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Finite Element Analysis of Hybrid Skin Sandwich Composite

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Abstract

Sandwich structured composite is a particular classification in composite materials. This type of structure has been mainly used in recent studies because of its high specific strength, low density, and stiffness. It is increasingly more commonly employed in structural designs due to its features and performance. The sandwich composites used in this investigation are made of aluminium alloys and areca fibre. The sandwich composite's face sheet comes in a variety of thicknesses. The adhesive skin layer is also varied to investigate the effect of using natural fibre. The sandwich composite is subjected to 3 point bend test. The modal analysis is investigated using the finite element method. The 3D model of sandwich composites is modelled using solid works 2020. Using Altair Hyper Works, the boundary conditions and meshing is carried out. ANSYS Mechanical APDL is used to analyse the sandwich composites. This investigation analyses the behaviour of composite sandwich beams.

Keywords: *Sandwich structured composite, Aluminium alloy, Areca fibre, ANSYS Mechanical APDL.*

1.0 Introduction

Composite material is made up of two or more compounds that form elements with significantly have different physical or chemical properties [1-2]. When combined together forms a structure, this structure will have unique features compared to individual components. In the latter case, the inseparable remains independent and fragmented, understanding compounds from compounds and solid solutions [3-5]. These materials are famous in building construction for various reasons for their durability, lightweight, and low cost.

Sandwich structured composite materials are one of the unique classification in composite materials. In this type, it consists of two thin face sheets or laminate which acts as an upper skin and parallel to it an adhesive layer is combined which will act as a lower skin and a thick core structure[6-9]. In hybrid composites, it consists of two or more fiber ingrained in them at the nanometer or molecular level[10-11]. The natural fiber used in the composite will have some desirable features found in recent studies. Using blended combinations will provide better energy and reduce the weight and cost of materials. In many applications, weight is one of the crucial factor [12]. The use of natural fibers in composite structures will provide additional benefits like better durability, sustainability, skin compatibility, high specific properties, high moisture retention, lightweight eco-friendly easily affordable, and available.

Sandwich composite beams are significantly used in

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engineering applications such as aerospace, automotive, ships, and marines sectors. This type of structure has been used mainly due to its high specific strength, low density, corrosion resistance, capable of operating at high-temperature range, and durability in recent research. Nowadays, it is more popularly used in structural designs because of its properties and performance. It is possible because two materials are separated with a lightweight material core of the structure, giving them more strength, less weight, and stiffness. The importance of composite engineering is that two or more contrasting materials combine to form the best possible combinations[13]. The composite structure will mainly depend on the face sheet where the system is supported on both sides of the composites. Also, they are dependent on the interface between the core and the skin of composites[14].

Many of the previous research works have been carried out on finding load carrying capacity and flexural strength of the hybrid sandwich panel. It is also found that some of the research works are made to establish designs that are more efficient and competitive in terms of performance and cost[15-16]. Some of them worked to enhance the thermal and acoustical properties along with the optimal weight and strength. Certain works are conducted on the weight optimization of the structures by altering the composites and alloys[16-17]. Some papers worked on the investigation of crack initiation, crack growth, fast fracture, and crack arrest features in the stiffened panel[18-20]. From this it is also found that it is important to choose materials that are light in weight and have relatively high strength. In the present work the composite structure is of aluminum alloy 6061 plate, aluminimun alloy 6063 tubes and areca natural fiber mat is used. This materials have good superior properties compared to others and this type structure using areca natural fiber is yet to be designed and analysed.

In this thesis analysis of beams with different face sheet thickness and adhesive layer embedded in the structure under simply supported conditions applied to 3-point bending test. To analyse the transfer of load between the face sheets and core structure by variation of face sheets[21]. The face sheet thickness of 1mm, 1.5mm and 2mm is selected based on the low weight, less cost and also availability. Further the adhesive layer in varied and similairly analysed to structural strength of the composites. Comparing the results of analytical and numerical data various parameters are studied[22]. They have significant effects on the maximum deflections, maximum strain, and natural frequency.

2.0 Methods and Materials

A sandwich beams composed of aluminum plate as a front sheet, an aluminum tubes as a core, and areca fiber mat as an adhesive layer. The aluminium plate is of aluminium alloy 6061 T6, the core is of aluminum alloy 6063 T6. The structure of the sandwich beam is shown in the Figure 1(a). Initially the adhesive layer of thickness 0.1mm is fixed and face sheet thickness of 1mm, 1.5mm and 2mm is varied in the structure and modelled. Later in the hybrid structure the adhesive

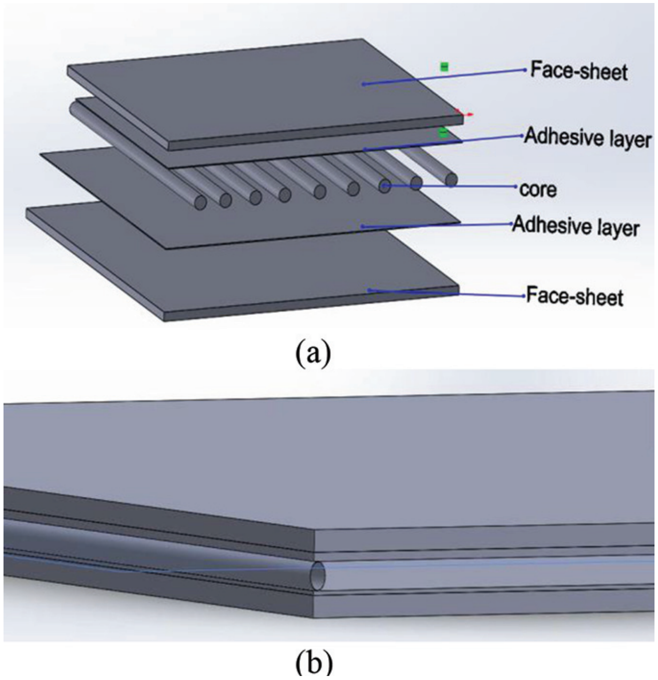

Figure 1(a)(b): Structure of sandwich composite

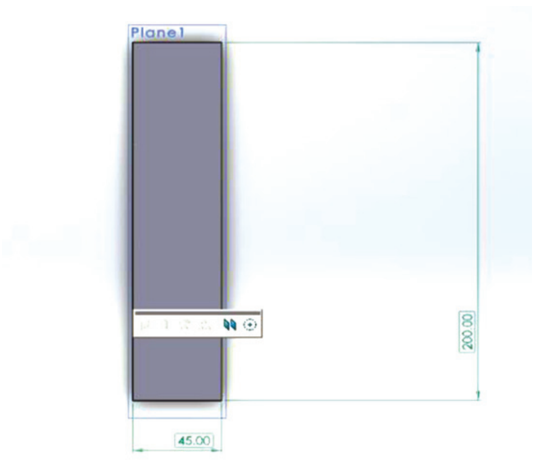

Figure 2: Dimensions of sandwich panel

layer is embedded and fixed. The thickness of adhesive layer is 0.3mm similarly again the face sheet of the structure is varied. The diameter of the aluminum is 0.65mm and of thickness of tube 0.1mm.

The composite structure dimension is also one of the essential factors. For this construction of sandwich material, the ASTM C393 method is used to determine the properties of constructed sandwich material. In composite sandwich structure, the thickness of the adhesive and face sheet layers is varied. For different thickness, the structure will have different height and they are fixed based on the the other dimensions required are calculated using ASTMC393 and verified. The dimensions are of the structure is 200mm*45mm (L*W) is valid for all the structure.

The Table-3 gives the properties of individual components used. The properties of the areca fiber mat are obtained from the manufacturer. The aluminum 6061 T6[21] and aluminum 6063 T6[22] are obtained from the experimental investigation of mechanical

Table 1: Variations of face sheet thickness for 0.1mm areca fibre

Condition	Face sheet thickness (mm)	Height (mm)
1	1	2.85
2	1.5	3.85
3	2	4.85

Table 2: Variations of face sheet thickness for 0.3mm areca fibre

Condition	Face sheet thickness(mm)	Height(mm)
1	1	3.25
2	1.5	4.25
3	2	5.25

Table 3: Material properties

Parameter	Face Sheet	Adhesive	Core
Material	Aluminium 6061T6	Areca fibre	Aluminium 6063T6
Young's Modulus in GPa	68.9	2.85	68.9
Poisson's Ratio	0.33	0.38	0.30
Density in kg/m3	2700	750	2710

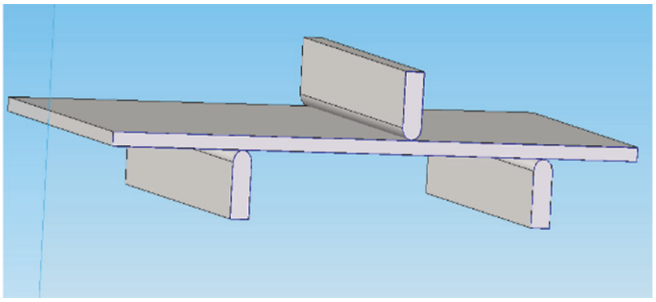

Figure 3: 3-point bending structure

properties of the material.

Step-wise procedure for the design and analysis of composite structure.

3D Composite Structure Modelling

Composite Structure Modeler was developed using Solid Works 2020. The diameter of the core circular tube is 0.65mm. 1.00mm, 1.5mm, and 2.00mm face sheet materials are used to change the height/thickness of the composite material. Adhesives with thicknesses of 0.1 mm and 0.3 mm were developed according to the same variant. The overall length is 200mm and the overall width is 45mm. The entire model is designed and output in STEP format. These parameters are fixed according to ASTM standards. This is a design parameter of the composite structure.

Finite element meshing

Meshing the model is important, it relates the structure to the numerical simulation. In this proceeding, the entire geometrical model is converted to finite element entities. The software input should be in STEP file format. Any model has to properly mesh so that it helps to reduce the time. They also can increase performance and get accurate results. Also, the loads and boundary conditions are applied to the composite structure using the Hypermesh software. In this case, the boundary layer condition is kept constant. The force and moment applied are taken as classic load entities and the pressure as the dynamic load entities.

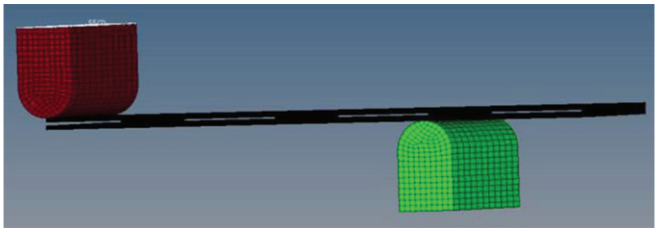

Figure 4: Meshing

Finite element analysis

For analysis of the composite materials, ANSYS mechanical APDL software is used. In Ansys APDL software the input is in .cmdb file format. The importing includes mesh, case, and data files. The Ansys software is a finite element method solver which enables computer-aided simulation. The structural type simulation is carried out. The large displacement static analysis with a time increment factor. In this case, the element type used is solid 185. The 3-point bending tests carry the non-linear load-displacement relationship. Various parameters are solver and the results are noted as per the requirement of the analysis.

3. Result and discussion

The analysis is carried out using ANSYS APDL software for the following boundary conditions two ends are fixed and the middle load is applied. Results of displacement, Y-component stress, von misses stress, principal strain, and modal analysis are noted and are found to be within the limit as shown below.

3.1 Static analysis Deflection

The displacement under the application of load with different thicknesses of plates is shown in the figures.

3.2 Y-component stress

The figures shows the result of stress along the Y-direction using ANSYS APDL software.

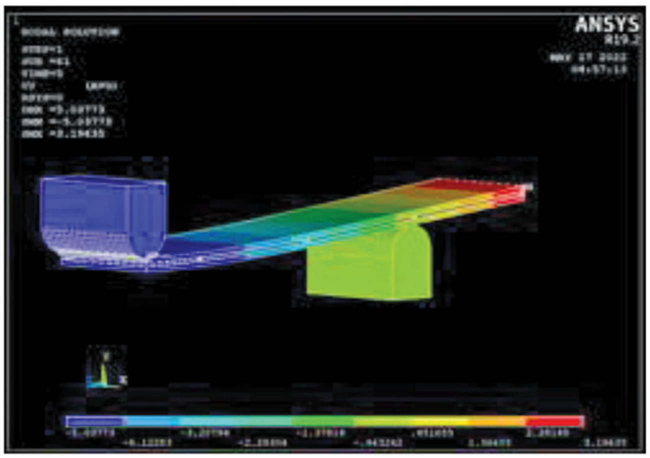

Figure 5: Displacement for 1mm AL and 0.1mm Areca fibre

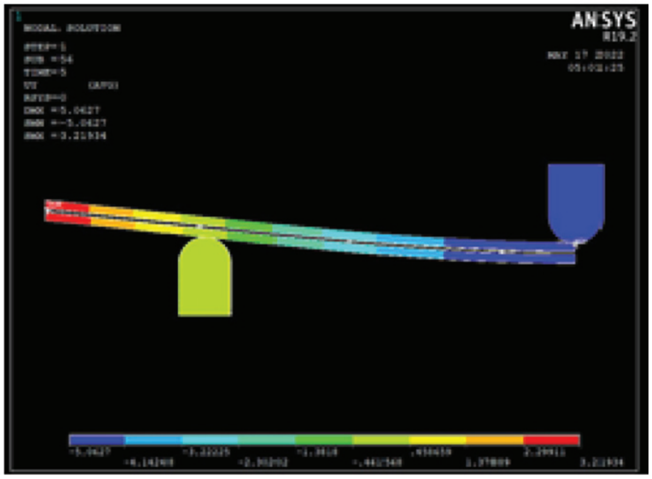

Figure 6: Displacement for 1.5mm AL and 0.1mm Areca fiber

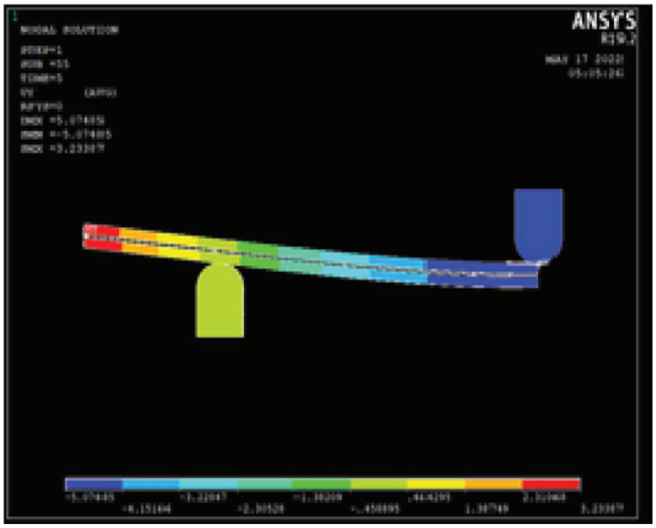

Figure 7: Displacement for 2mm AL and 0.1mm Areca fiber

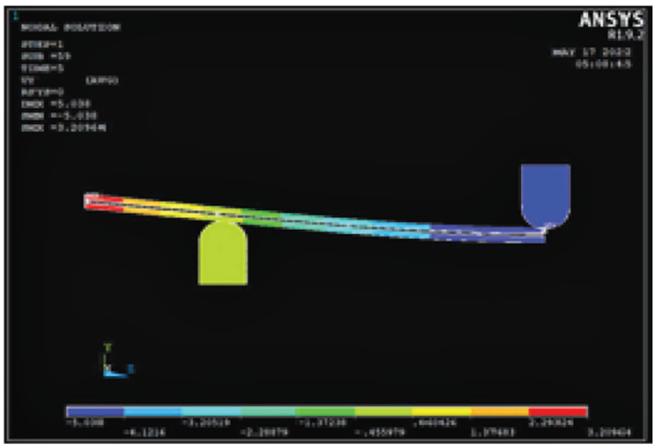

Figure 8: Displacement for 1mm AL and 0.3mm Areca fiber

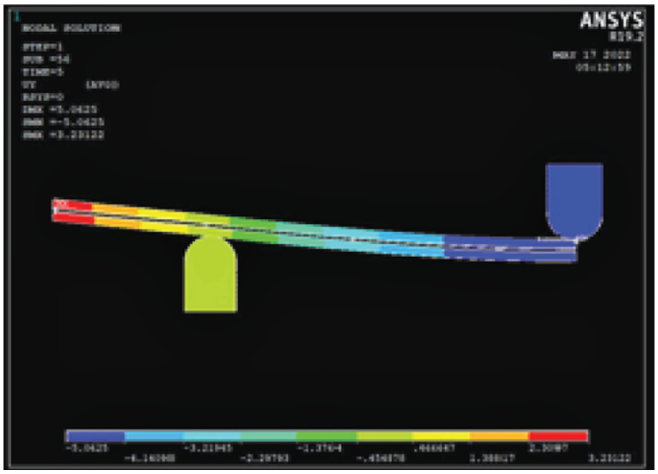

Figure 9: Displacement for 1.5mm AL and 0.3mm Areca fiber

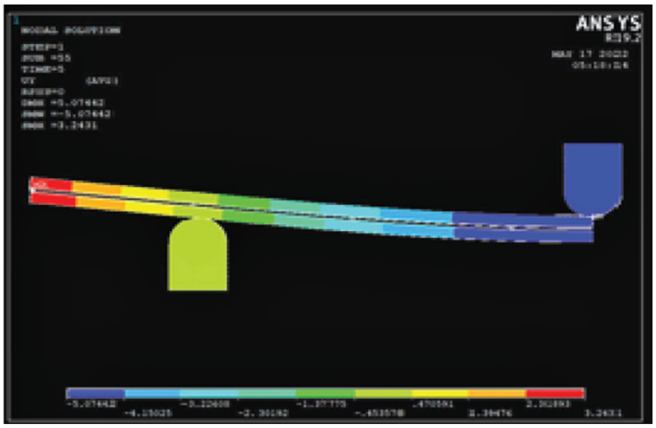

Figure 10: Displacement for 2mm AL and 0.3mm Areca fiber

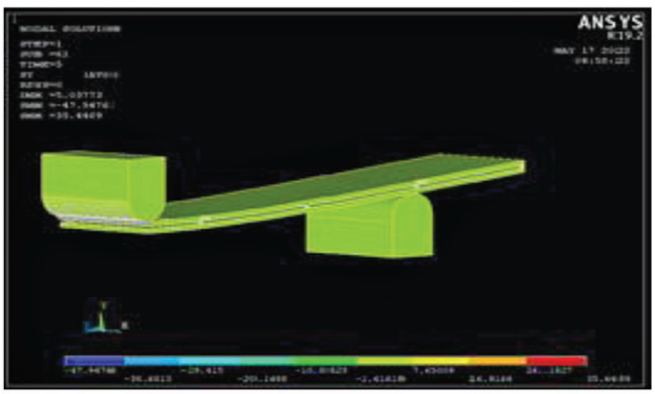

Figure 11: Y component stress for 1mm AL and 0.1mm Areca fiber

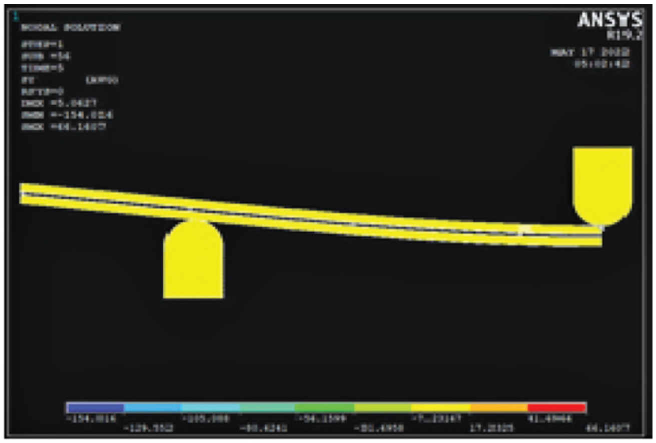

Figure 12: Y-component stress for 1.5mm AL and 0.1mm Areca fiber

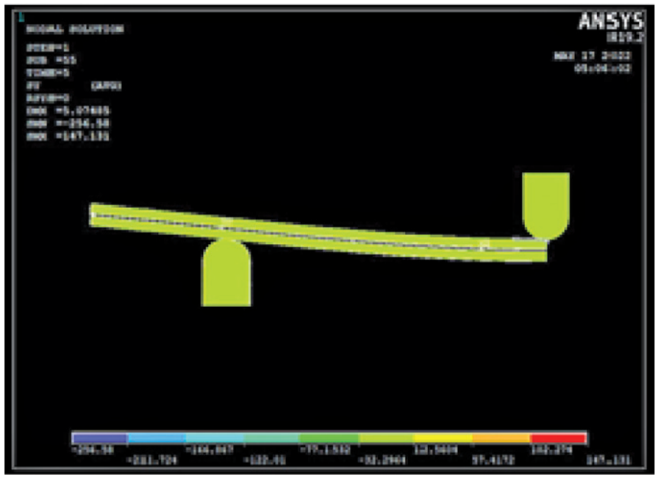

Figure 13: Y component stress for 2mm AL and 0.1mm Areca fiber

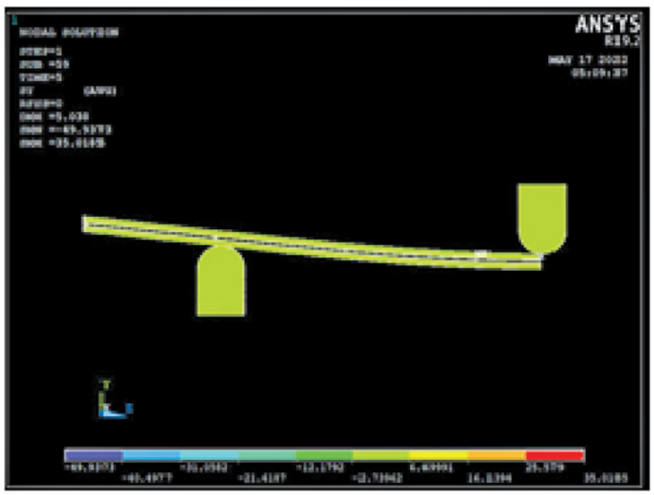

Figure 14: Y component stress for 1mm AL and 0.3mm Areca fiber

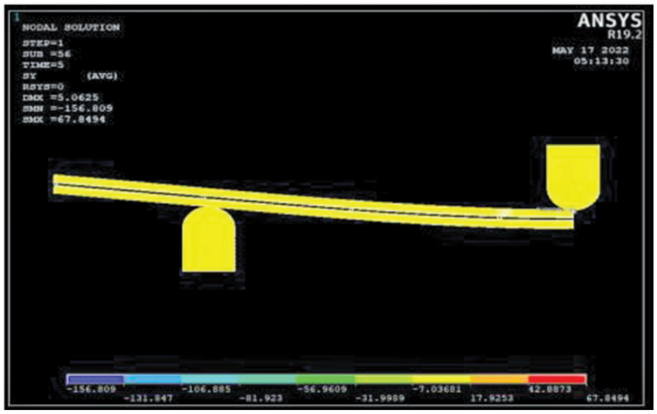

Figure 15: Y component stress for 1mm AL and 0.3mm Areca fiber

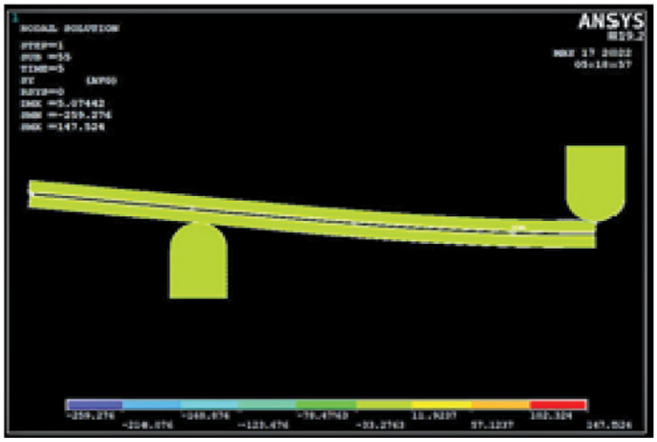

Figure 16: Y component stress for 2mm AL and 0.3mm Areca fiber

3.3 Principal strain

Result of principal strain are shown in the above figure and is found to be within the limit.

3.4 Von-misses stress

The maximum von misses stress is found to be 210MPa under the application of load.

To compare the results, the different structure composite structure beam is labelled as follows

While comparing the deflection of the beams, as the thickness of the face sheet increases, the deflection of the beam will decrease. Then as the adhesive thickness of the beam layer increases and similarly compared with each other (case-1&4) (case-2&5) (case -3&6), the deflection in the beam decreases as the use of natural fibre in the beam. They are analyzed to understand the span length.

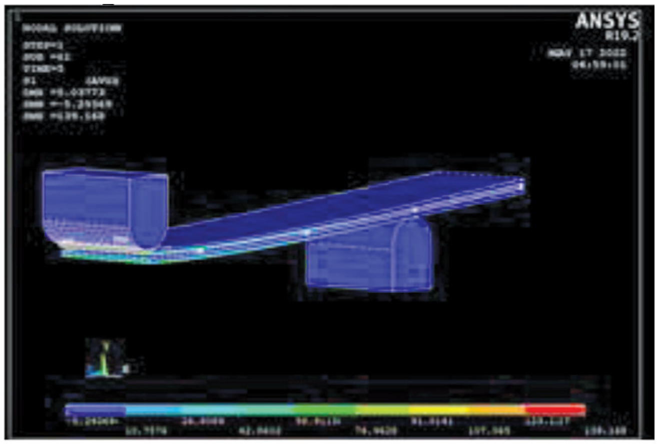

Figure 17: Principal strain for 1mm AL and 0.1mm Areca fiber

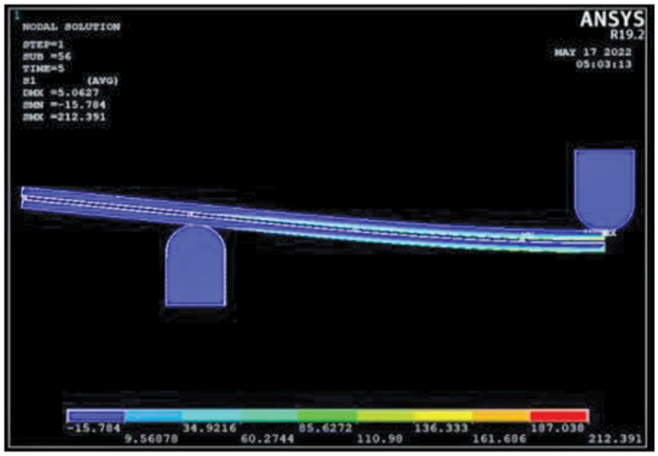

Figure 18: Principal strain for 1.5mm AL and 0.1mm Areca fiber

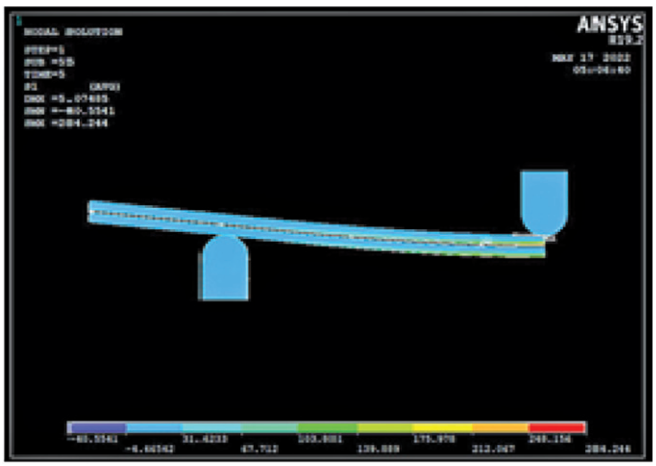

Figure 19: Principal strain for 2mm AL and 0.1mm Areca fiber

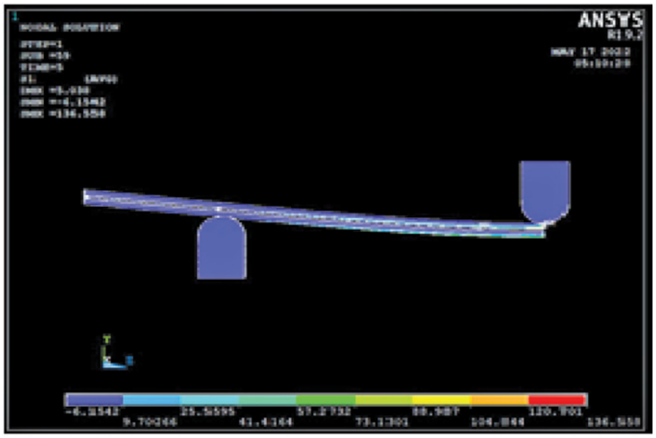

Figure 20: Principal strain for 1mm AL and 0.3mm Areca fiber

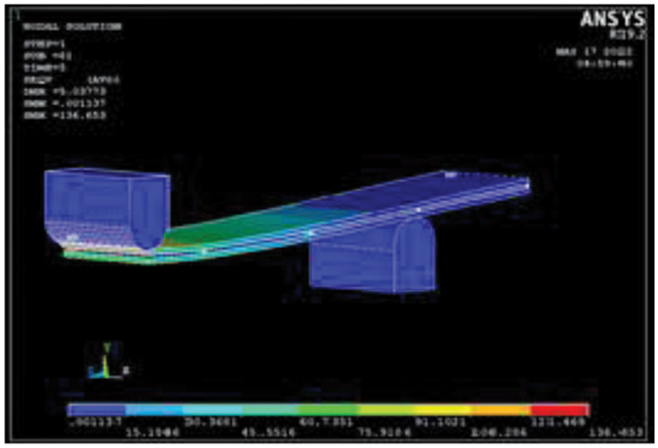

Figure 23: Von-misses stress for 1mm AL and 0.1mm Areca fiber

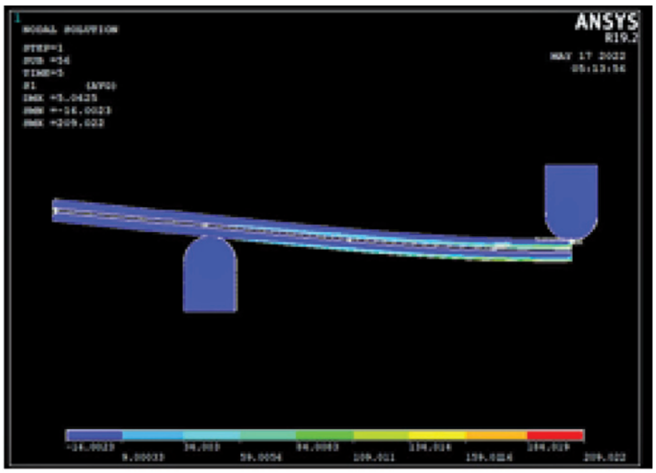

Figure 21: Principal strain for 1.5mm AL and 0.3mm Areca fiber

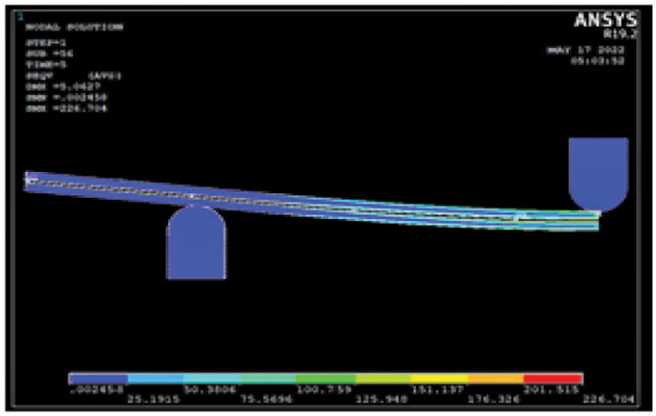

Figure 24: Von-misses stress for 1.5mm AL and 0.1mm Areca fiber

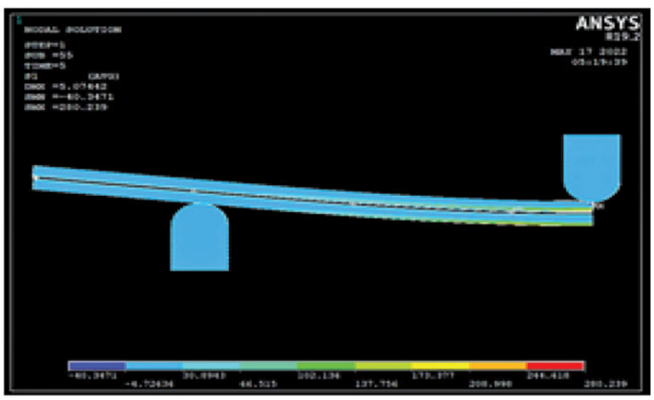

Figure 22: Principal stress for 2mm AL and 0.3mm Areca fiber

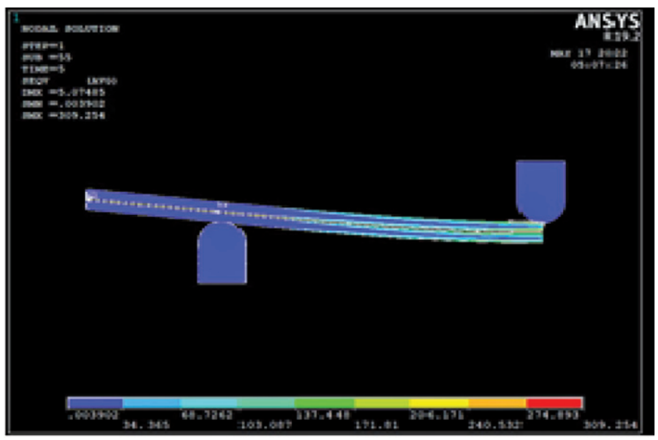

Figure 25: Von-misses stress for 2mm AL and 0.1mm Areca fiber

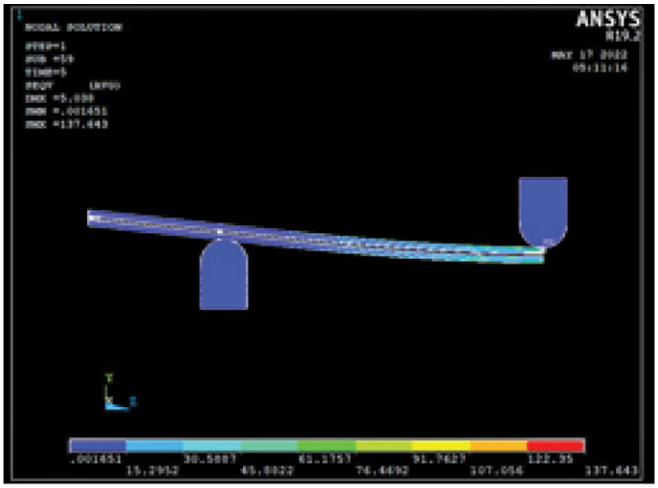

Figure 26: Von-misses stress for 1mm AL and 0.3mm Areca fiber

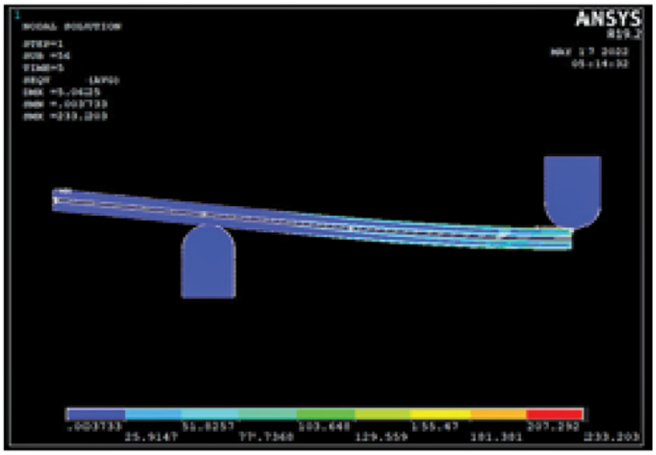

Figure 27: Von-misses stress for 1.5mm AL and 0.3mm Areca fiber

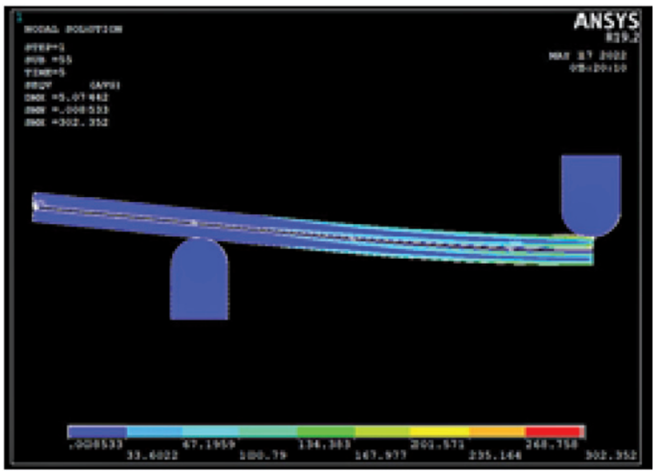

Figure 28: Von-misses stress for 2mm AL and 0.3mm Areca fiber

Table 4: Label of different structure

Face-sheet thickness (mm)	Adhesive thickness (mm)	Label
1	0.1	Case-1
1.5	0.1	Case-2
2	0.1	Case-3
1	0.3	Case-4
1.5	0.3	Case-5
2	0.3	Case-6

Table 5: Maximum deflection

Parameter	Deflection(mm)
Case-1	2.18773
Case-2	1.2127
Case-3	0.22485
Case-4	1.788
Case-5	0.8125
Case-6	0.17

Table 6: Y-Component stress

Parameter	SMX (Nmm^{-2})
Case-1	35.018
Case-2	66.1607
Case-3	147.131
Case-4	35.4489
Case-5	67.8494
Case-6	147.524

Table 7: Principal strain

Parameter	ε_1 (Nmm^{-2})	ε_2 (Nmm^{-2})
Case-1	36.621E-03	0.372E-10
Case-2	83.16E-03	-0.227E-05
Case-3	116 E-03	-0.702E-03
Case-4	39.339E-03	0.321E-10
Case-5	91.429 E-03	0162E-09
Case-6	127.086 E-03	-0.981E-06

Table 8: Von mises stress

Parameter	SMX (Nmm"2)
Case-1	136.653
Case-2	226.704
Case-3	309.254
Case-4	137.643
Case-5	233.203
Case-6	312.352

The 1st Principal strain is analyzed to understand the maximum and minimum normal strain possible for a specific point on the structure due to the loading conditions. Compared to each other, the increase in face-sheet thickness will increase the strain rate from the obtained solution. As the adhesive thickness is varied and compared, there is a increase in the strain of the beam.

Von mises stress is stress used to determine the composite beam at which it will yield or fracture. Most commonly, this method is implicated in ductile materials. When the composite beam under the load is equal to or greater than the yield limit, the beam will yield.

In comparing the obtained results, the structure's stresses are increased as the face sheet is varied. The use of fibre in the beam will also increase the maximum stress of the beam

The graph between displacement and reaction force.

The above graphs show the results of displacement and reaction forces for the thicknesses of 0.1 and 0.3mm.

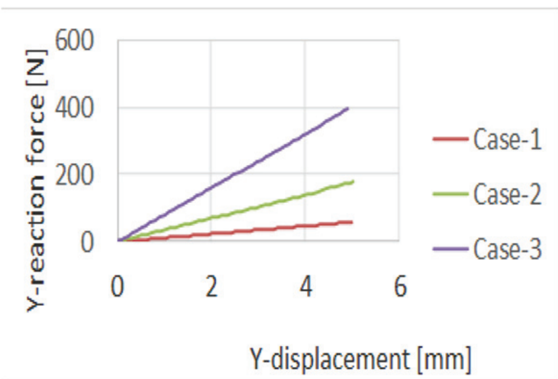

Figure 29: Displacement vs reaction force for 0.1mm areca fiber in different structures

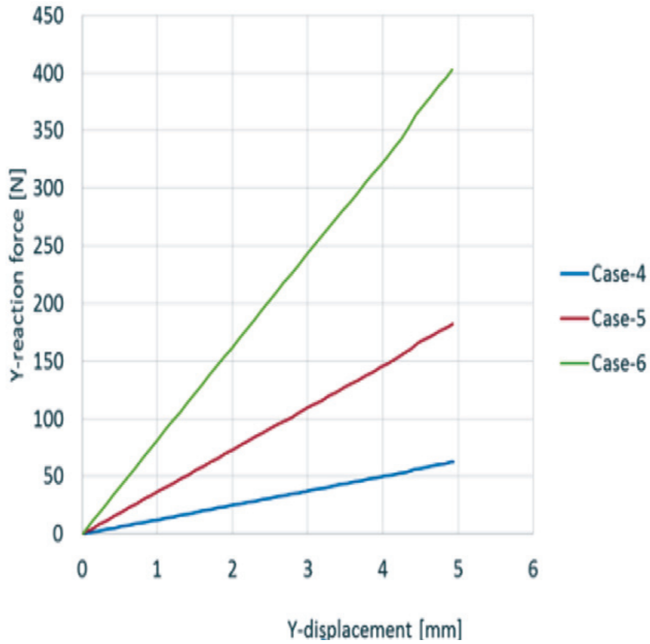

Figure 30: Displacement vs reaction force for 0.3mm areca fibre in various forms

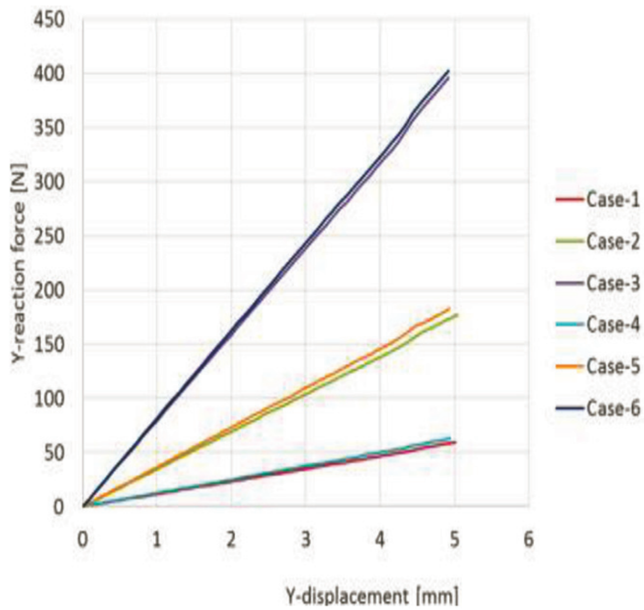

Figure 31: Displacement vs reaction force for all structures

3.5 Modal analysis

From the following table, we can note that with the variation in the thickness of the face sheet and the adhesive layer, the frequency increases in the model analysis. Thus, it indicates that the use of natural fiber

Table 9: Model Frequency for 0.1mm thickness Areca fiber for different Al thickness

Mode set	Case-1	Case-2	Case-3
1	8.75E-03	1.00E-02	1.09E-03
2	1.0278	1.1278	1.2278
3	2.8278	2.9278	3.0178
4	3.4296	3.7278	3.9178
5	4.4296	4.8278	5

Table 10: Model Frequency for 0.3mm thickness Areca fiber for different Al thickness

Mode set	Case-4	Case-5	Case-6
1	1.31E-02	1.53E-02	1.75E-02
2	1.8278	1.9278	2.0178
3	2.9978	3.1278	3.2278
4	3.6641	3.9278	4.2278
5	4.7641	4.9278	5

in the beam will pair together and differ the structure's natural frequency.

3.6 Numerical analysis

In any composite material, the load (P) applied to the structure is distributed to every member. The total load of the composite is the sum of the load of the individual member. Some of the assumptions are made: P_i-Load shared by element ith term. P-Total Load of the composite structure. σ_i-Stress in element ith term A_i-Area of the element ith term.

$$P = P_1+P_2+P_3+P_4+P_5 \quad \text{... (1)}$$

$$P = \sigma_1 A_1+\sigma_2 A_2+\sigma_3 A_3+\sigma_4 A_4+\sigma_5 A_5 \quad \text{... (2)}$$

The maximum deflection of the simple support beam is calculated using δ =PL³/48EI. Assuming the structure in the principal plane stress condition.

$$\begin{Bmatrix}\sigma_{11}\\ \sigma_{22}\\ \tau_{12}\end{Bmatrix} = \begin{bmatrix} Q_{11} & Q_{12} & 0\\ Q_{12} & Q_{22} & 0\\ 0 & 0 & \gamma_{12}\end{bmatrix}\begin{Bmatrix}\varepsilon_{11}\\ \varepsilon_{22}\\ \gamma_{12}\end{Bmatrix} \quad \text{... (3)}$$

Where π_{11}, σ_{22} and τ_{12} represents the longitudinal, transversal and shear stresses components. are the plane stress for the lamina. The maximum strain energy theory for the ductile materials is calculated using Haigh's theory. The failure or the yielding occurs when the strain energy per unit volume in a strained material reaches the limiting strain energy per unit volume as determined from the tension. The maximum energy which a body can store without deforming plastically is constant for the material irrespective of the manner of loading.

$$\epsilon_1 = \frac{1}{E}(\sigma_{11} - v\sigma_{22}) \quad \text{... (4)}$$

$$\epsilon_2 = \frac{1}{E}(\sigma_{22} - v\sigma_{11}) \qquad \epsilon_1 > \epsilon_2 \quad \text{... (5)}$$

$$\tau_{max} = \frac{(\sigma_{11} - \sigma_{22})}{2} \quad \text{... (6)}$$

The strains are calculated using equations (3) (4) (5) (6) and (7). The von-mises stress is calculated using von-mises yielding criteria which is the most appropriate method for the ductile materials. The von-mises stresses are also calculated using the equation.

4. Conclusions

From the present analysis work that has been carried out this is the following conclusions noted:

- It is observed from the results as the thickness of the face sheet increases, the deflection of the beam will decrease. Similarly, the variation in the adhesive layer will also reduce the deflection of the beam.
- It is observed from the results variation of the face sheet increases the maximum strain. Comparing it by variation of adhesive layer indicates the increase in the maximum strain of the beam structure composite.
- It is observed from the analysis of the composite structure beam varying the thickness of the face sheet and adhesive layer that various parameters are noted.
- It is observed from the modal analysis, that the variation in the thickness of the face sheet and adhesive layer also varies the frequency of the structure. It indicates that natural frequency increases as the thickness of the skin increases.

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