of these values clearly for both front and rear door panels.

Figure 11: Comparison of the results of different materials; (a) equivalent stress, (b) maximum displacement, (c) weight of the panel.

Internal door panel	Equivalent Stress (MPa)		Maximum Displacement (mm)		Mass (kg)	
	Front	Rear	Front	Rear	Front	Rear
Polypropylene panel	44.13	46.31	4.80	7.35	1.45	1.29
Ligno-cellulosic composite	42.23	44.93	3.66	5.90	1.42	1.27
BFREC panel	36.58	36.63	2.43	3.91	1.34	1.20

Table 2: Comparing the FEA results of the panels at an acceleration of 350 m/s^2.

	Front door	Rare door
Number of nodes	47136	41751
Number of elements	22785	20015

Table 3: Geometric meshing of the model on ANSYS Workbench.

4. Small values of displacements resulting for BFREC component are due to the high rigidity and low weight material component given its lower thickness of the panel.
5. Moreover, the mass of the newly modeled panel is reduced by 6% and 8% than that of ligno-cellulosic composite and polypropylene materials respectively.

Finally, it is recommended that bamboo fiber reinforced with epoxy composite materials are suitable for internal structural automotive door panel applications.

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