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Experimentation on 3D Printed Core Material – Application in Automotive Industry

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Abstract

The emission of gases and fuel efficiency of vehicles are two important issues in these days. The best way to increase the fuel efficiency is to reduce the weight of vehicle parts. Without sacrificing safety, we have to employ composite materials in the bumper. Polymer composite materials have been a part of the automotive industry for several decades but the economic and technical barriers have constraint their use. In this context, a composite sandwich structure is prepared using 3D printed material as a core sandwich structure with the top layering of natural fibre. The composite structure is prepared using vacuum bagging process. The specimens are cut using water jet machine and prepared for several analysis test is conducted on Ansys software to compare the present material and the material to be prepared.

Keywords: *3D printed material, Bumper, Sandwich Composite structure, Natural fiber.*

1.0 Introduction

This paper will study about composite sandwich structure which is used in automobile industry for the creation of bumper material A composite material, also known as a composite, is a solid that is produced when two or more distinct substances, each with its own qualities, are mixed to produce a new substance with better properties than the original components in a particular application: The application of this paper is in automotive industry e.g., bumper of car. An automotive bumper is the rear most or front most part of the vehicle which is used to protect the passengers inside from the impact during a collision. The bumper plays an important role in the energy absorption during a collision. The bumpers are not capable of reducing the effect of impact at high speeds instead they are focused on mitigate injury to pedestrians struck by cars. The materials selected for automotive bumper has been recently a concern. There are two main factors that has to be considered while the selection of bumper materials; i.e., it should provide better performance than the previous materials, should be cost efficient and secondly there should be increase in strength at the cost of reduced weight. Experimental and numerical assessment of high-velocity impact behaviour of syntactic foam core sandwich structure is undertaken in which the results are found that when the projectile shape is changed, no significant changes are occurred in the residual velocities of the projectiles and energy absorption of sandwich structures. These small differences are, primarily, due to the different modes of specimen perforation[1]. An experiment on crash analysis of a passenger car bumper assembly to improve design for impact test is conducted in which it is resulted that the reinforced thermoplastic is more suitable than the other material as it has higher impact absorbing capacity during road collision[2]. In the detailing of design aspects and method of analysis with particular reference to the application of composite materials to automotive front bumper subsystem, crash box and bumper beam, it is said that

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the lowest tensile strength was exhibited by GMT. It is evident to observe the experimental results that inclusion of unidirectional fibres inside the GMT improved the tensile strength by 125% in the longitudinal direction. The transvers tensile strength was reduced by 11%[3]. A study on corrugated design-based 3D printed sandwich panels subjected to quasi-static compression is undertaken, it can be concluded that the sandwich panel with CFS-3 core design has an optimal structural performance[4]. A numerical analysis of natural fiber reinforced composite bumper is undertaken in which it can be concluded that the natural fiber hybrid composites are the best option for automobile manufacturers to make their vehicles eco-friendlier and also reducing the weight and increasing the fuel economy of the vehicle[5]. In an experiment of design improvements of vehicle bumper for low-speed impact, it can be concluded that the front of metal bumper beam takes the major contribution in the energy absorption during low-speed impact. The modifications done in the design of bumper beam has resulted in improvement in energy absorption capacity of the bumper[6]. In an experiment of 3D printed sandwich beams with bioinspired cores, it is resulted in the geometrical parameters and the relative density of the core have a significant influence on their bending stiffness, maximum load and energy absorption capacity, while the core topology has limited effects on the bending stiffness but affects the maximum load and energy absorption remarkably[7]. An analysis on the effect of geometrical parameters on the flexural properties of sandwich structures with 3D-printed honeycomb core and E-glass/epoxy face-sheets, it is resulted in the biggest values of normalized face-sheet bending and core shear stresses were corresponded to the horizontal core sandwich panel with the cell wall thickness of 2mm. These values are equal to 145.59 MPa/kg and 2.9118 MPa/kg, respectively[8]. An analysis of formation, characterization and suitability of polymer matrix composite materials for automotive bumper is undertaken, in which it is said that the subsequent conclusions are made. The ultimate tensile strength of the Aramid composite of sample A is 147 MPa which is comparatively above that of existing light weight stainless steel with 120 MPa. The impact load of sample A is 20 Joules which is quite greater than the impact load of stainless steel which is 9 Joules[9]. In an experiment of aluminum honeycomb impact tests with various velocities and parametric, it can be resulted in mechanical property and energy absorption capability of aluminum honeycomb structures vary with impact velocity, which proves the velocity sensitivity for honeycomb structure[10].

2.0 Experimental Details

An experiment to form the sandwich structure of two different 3D printed core material and natural fibre for automobile application. Reinforcement of 3D printed core material with natural fibre was done by vacuum bagging method to form the sandwich structure. To analyse the structural properties. Materials used here are natural fibre, 3D printed material (ABS and PLA), epoxy and hardener. Natural fibers can be matted into sheets and formed a layer upon the composite materials. By the study of literature survey, it is understood that there is a greater specific stiffness and specific strength, more resistance and corrosion, better recyclability, large fatigue strength, more impact absorption capacity. A 3D printed material are used as the core material with top covering of natural fiber. In this experiment, Acrylonitrile Butadiene Styrene (ABS) and Polylactic acid (PLA) is used as the main core sandwich structure. Araldite LY 556 by Huntsman is a medium-viscosity, unmodified epoxy resin based on bisphenol. A that possesses excellent mechanical properties and resistance to chemicals. Hardener is the epoxy curing agent that is responsible for reacting with the epoxy groups contained in the epoxy.

2.1 Preparation of Composite Material

Vacuum bagging is a simple method for composite production. Initial step in the specimen preparation starts by cleaning the flat surface, then applying the wax on the flat surface so that the composite form does not stick to the flat surface. Araldite LY 556 resin is poured evenly on the surface and natural Sisal fibre is placed above that. A composite which has to be prepared is not to be joined directly to another structure. Before the process, 3D printed material is to be prepared working as per the dimensions of the work required. Initially a layer of natural fiber is spread over the flat surface

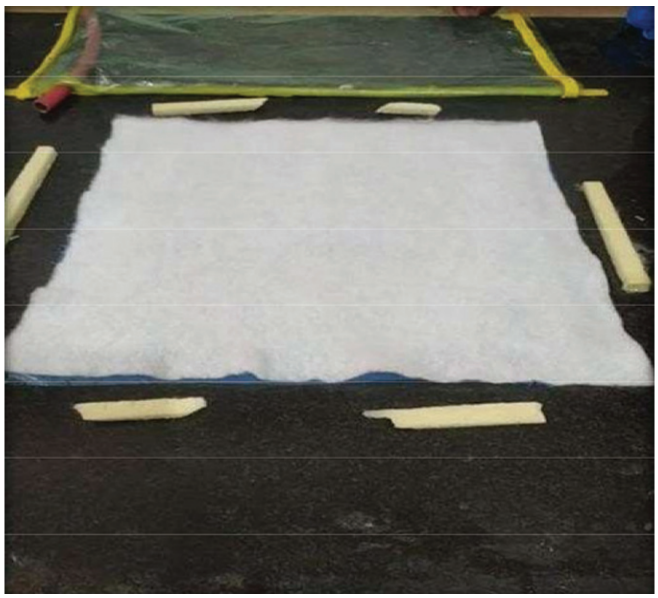

Figure 1: Experimental set up for Vacuum

Figure 2: Composite material after water jet cutting

along with the 3D material and epoxy for proper adhesion further another layer of fiber is placed above the 3D material with the help of epoxy and hardener for proper adhesion the fiber thus to from the composite. Further the process is carried out with vacuum bagging process by applying vacuum pressure. The experimental set up for vacuum bagging process is shown in the Figure 1. Peal ply, release film, breather fibre and vacuum bag film are placed one above the other and sealant tape is used on the top to avoid the air flow during the vacuum bagging.

Since the exact cutting of vacuum bagging layers and 3D printed material to the required dimension is not possible, these are kept for an extra dimension of 5mm for all the sides during the process and a composite material is prepared. The composite material is then shaped to the required test dimension by cutting through water jet cutting process.

3.0 Result and Discussion

The composite materials of ABS and PLA 3D printed material is made using vacuum bagging process. Both the composite materials can be used for the application of bumper. As this work aims to compare both the materials and select the most effective material, an analysis is carried out with the help of ANSYS software. Several tests were conducted like impact, tensile 3 Point Bending test the results after carrying out the analysis of ABS shown in the Figures 3, 4 and 5 and Figures 6, 7 and 8 for the PLA. The maximum and minimum value of total deformation and equivalent stress is tabulated in the Tables 1 and 2 for ABS and PLA composite materials respectively.

3.1 Tensile Test Results

3.1.1 Tensile test for 1 sample ABS

Table 1: Tensile Test ABS Materials specification

Width of specimen	25 mm
Thickness of specimen	5 mm
Gauge length	150 mm
Original grip separation	0 mm

Table 2: Tensile test Results for ABS Materials

	Given strain %	Tensile strength (MPa)	Tensile strength at yield (MPa)	Tensile strength at break (MPa)
No.1		25.58	24.36	24.23

Percentage elongation at break (%)	Percentage elongation at at yield (%)	Modulus of Elasticity (MPa)
2.64	2.33	1664.06

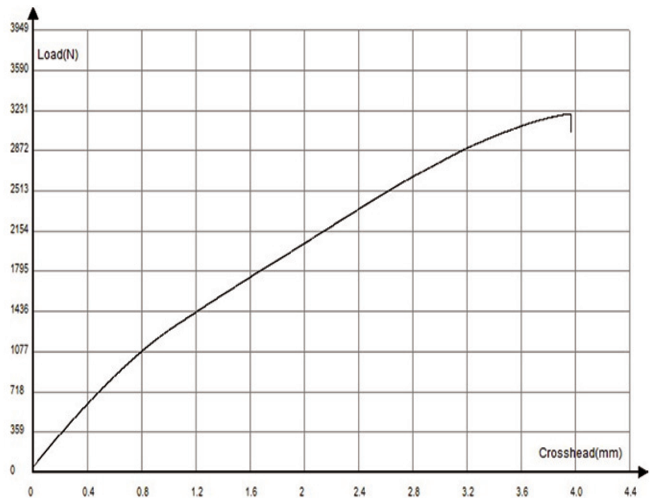

Figure 3: Tensile Test results for ABS Material

3.1.2 Tensile test for 2 sample PLA

Table 3: Tensile test PLA materials specification

Width of specimen	25 mm
Thickness of specimen	5 mm
Gauge length	150 mm
Original grip separation	0 mm

Table 4: Tensile test Results for PLA Materials

	Tensile strength (MPa)	Tensile strength at yield (MPa)	Tensile strength at break (MPa)
No.1	25.31	23.44	23.71
Percentage elongation at break (%)	Percentage elongation at at yield (%)	Modulus of Elasticity (MPa)	
3.04	2.21	1788.85	

3.2 Bending Test Results

3.2.1 Three-point Bending test ABS

Table 5: Three point bending test for ABS material

Input data		Output data	
Specimen width	24.91mm	Load peak at	0.195kn
Specimen thickness	5mm	Deflection at peak	3.128mm
Length	140mm	Flexural Strength	28.18 lN/ mm2
Span length	60mm		
Per value load	0kn		
Max. load	1000kn		
Max deflection	1000mm		
Specimen c/s	124.550 mm2		

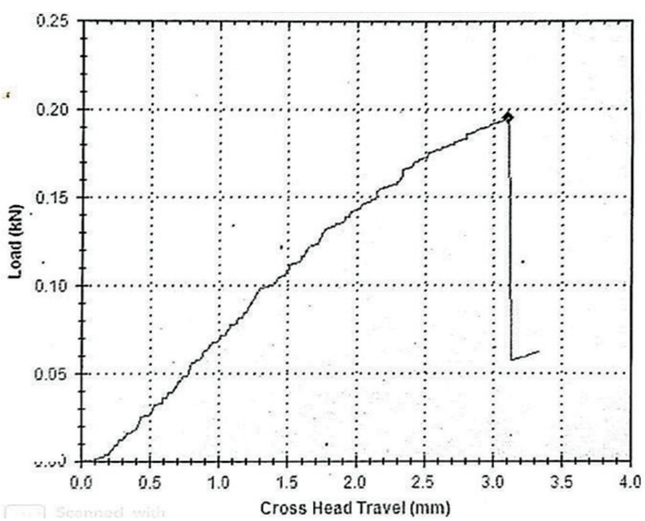

Figure 4: Point Bending Test Results for ABS Materials

3.2.2 Three point bending test for PLA

Table 6: Three point bending test for PLA material

Input data		Output data	
Specimen width	24.86mm	Load at	0.188kn
Specimen thickness	5.09mm	Deflection at peak	9.693m
Length	140mm	Flexural strength	26.270N/ mm2
Span length	60mm		
Pre-load value	0		
Max. load	100kn		
Max deflection	1000mm		
Specimen c/s	126.537 mm2		

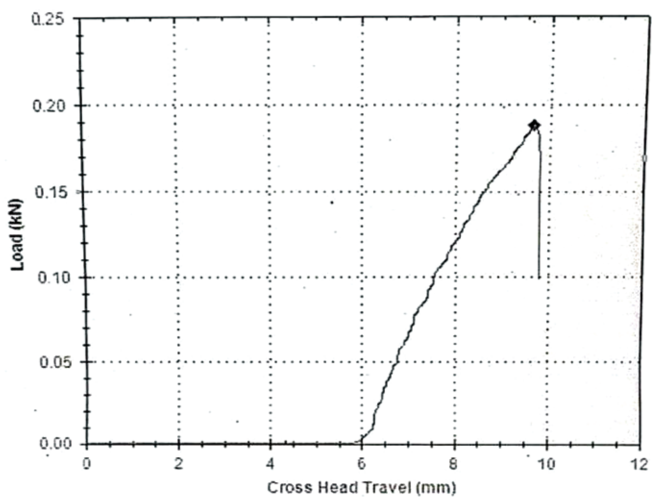

Figure 5: Point Bending Test Results for PLA Materials

3.3 Impact Test Results

3.3.1 Impact Test for ABS Materials

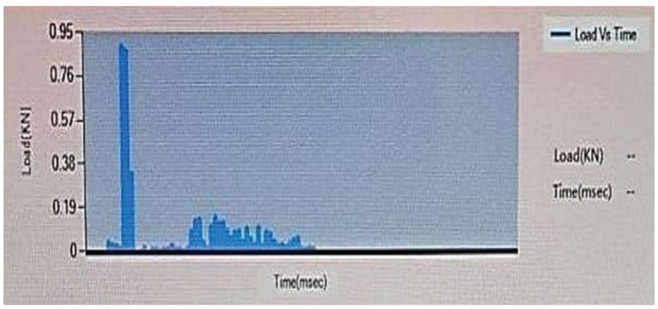

Figure 6: Impact Test Results for ABS materials

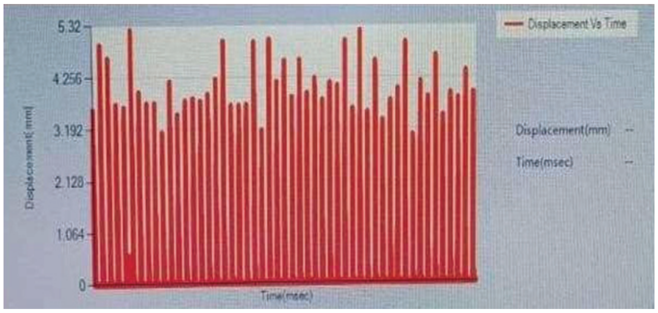

Figure 7: Impact Test Results for ABS materials

Table 7: Impact Test for ABS Material

Input		Output	
Type of specimen	Laminated	Load	0.93KN
Size of the panel	100*100	Maximum load	0.95 KN
Mass of impactor	5.5	Time	1298.3 (m sec)
Height of fall	31.9	Time 1	973.35 (m sec)
Thickness of the specimen	5mm	Time 2	1021 (m sec)
Temperature	0	Vi	5.05 (m/sec)
Velocity of impact	0	Ei Vt	70.132J 5.05(m/sec)

3.3.2 Impact Test for PLA Material

Table 8: Impact test for PLS material

Input		Output	
Type of specimen	Laminated	Load	0.95KN
Size of the panel	100*100	Maximum load	0.95KN
Mass of impactor	5.5	Time	1501.35 (m sec)
Height of fall	31.9	Time 1	2404.3 (m sec)
Thickness of the specimen	5mm	Time 2	1451.8 (m sec)
Temperature	0	Vi	2.824 (m/sec)
Velocity of impact	0	Ei Vt	21.931J 2.824(m/sec)

Figure 8: Impact Test Results for PLA materials

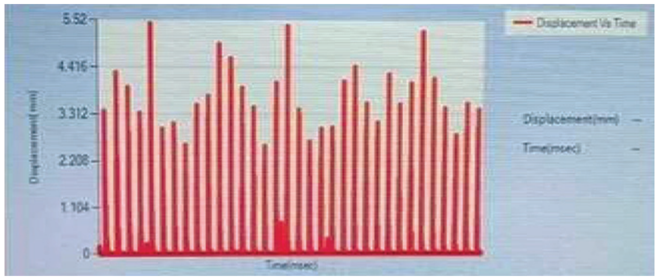

Figure 9: Impact Test Results for PLA materials

3.4 ANSYS Results

3.4.1 Bending test results

Ansys results for bending are given below for (a) 3D material ABS (b) 3D material PLA, where in the Figure 10 the equivalent stress results are given for the materials

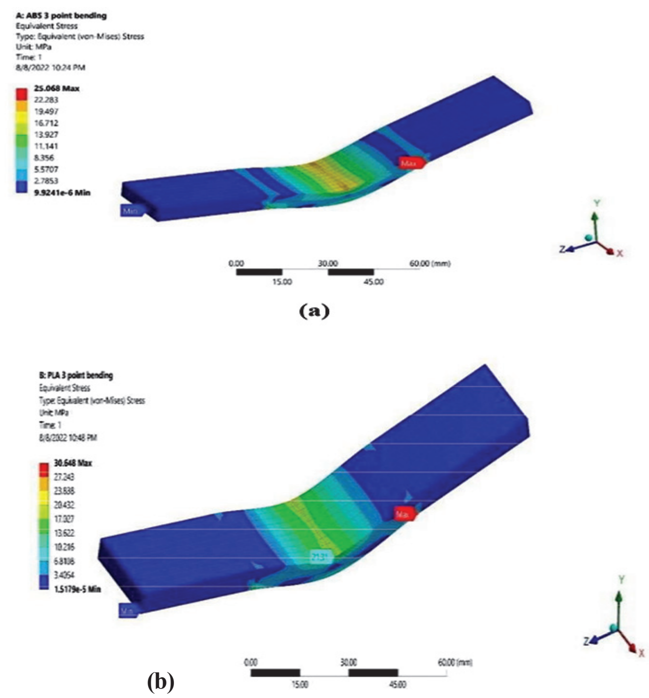

Figure 10: Equivalent Stress Results for (a) ABS Material (b) PLA Material

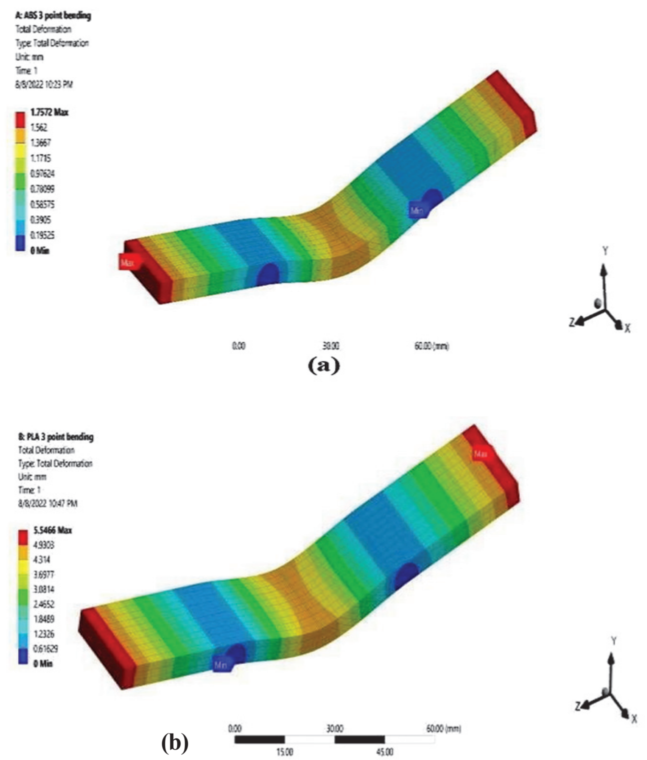

Figure 11: Total Deformation Results for (a)ABS Material (b) PLA Material

3.4.2 Tensile Test

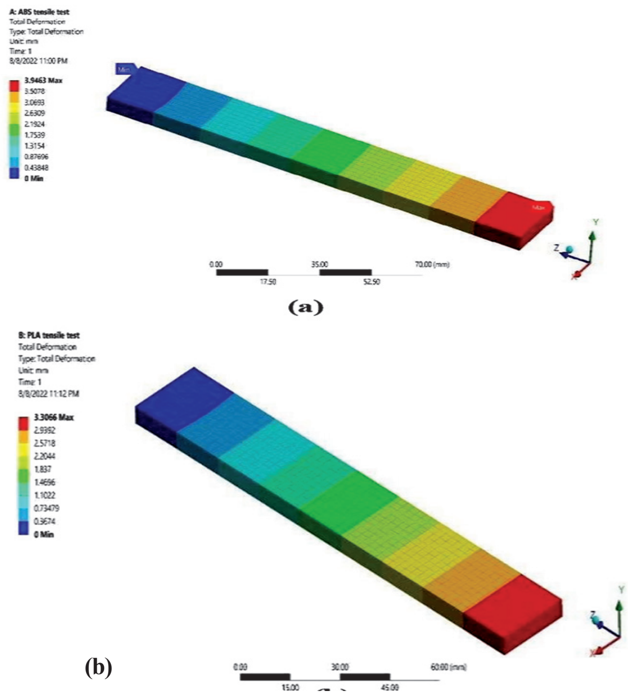

Figure 12: Total Deformation Test Results for (a)ABS Material (b) PLA Material

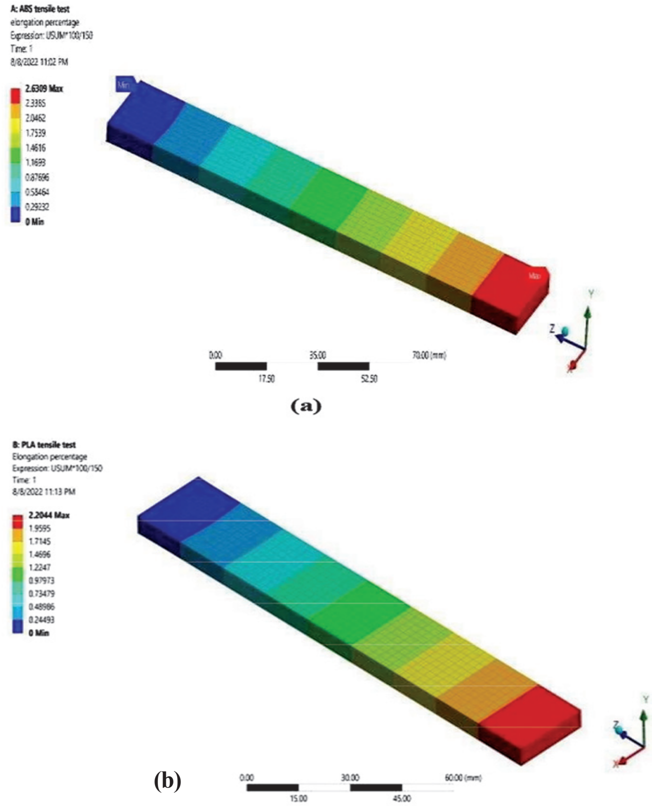

Figure 13: Total Elongation for (a) ABS Material (b) PLA Material

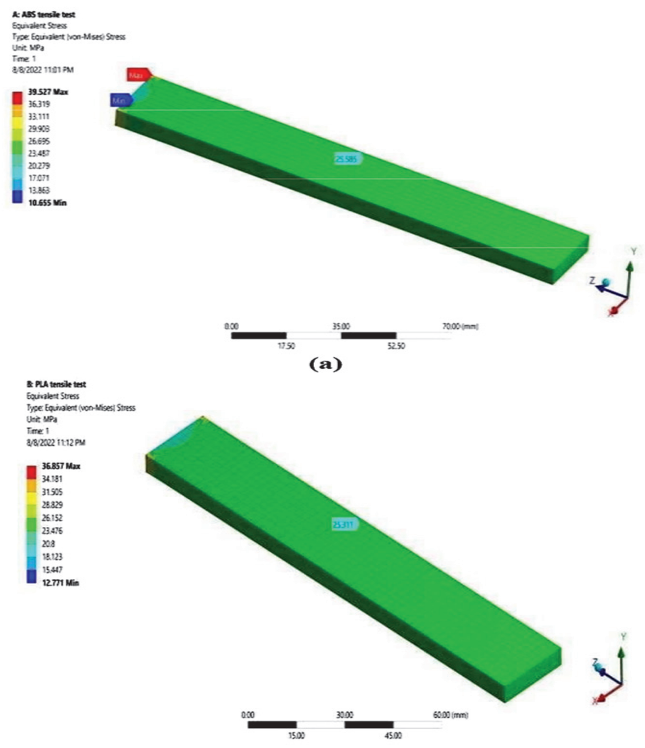

Figure 14: Equivalent Stress Results for (a) ABS Material (b) PLA Material

3.5 Comparison

3.5.1 Tensile test

Material	Percentage elongation at break	Percentage elongation at yield
ABS	2.64	2.33
PLA	3.04	2.21

3.5.2 Ansys result for tensile test

Material	Total deformation	Total elongation
ABS	3.964	2.02
PLA	3.30	2.63

3.5.3 Bending test

Material	Deflection at peak	Flexural strength
ABS	3.12	28.181
PLA	9.693	26.27

3.5.4 Ansys results for bending test

Material	Equivalent stress	Total deformation
ABS	25.063	1.757
PLA	36.64	3.94

According to all the test conducted. It is concluded that PLA material has all the properties required for this experimentation so it concluded that PLA material is preferred over ABS

4.0 Conclusions

Determining the right material during the selection process is very important. The material selected should meet as per the expectation of the experiment requirement. The material should prove mechanically feasible and should be economical. Apart from this the selected material must convincingly prove better than the currently used material. The proposed material properties may help the material selection during the selection stage. Various studies have been done carried out recently about the selection of right material. A novel class of 3D printed sandwich structure with sisal fibre were investigated in this work. Primitive, sandwich was 3D printed by A vacuum bagging process. The flexural properties of the pure PLA panels and ABS material laminated composite sandwich structure were studied.

The results showed the sandwich panels epoxy laminated components. The modifications done bumper beam has resulted in improvement in energy absorption capacity of the bumper. The composites we discussed here have some desirable properties like light weight, corrosion resistance, high strength to weight ratio and high durability. In order to find an optimized composite for the automotive bumpers dynamic study has to be carried out. The dynamic study includes tensile and impact analysis for the model analysis were carried for both the composite material prepared. Other than the manufacturing of the bumpers, the composite materials also provide a wide range of other potential automotive applications such as body panels, suspension, steering, brakes and other accessories.

Apart from body panels, the current, limited automotive application of composites include bumper systems, instrument panels, leaf springs, drive shafts, fuel tanks.

5.0 References

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