IMPACT DAMAGE ANALYSIS OF AN AUTOMOBILE BONNET OF NATURAL COMPOSITE MATERIALS

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Abstract - *The design of Bonnet plays a vital role in Automobile industries. Nowadays automotive industries are demanding a shift of their design from oil-derived polymers and mineral reinforcement materials to natural materials to exploit the lightweight-ness, recyclability, high corrosion resistance, high specific strength and stiffness, height to weight ratio and biodegradability of green products. In this dissertation work, an attempt has been made to analyze and compare the bonnet of different natural composite materials made of Flax fibre/Epoxy, Bamboo fibre/Epoxy and Jute fibre/Epoxy and are compared with Glass fibre/Epoxy and Aluminium materials for two different impact tests and to identify the material with lesser wait with better characteristics. The impact tests consisted of the impact of a wall or a vehicle in the opposite direction on bonnet and impact of head-form on the bonnet. Here CATIA V5 and ANSYS Workbench were used to design the model and to analyze of the bonnet respectively. From the results obtained from ANSYS, the deformation, stresses, strain, stiffness and FOS values were compared. From these comparisons, it can be concluded that the Jute fibre/Epoxy material with higher FOS value for the given impact loads and with lesser weight can be used for automobile bonnet.*

Key Words: Automobile Bonnet, Natural Composites, Impact Damage, Car Bonnet, Ansys Workbench

1. INTRODUCTION

"Natural fibre reinforced composites are composite materials, in which at least reinforcing fibres are extracted from renewable and carbon dioxides free neutral resources such as wood or plants". Natural fibre composites are manufactured by combining various natural fibre preforms and matrix resins derived from natural polymers or synthetic polymers. The matrix resins used are either thermosets or thermoplastics.

Among the previous studies, design and manufacturing of automobile hood using natural composite structure using natural flax fibre composite [1]. A study has also been made on mechanical properties of representative natural fibres such as flax and hemp fibres [2]. RTM (resin transfer moulding), is the method used in manufacturing natural composites [3]. A study has also been performed on obtaining an interesting solution for replacing fibre-glass in yachts, intending to increase the environmental sustainability of the nautical sector [4].

The thermal and mechanical properties of bamboo fibre reinforced composite (BFRC) derived from Gigantochloa scortechinii were used in this work [5]. A previous study also been focused on natural fibre composites (NFCs) in which the matrix materials are polymeric resins. NFCs are composite materials comprising at least one major component derived from a biological origin [6]. A previous research on comprehensive review of the properties of natural fibres was made and used as fibres for composite materials reinforcement is presented, aiming to map where each type of fibre is positioned in several properties [7].

A study on experimental investigations which were conducted previously on flax and E-glass fibres reinforced epoxy matrix composites subjected to quasi-static loadings are used to find the properties of Flax Epoxy-090 and Flax Epoxy-45 and they have been compared to E-glass fibre reinforced epoxy (GE) composites having similar stacking sequence (noticed GE-090 and GE-45) and fibre volume fraction [8]. From another detailed investigation of physical, mechanical and thermal properties of jute and bamboo fibre reinforced epoxy resin unidirectional void free composites, some of the properties were used [11].

Of late automotive manufacturing companies are demanding a shift off their design from oil-derived polymers and mineral reinforcement materials to natural materials to exploit the lightweight-ness, recyclability and biodegradability of green products. Lightweight components in an automobile is a significant area in structural design. It is a direct factor of enhancing accelerating force and braking power that is the basic performance.

In this study, the impact damage analysis of the environment friendly structure of an automobile using natural fibre composite materials was performed.

2. Problem Definition

Typically, automobile hoods/bonnets are manufactured using Steel, Aluminium and Carbon fibres (recent days). The oil-derived polymers and mineral reinforcement materials are used in the case of composite materials. Since these are the extract of petroleum, there is a drastic decrease in worldwide reserves. Hence, natural materials can be utilized to achieve the lightweight-ness, recyclability and biodegradability of green products.

2.1 Objective

To carry out the impact damage analysis of automobile bonnet made of natural fibre reinforced composites.

2.2 Scope

To explore the suitability of the natural composite materials for the automobile components.

3. NATURAL FIBRE REINFORCED COMPOSITES

In this dissertation work, the different natural fibre reinforced composites are considered for the purpose of analysis. Following materials are some of the natural fibre reinforced composites.

3.1 Flax Fibre Reinforced Epoxy Composite (FFREC)

In this type of natural composite material, Flax fibres are used as fibre matrix and epoxy resin is used the reinforcing material, which is a thermosetting resin. The flax fibre has been used in various application due to its high strength. The main advantage of these fibres is that it has less density and available at a lower cost. Stiffness of the flax fibres, which are the most promising at the current stage, is comparable to that of glass fibres. Besides, flax fibres have a high vibration damping potential which can be used in load-bearing applications. The table 1 below shows the mechanical properties of unidirectional flax composite materials.

Table -1: Properties of FFREC Material

Material Properties	FFREC
Density (ρ) (Kg/m^3)	1400
Young's Modulus or Modulus of Elasticity (E) (G Pa)	24.7
Shear Modulus or Modulus of rigidity (G) (G Pa)	1.96
Poisson's Ratio(ν)	0.35
Ultimate Tensile Strength (MPa)	318

3.2 Bamboo Fibre Reinforced Epoxy Composite (BFREC)

In this type of natural composite material, Bamboo fibres are used as fibre matrix and epoxy resin is used as the reinforcing material. Epoxy resin is used as the polymer in bamboo fibre composite materials due to its outstanding mechanical properties, chemical resistance and electrical insulation. These composites possess good tensile strength and flexural strength. The Physical and Mechanical properties of BFREC given below in Table 2.

Table-2: Properties of BFREC Material

Material Properties	Bamboo/Epoxy
Density (ρ) (Kg/m^3)	900
Young's Modulus or Modulus of Elasticity (E) (G Pa)	27.93
Shear Modulus or Modulus of rigidity (G) (G Pa)	1.889
Poisson's Ratio(ν)	0.3
Ultimate Tensile Strength (MPa)	320

3.3 Jute Fibre Reinforced Epoxy Composite (JFREC)

Jute is the second most used natural and biodegradable fibre. Jute fibre is an exceptional substitute when strength, thermal conductivity, and costs are major apprehensions. Also, jute fibres are environment friendly. Currently, jute fibre-reinforced polymer composite materials have become an important area of study. Typically, jute fibre is used for basic and low-end textile products. If the properties of jute could be modified in favour of high value and technical textiles, not only the cost but also the environment would benefit a great deal. The table below gives the properties of JFREC Material.

Table-3: Properties of JFREC Material

Material Properties	JFREC
Density (ρ) (Kg/m^3)	1300-1490
Young's Modulus or Modulus of Elasticity (E) (G Pa)	26.5
Poisson's Ratio(ν)	0.3
Ultimate Tensile Strength (MPa)	393-792

4. FINITE ELEMENT ANALYSIS OF NATURAL COMPOSITE HOOD/BONNET

"Finite element method is a computer-based numerical technique for calculating the strength and behaviour of many engineering structures". In this work, Finite Element Analysis is done for different natural composite materials for the complete impact damage analysis of composite bonnet using ANSYS Workbench software.

4.1 3-D Modelling of a Composite Bonnet

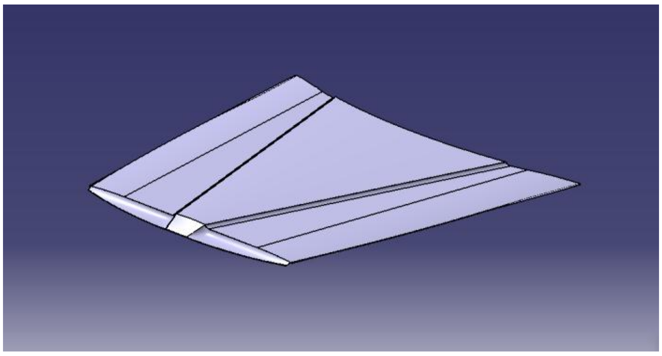

Fig-1: Isometric View of Bonnet

The 3-D model of an automobile bonnet was created using CATIA V5 R20 software. The bonnet is shown in the figure above.

4.2 Finite Element Modelling of Bonnet

For the FEA of composite bonnet ANSYS Workbench software was used. The Model of Bonnet which was created in CATIA V5 was later imported to ANSYS Workbench. The bonnet thickness of 3mm was considered. For meshing, element size of 0.1m was taken. The below figure shows the model of meshing.

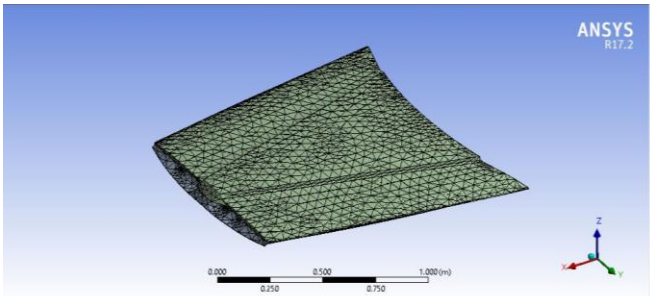

Fig-2: Finite Element Model of a Bonnet

4.3 Impact Damage Analysis of Bonnet

In this work, there were two different conditions of impact damage analysis of bonnet were conducted for different natural composite materials. The analysis includes finding the unknowns like deformation, stress and strain caused to impact. The failure of the bonnet is mainly due to the stresses induced and the deformation as it is undergoing impact loads. So, impact damage analysis is necessary to determine whether the bonnet can withstand these impact loads. This aims at finding out the maximum deformation and the maximum von mises stress under the application of these impact loads.

The boundary condition for impact damage analysis is that the bonnet is given a velocity of 60 m/s or 215 Kmph in the first condition and the wall is fixed. In the second condition, the analysis was performed for pedestrian head impact on the bonnet, for this, a head-form is used which resembles the head of the pedestrian. The diameter of head-form was considered as 165mm and a weight of 5 Kg. Here, the bonnet is fixed and head-form is allowed to hit the bonnet with a velocity of 40 Kmph.

4.3.1 Impact of Wall on the Bonnet

The loading and the boundary conditions of the bonnet are shown in the below figures. Here the bonnet is given a velocity of 60 m/s and the wall is fixed on both the sides.

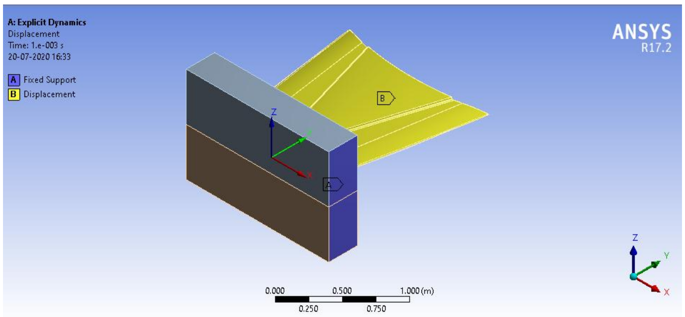

Fig-3: Loading and Boundary Conditions for the Bonnet

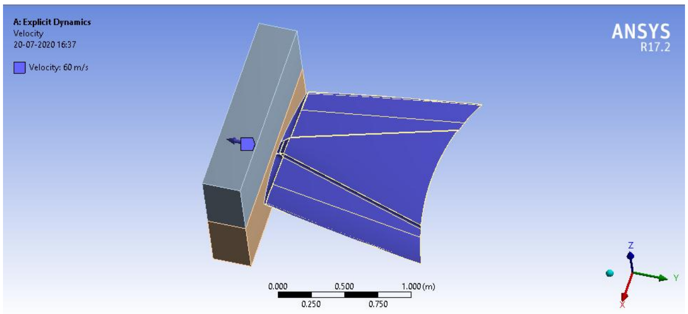

Fig-4: Initial condition i.e., velocity given to the Bonnet

4.3.2 Impact of Head-form on the Bonnet

For the purpose of investigating the safety of designed bonnet against impact, modelling was performed for adult head-form to perform impact analysis. It analyzed the displacement and stress of bonnet in the case of male adult head colliding at the centre of the panel at 40km/h speed. As for the adult head-form, it needs to be a globe shape in accordance with the European pedestrian protection regulation. The head-form consists of 165mm in diameter and 4.9kg in weight, as shown in Figure.5. According to the European pedestrian protection regulation, impact analysis was performed at 40km/h speed vertically colliding at the centre, which is the most structurally vulnerable area.

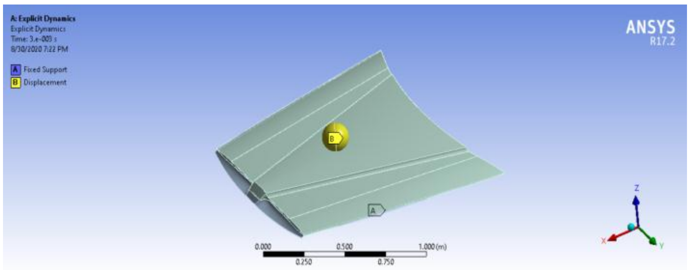

Fig-5: Loading and Boundary Conditions for the impact of Head-form of the Bonnet

5. RESULTS OBTAINED FROM ANSYS

The results obtained from the Ansys workbench is shown in the contours below. The contours of total deformation, Von Mises equivalent stresses for bonnet are shown for different natural composite materials in the below figures.

5.1 Results for Impact of Wall on the Bonnet

I. Flax Fibre Reinforced Epoxy Composite

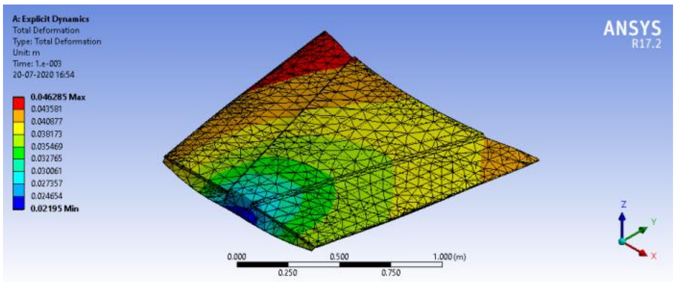

Fig-6: Total Deformation of Flax Fibre Reinforced Epoxy Composite Bonnet

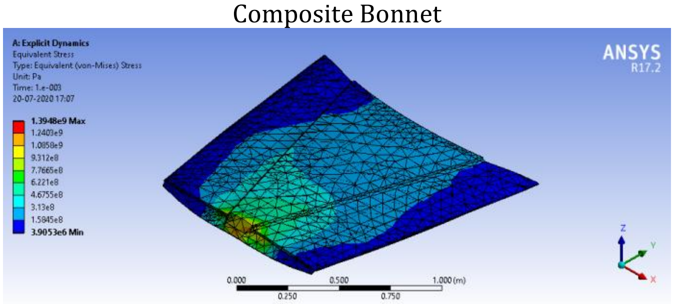

Fig-7: Equivalent Von-Mises Stress of Flax Fibre Reinforced Epoxy Composite Bonnet

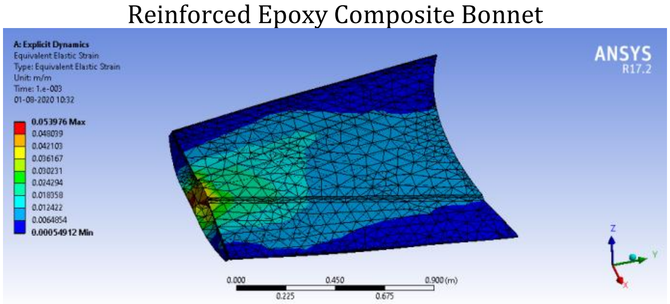

Fig-8: Equivalent Elastic Strain of Flax Fibre Reinforced Epoxy Composite Bonnet

II. Bamboo Fibre Reinforced Epoxy Composite

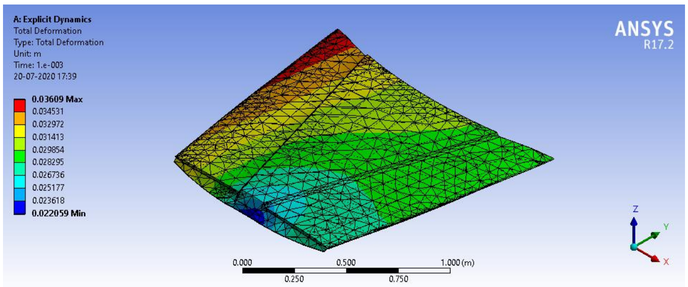

Fig-9: Total Deformation of Bamboo Fibre Reinforced Epoxy Composite Bonnet

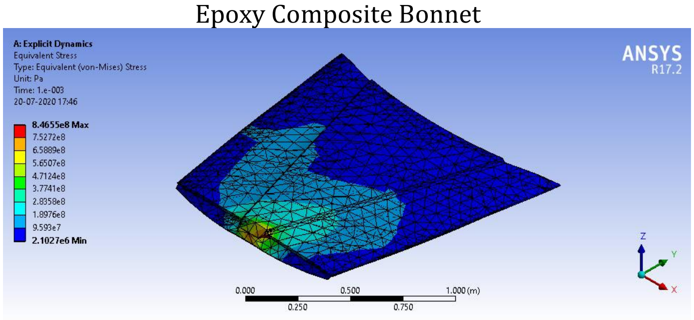

Fig-10: Equivalent Von-Mises Stress of Bamboo Fibre Reinforced Epoxy Composite Bonnet

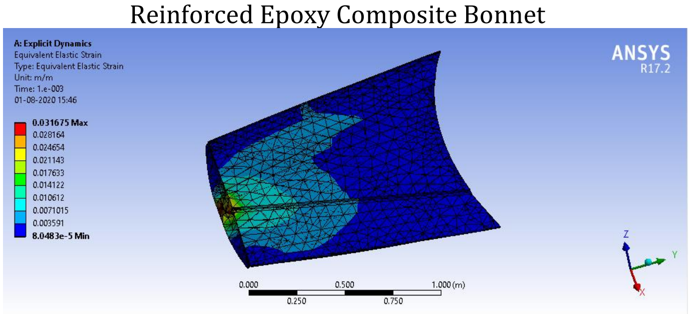

Fig-11: Equivalent Elastic Strain of Bamboo Fibre Reinforced Epoxy Composite Bonnet

III. Jute Fibre Reinforced Epoxy Composite

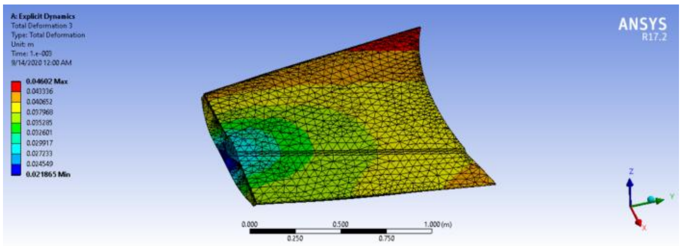

Fig-12: Total Deformation of Jute Fibre Reinforced Epoxy Composite Bonnet

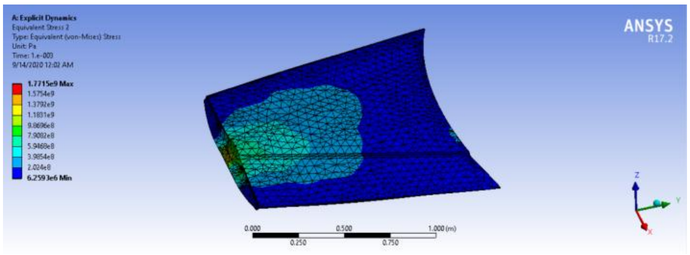

Fig-13: Equivalent Von-Mises Stress of Jute Fibre Reinforced Epoxy Composite Bonnet

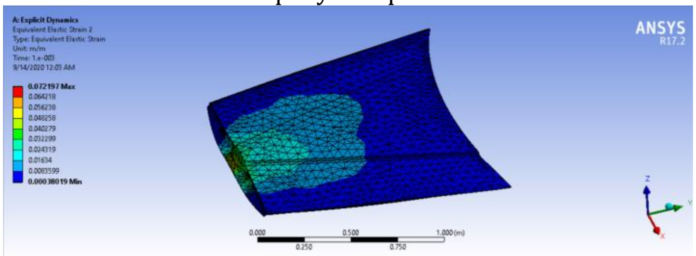

Fig-14: Equivalent Elastic Strain of Jute Fibre Reinforced Epoxy Composite Bonnet

5.1 Results for Impact Head-form on the Bonnet

I. Flax Fibre Reinforced Epoxy Composite

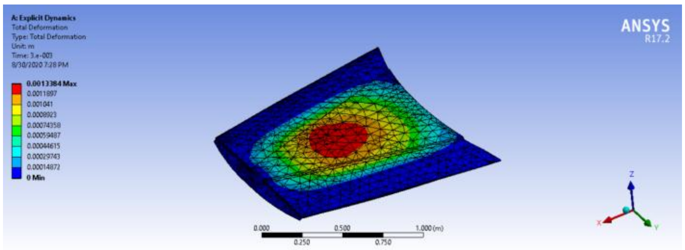

Fig-15: Total Deformation of Flax Fibre Reinforced Epoxy Composite Bonnet caused due to Impact of Head-form

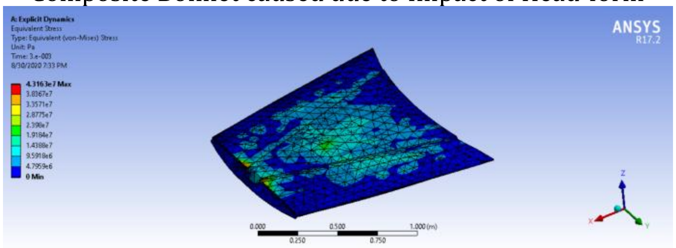

Fig-16: Equivalent Von-Mises Stress of Flax Fibre Reinforced Epoxy Composite Bonnet

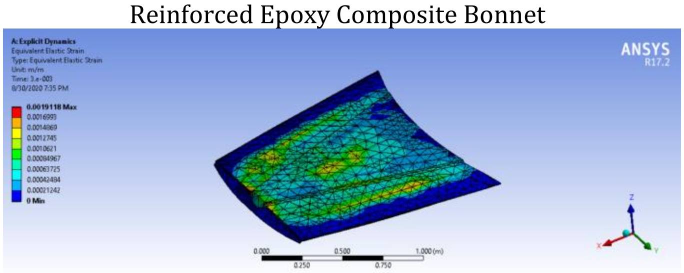

Fig-17: Equivalent Elastic Strain of Flax Fibre Reinforced Epoxy Composite Bonnet

II. Bamboo Fibre Reinforced Epoxy Composite

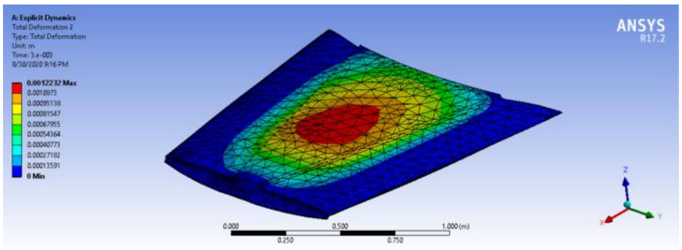

Fig-18: Total Deformation of Bamboo Fibre Reinforced Epoxy Composite Bonnet

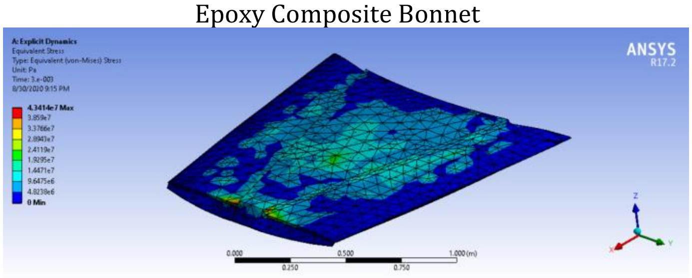

Fig-19: Equivalent Von-Mises Stress of Bamboo Fibre Reinforced Epoxy Composite Bonnet

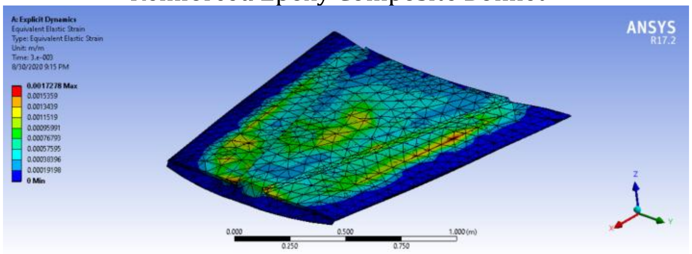

Fig-20: Equivalent Elastic Strain of Bamboo Fibre Reinforced Epoxy Composite Bonnet

III. Jute Fibre Reinforced Epoxy Composite

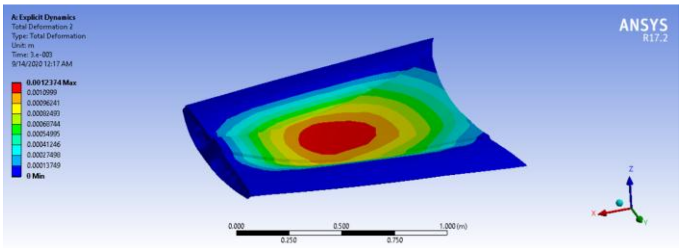

Fig-21: Total Deformation of Jute Fibre Reinforced Epoxy Composite Bonnet

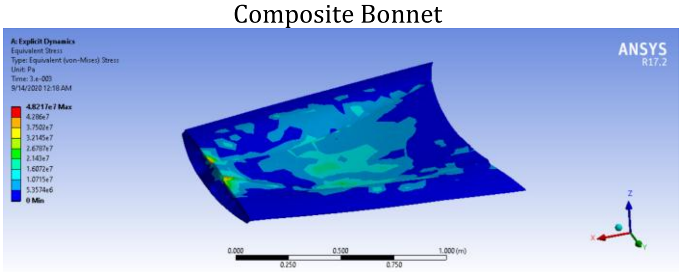

Fig-22: Equivalent Von-Mises Stress of Jute Fibre Reinforced Epoxy Composite Bonnet

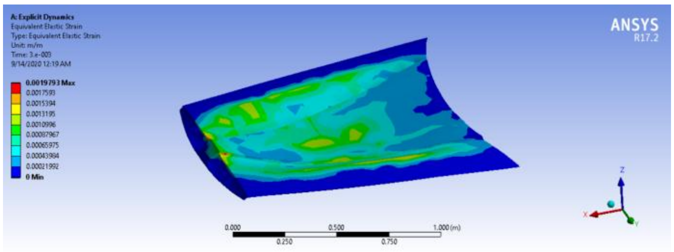

Fig-23: Equivalent Elastic Strain of Jute Fibre Reinforced Epoxy Composite Bonnet

6. RESULTS AND DISCUSSION

6.1 Results

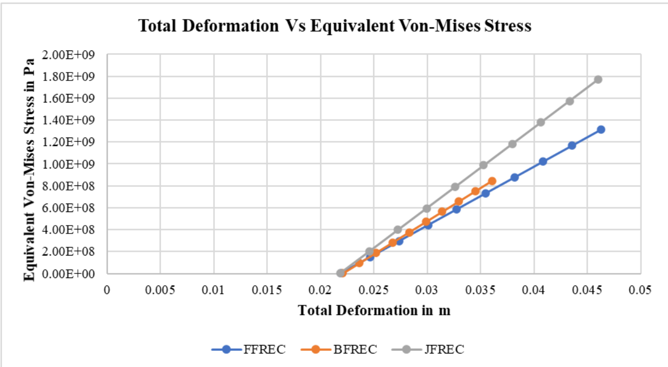

Fig-24: Total Deformation Vs Equivalent Von-Mises Stress Comparison of Different Materials for Impact of Wall on Bonnet

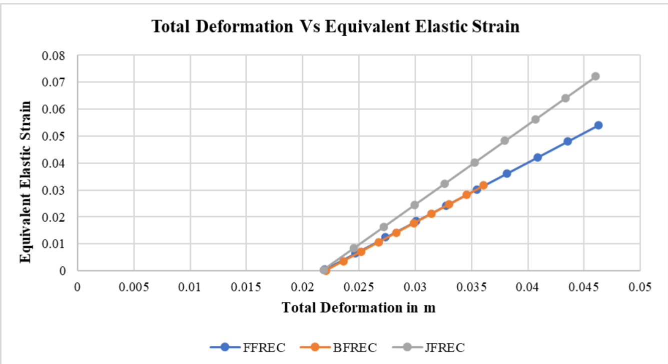

Fig-25: Total Deformation Vs Equivalent Von-Mises Strain Comparison of Different Materials for Impact of Wall on Bonnet

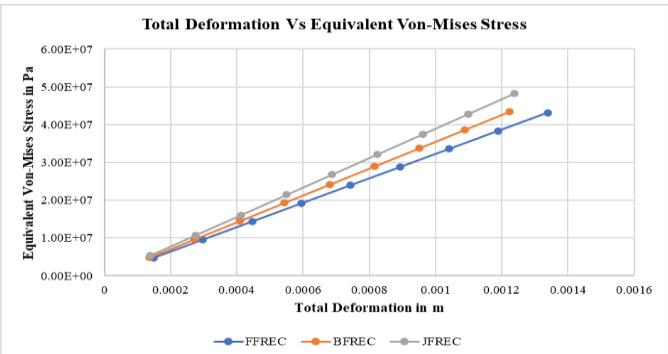

Fig-26: Total Deformation Vs Equivalent Von-Mises Stress Comparison of Different Materials for Impact of Head-form on Bonnet

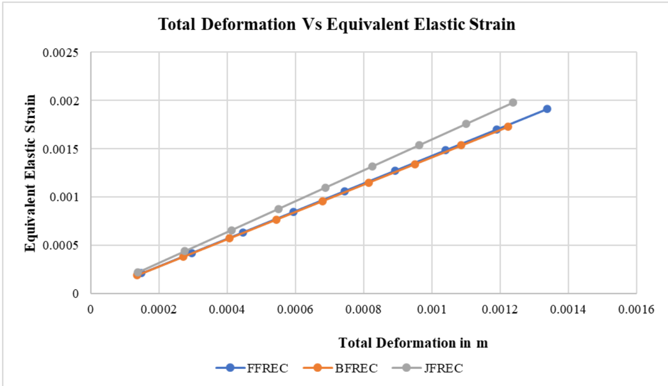

Fig-27: Total Deformation Vs Equivalent Von-Mises Strain Comparison of Different Materials for Impact of Head-form on Bonnet

6.2 Discussion

From the results obtained it is confirmed that the bonnet of BFREC material showed less deformation compared to other material, the maximum equivalent stress was found to be GFREC material as shown in figure.24., but the maximum equivalent strain found to be JFREC as shown in figure.25. When it is subjected to impact on a wall or a vehicle in its opposite direction.

For the condition of the impact of head-from on the bonnet, the maximum deformation was found to be by the FFREC and minimum deformation by BFREC, the maximum equivalent stress and the maximum equivalent strain was obtained by the JFREC material as shown in figures.26. and 27. Respectively.

For the Factor of Safety, it was found that FOS value JFREC material was found to be 8.15, which highest compared to all other material used. The FFREC and BFREC showed similar FOS values which are 7.3. The Comparison of FOS values is shown in figure.28. Among all the materials used the material with lesser weight was found to be FFREC, which is about 1.8 Kg, the comparison for weights of different materials is shown in figure.29.

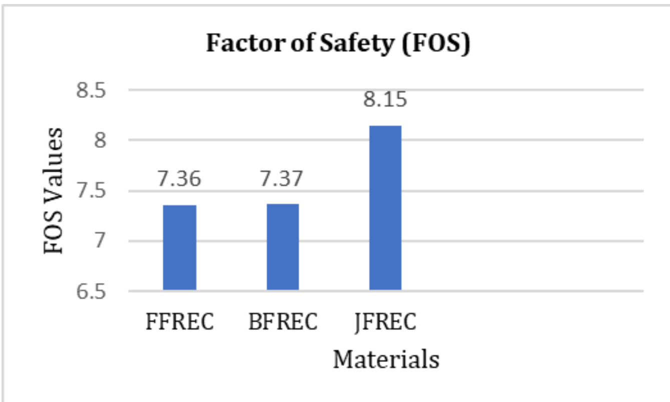

Fig-28: Comparison of FOS Values of Different Materials Used

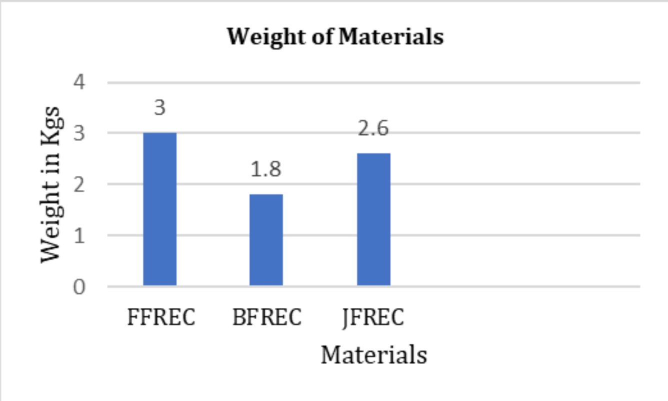

Fig-29: Comparison of Weights of Bonnets of Different Materials Used

7. CONCLUSIONS

In this dissertation work, the impact damage analysis of bonnet of different natural composite materials made up Flax-fibre/Epoxy, Bamboo-fibre/Epoxy and Jute-fibre/Epoxy under the influence of impact loads were carried out using CATIA and ANSYS Workbench for design and analysis respectively. From the obtained results it can be concluded that,

- The BFREC natural composite showed less deformation compared to FFREC and JFREC in both the impact tests performed. But the deformation of aluminium was too less compared to BFREC.
- The weight of BFREC material was found to be lesser compared to other materials which weighed 1.8 Kg. JFREC was the second material with lesser weight which weighed 2.6 Kg.
- The Factor of Safety value was higher for JFREC, which was found to be 8.15 and FOS value for both FFREC and BFREC found to be 7.3. So, it can be concluded that JFREC material with higher FOS value and less weight can be used for automobile bonnet.

From this dissertation work, it can be concluded the natural fibre composite materials can be used as an alternative material for automobile bonnets and other similar components.

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