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Research Article

Comparative Analysis of Natural Fibre Reinforced Composite Material Using ANSYS

K. G. Saravanan,[1] **R. Prabu**,[2] **A. Sivapragasam**,[1] **and Nahom Daniel**[3]

[1]*Department of Mechanical Engineering, Sona College of Technology, Salem, Tamil Nadu, India*
[2]*Department of Mechanical Engineering, Mahendra Engineering College, Namakkal, Tamil Nadu, India*
[3]*Department of Chemical Engineering, College of Biological and Chemical Engineering, Addis Ababa Science and Technology University, Addis Ababa, Ethiopia*

Correspondence should be addressed to K. G. Saravanan; kgsmechanical@gmail.com and Nahom Daniel; nahom.daniel@aastu.edu.et

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The regulations of legislative bodies regarding the recycling and reusage of automotive materials has caused a great deal of obligation among automotive manufacturers to use natural fibres or green composites. Green composites or more commonly known as bio-composites are made up of natural fibres. Natural fibres are used by humankind since prehistoric times. The natural fibre is obtained from plants as well as animals. Since the natural fibre is obtained from natural as well as biological resources, it is biodegradable and recyclable. This paper presents the study and analysis conducted to address the suitability of natural fibre in the automotive industry. This paper discusses the finite element analysis of four different natural fibre composites used for making car door panel, i.e., flax, jute, sisal, and leather are taken for the material study. This paper helps to find the effectiveness of each of the four natural fibre composites that have already been used in the automotive sector. This paper includes the analysis of four different natural fibres with and without the addition of the aluminium as the reinforcement material. This project revolves around the design of the composite fibre sheet and analysis of the mechanical parameters such as equivalent stress, shear stress, strain, deformation, and so on. The studies and observations of the analysis showed that the natural fibre with the aluminium reinforcement proved to be much stronger than that without the reinforcement. The results of finite element analysis showcased lowest total deformation and equivalent strain in the flax as 1.026 m and 0.017 mm/mm, respectively. However, sisal showed the lowest equivalent stress and shear stress which were 68.09 and 38.178 MPa, respectively. Additionally, leather showed the highest amount of stress, strain, and deformation, and hence leather was deemed to have undesirable properties regarding the usage in car door panels. All the materials except leather were found to be safe under the loading conditions. Hence, the flax fibre is recommended by the project to have superior properties compared to the other materials.

1. Introduction

The ever-increasing demand and popularity of the environment-friendly natural resources have caused a major movement in the automotive industry [1]. The usage of natural fibre bio-composite has been increasing in the automotive industry for a long time. The high-strength fibres having high tensile strength such as Kevlar, glass fibre, carbon, and so on are difficult to recycle and are very costly to manufacture. Hence, the environmental impact of synthetic material and the rising prices of the such artificially developed materials are also the causes of the growing demand of the natural fibre composite materials [2–4]. The industry research found out that the industrial use of natural fibre reinforced polymer composite was nearly 2.1 billion USD in 2010 [5, 6]. This market size is currently on the growing trend and is predicted to grow to 6.50 billion USD in 2021. Around 80000–160000 tons of natural fibres are used every year in the automotive industry across the globe [7]. Natural fibres or green fibres are obtained from plants and animals. They are hence readily available throughout the world. Some of the natural fibres that have been in use are flax, sisal, coconut, bamboo, coir, jute, feather, leather, wool, etc [8, 9]. Natural fibre polymer composites are made by using natural fibres with various polymer matrices or resins. The polymers or resins can be thermoplastic or thermoset [5, 10]. The thermoplastic matrix becomes softer material when the heat is applied to the surface of the material. Reshaping of thermoplastic resin can be done with the application of heat and pressure. Some of the examples of the thermoplastics are polyethene, PVC, PP, etc [5, 10]. Thermosets, on the other hand, cannot be moulded and melted into the final shape. They can become soft under the application of heat and have superior mechanical properties compared to the thermoplastics. This is why they are very difficult to be easily recycled and reused [1, 11]. But few of the research studies show that recycling and reusing of thermosets are possible. Thermosets are in low melting solids and liquids for and are difficult to cure. Some of the thermoset polymers include polyester, acrylics, epoxies, phenolic resins, vinyl esters, polyurethanes, etc [10, 12].

Composite materials most commonly have a continuous bulk phase, called a matrix, and one scattered, contiguous phase, which is considered a tougher and stronger refurbishment. Strengthening content may contain fibres, fragments, or flakes. The principle of composites is that in the bulk process, the load is borne on a broad surface and moved to the reinforcement, which, being more solid, increases composite strength [13, 14]. The interface bonding of the natural fibre and the polymer matrix dictates the physical properties of the natural fibre reinforced polymer composites. The interface bonding tests such as single fibre compression, pull out, and compression tests are commonly used to test the bonding effectiveness in the fibre reinforced composites [3].

The effectiveness of the natural fibre composites is dependent upon the number of the fibre strands, shapes, and lengths as well as the fibre orientation and adhesion quality of the matrix [1, 13]. The properties of natural fibres can vary due to some factors such as maturity, size, and processing methods. Fibre reinforced composites have woven and nonwoven arrangements where the woven fabric has the characteristics of the interlacing of the yarns which are perpendicularly interlocked fibres. The twist angle of the yarn also plays a role in the fibre cohesion and woven strength. However, the twist angle can be effective up to certain limit after which it is shown to have reduction in the bonding strength of fibre and polymer resins [1, 15]. The natural fibres, when embedded with the resin matrix, can impart high strength, less density, high stiffness, and better damping characteristics onto the NFRP composites [5, 10]. Even though natural fibres have bit lesser strength compared to glass fibres, they are twice as light compared to glass fibres and have similar stiffness, which is a great advantage. The utilization of the natural fibre composites provides 20% of cost reduction and 30% of reduction of the weight of automotive parts [10, 11]. The natural fibre materials are also shown to have better cost-effectiveness and better energy recovery compared to glass and carbon fibres [8].

Though natural fibres offer a lot of advantages, they also have many more shortcomings on their own. The natural fibres are found to be hydrophilic because of the polarity of hydroxyl groups present in the lignin and cellulose material. Hydrogen bonding of hydroxyl groups helps to retain water in the natural fibres, and this is the reason why the humidity sensitizes the composite materials and can cause swelling of the natural fibres and resins [8, 16]. Also, the plant fibres have bigger oscillations due to the growth of the plant fibres [7]. The binding of the fibre and polymer composites can be difficult to execute because of variations of fibre and matrix chemical structures [5, 17]. From the research, it is determined that the natural fibre modulus can reduce with the increase in its diameter [18, 19]. Hence, the bonding capability of the fibre and resin can be greatly improved by the surface modification processes of fibres such as plasma treatment, chemical treatment, and biological treatment methods [17]. Fahim et al. carried out the tensile behavior study of dried plant and animal fibre composites, and they found out that the rice straw showed the downward trend with the increase in fibre loading volume proportion till 40% of rice straw volume and increased further on fibre loading at 50%. The tensile strength of hybrid fibre (i.e., combination of chicken feather and rice straw) was found to be higher than rice straw and chicken feather at 50% fibre loading. Fibre length can also impact the bonding of matrix and fibre, causing clamping [3].

Natural fibre composites are in growing use in the automotive industry since the 1990s [10, 20]. Since the popularity of natural fibre, Germany has been the leader in using natural fibre composite materials. The first and significant attempt for utilization of natural fibres in the automotive industry was made by German manufacturer Mercedes-Benz. In 1996, Mercedes-Benz made use of epoxy matrix along with jute fibre in the E-class cars. In 1999, they manufactured the inner door panel by utilizing 35% of semirigid elastomer and 65% of blend mixture of hemp, flax, and sisal fibres. Along with Mercedes-Benz, other automobile manufacturers such as BMW, Volkswagen, and Audi have used natural fibre composites for interior and exterior applications [7, 20]. Audi also attracted considerable attention after they manufactured the door trim panels of A2 midrange car by using a mixture of flax/sisal along with the polyurethane matrix. Volvo used soya bean foam linings for the seats in V70 and C70 models. They also employed the cellulose-based floor tray for noise reduction purpose. In the United Kingdom, Ford Mondeo utilized the kenaf fibre and propylene polymer for its door panel which has reduced the mass of the door by 5–10% [7, 21]. In the recent times, various automotive manufacturers have started to adopt NFRPC in the interior and exterior parts of the vehicle such as door panels, trunk liners, seat backs, spare tyre lining, boot lining, door trim panels, windshield, back cushions, spare wheel compartment cover, and so on [20, 22–24].

2. Material Selection

As stated earlier, several natural fibres are used by automotive industries since the 90s. The prospect of the usage of NFPC in the automotive sector is great and hopeful. Modern auto manufacturers have employed the natural fibre composites for the car panels, seats, floors, etc. Hence, this project is also involved in finding out appropriate natural fibre materials for the door panels. Materials such as flax, jute, sisal, and leather are selected for review and analysis. Along with them, the bonding agent epoxy resin and another reinforcement metal Al-3003 are also discussed in this paper. The description of the aforementioned materials is presented below.

2.1. Flax. Flax is a member of the genus *Lignum* of the limacine family and also known as common flax or linseed. This is a grain and fibre crop grown in colder areas of the country. The term "flax" refers to the spun fibres of the flax plant in addition to referring to the plant itself. Flax is cultivated for its seeds which can be ground into a meal or converted into linseed oil, a component found in many wood-finishing products as a dietary substitute and as an ingredient. Flax has already been used as a replacement to glass fibres and carbon fibre materials in the automotive industry. A conference paper published by Christiano et al. presented a study of ECOSHELL frame in which the manufacturing processes and mechanical properties of the various flax reinforcement structures were presented. Flax reinforcements, namely, non-woven mat, balanced fabric or woven fabric, and unidirectional fabric, were bonded with the epoxy resin and their mechanical properties were tested. The tests showed that the unidirectional fabric yielded the highest ultimate tensile strength and woven fabric induced a higher rate of shear stress with the corresponding increase in the shear strain. However, the woven fabric absorbed the highest energy during the drop weight impact test [6, 10]. Before rinsing and drying in the field, flax is replenished with dew or cold/warm water. Flax dressing is used to take the fibres out of the head, consisting of kicking, shaking, and pounding. Before making a bonding of flax fibre with the resin matrix, the fibres are dried properly. Flax fibres are very susceptible to the water and moisture absorption and will lead to poor adhesion between the resin and fibres [10]. Flax fibres have variation in their properties depending on the treatment methods and extraction procedures. In this project, we have taken a normal dried out flax fibre. The properties of the natural fibres are presented in the Table 1 [25, 26].

Table 1: Properties of flax fibre.

Properties	Values
Density (kg/m^3)	1400
Young's modulus (MPa)	60000
Poisson's ratio	0.41
Tensile strength (MPa)	343
Elongation at break (%)	2.1

2.2. Jute. Jute is a thick, gentle, and brilliant fibre that can stretch into coarse, strong threads. It is derived from the *Corchorus* family, which belonged to the *Tiliaceae* families. "Jute" is the name of the plant or of the fabric used in producing burlap, hessian, or gunny cloth. Jute plant is harvested in the subtropical climate regions such as Bangladesh, Nepal, India, Brazil, China, Thailand, and so on. The production of jute fibres has been steadily increasing and the production has increased from 1 million ton per year in 1900 to 3292 million tonnes in 2004.

Jute is one of the most widely available and cheaper natural fibers with variety of applications produced in cotton. The primary constituents of the jute fibres are cellulose as well as the lignin plant materials. They have irregular cross sections, and they have varying diameters ranging from 0.01 mm to 0.04 mm.

A design conducted by Cristiano et al. on the jute fibre composites determined that the vibration observed in the wet jute fibre was lesser than that of the treated jute fibres. However, the dried jute fibres were more susceptible to moisture due to the removal of the protective layer of wax and oils. The treatment in the jute fibres prompted the increase of the stiffness and reduction of strain in the composites [10]. Some of the properties of the jute fibres are listed in Table 2 [27, 28].

2.3. Sisal. Sisal is a plant species of Agave which is prevalently harvested in Southern Mexico but nowadays cultivated and naturalized in various countries. It is also known as *Agave sisalana*. It generates a steep fibre used in the manufacture of various goods.

The lightweight sisal fabric is hand- or machine-scrapped from the fibres. The fibres are drained and the remaining dirt is removed by the brushes, which renders them clean. Sisal produces durable and sturdy fabrics, which are highly moist and heat resistant. Natural fibres are viewed in their properties and compared to their properties. Regarding natural fibres, one must be mindful that due to natural conditions, there are wide differences in properties. Sisal cultivation can be done in short times, and it is having high tensile strength, tenacity, abrasion resistance, acid, saltwater, and alkali resistance. Which makes it very suitable in automotive applications [1]. Sisal fibres are used in the window panels and seats of the vehicle. The properties of the sisal fibre are shown in Table 3 [29, 30].

2.4. Leather. Leather is a fibre material which is obtained from animal skin. A variety of skins including the skin of birds, cattle, and wild animals are used for manufacturing leather. The animal skin is first subjected to a salt bath which decreases the bacterial growth. Then, the skin is subjected to a water bath. After that, the leather is subjected to the tanning process. After several processes, the leather is dyed and the final product is obtained. Leather and animal skins were used for preservation purpose, and it has been used for clothes, boots, handbags, furniture, and tools. Leather has a variety of mechanical properties depending upon the nature of skin and choice in the manufacturing processes. Additionally, properties of leather also vary accordingly to the water content and temperature. The striking feature of the leather is that it can withstand repeated flexure with sustaining failure [16]. The properties of leather are shown in Table 4.

Table 2: Properties of jute fibre.

Properties	Values
Density (kg/m^3)	1400
Young's modulus (MPa)	25000
Poisson's ratio	0.361
Tensile strength (MPa)	200
Elongation at break (%)	1.16

Table 3: Properties of the sisal fibre.

Properties	Values
Density (kg/m^3)	1330
Young's modulus (MPa)	38000
Poisson's ratio	0.4
Tensile strength (MPa)	468
Elongation at break (%)	1.9

Table 4: Properties of leather.

Properties	Values
Density (kg/m^3)	860
Young's modulus (MPa)	220
Poisson's ratio	0.4

2.5. Epoxy Resin. Epoxy resins are thermosetting resins that are converted into hard cured material under the application of curing methods. They are normally in the liquid form or soft solid. After curing, they remain solid even under the application of heat and degrade only after a certain temperature limit is reached. There are pure epoxy resins, vinyl-ester resins, and thermoset polyester resins [10]. In this project, pure epoxy resins are used in the fibre composite sheet for bonding the fibres. There are two ingredients in the pure epoxy resins: a resin and a hardener having equal or proportionate ratio. They are normally used in the structural applications such as in building and constructive applications. They are also used in manufacturing adhesives, paints, coatings, fabrics, floors, and other items. The properties of epoxy resin are shown in Table 5.

2.6. Aluminium-3003 (Al-3003). Aluminium-3003 is a type of non-heat-treatable alloy which can be obtained in the forms of flat-rolled coil, plate, and sheet. This alloy is the most widely used aluminium alloy and has excellent mechanical properties. Al-3003 has excellent corrosion resistance but cannot be hardened by the heat-treatment process. It can be slightly hardened by cold working and soft annealing processes [31]. It has fairly moderate tensile strength and has high ductility. This aluminium alloy is used as pipes in the automotive industry. Since these alloys are available in sheets, this project has contemplated the proposition of using Al-3003 in conjunction with the aforementioned natural fibres. The properties of aluminium-3003 are shown in Table 6.

Table 5: Properties of epoxy resin.

Properties	Values
Density (kg/m^3)	1280
Young's modulus (MPa)	35000
Poisson's ratio	0.35

Table 6: Properties of aluminium-3003 (adapted from [32]).

Properties	Values
Density (kg/m^3)	2730
Young's modulus (MPa)	73000
Poisson's ratio	0.33
Thermal conductivity (W/mK)	190
Tensile strength (MPa)	130
Elongation at break (%)	10
Fatigue strength (MPa)	55

3. Research Consideration

The procedure employed for the selection of the most efficient natural fibre involves few of the assumptions. The natural fibres which are to be analysed are supposed to be dried out and unwoven. The leather is considered to be tanned and is considered to be obtained from cattle. The project is not concerned about the examination of moisture effect on the natural fibres. The project considers the equal use of epoxy resin and hardener for bonding purpose. Along with the aforementioned considerations, the fibre composites are analysed upon following assumptions.

(1) Porosity is absent in the fibres.
(2) The fibres are considered to be isotropic and uniform.
(3) The fibres have uniform properties along their length.
(4) The bonding between the resin and fibres is supposed to be perfect without the presence of air bubbles and slippage.
(5) Fibre alignment is considered to be perfect and without non-uniformity.
(6) Voids and gaps in the composite material are absent.

4. Modelling

The modelling procedure is started by considering the dimensions of the natural fibre sheet that will be used for further analysis. The composite material which will be used for the further analysis is designed as a 10 mm thick sheet having bonding between the epoxy resin and natural fibres. The composite sheet is the constituent of the door panel of the car in which several of these sheets are supposed to be joined to achieve required dimensions of the door panel. There are supposed to be 6 fibre strands in the 10 mm thick panel sheet in which there is a 2 mm thick layer of the epoxy between the natural fibre strands. Hence, the epoxy resin is sandwiched between the alternative layers of the natural fibres. The natural fibre sheet is supposed to be made from 300 mm long fibre strands having 0.33 mm of diameter. The width of the sheet is designed to be 50 mm where 2 mm of the epoxy resin is sandwiched alternatively. There are two models to be designed for further analysis. The first model will be designed from natural fibre and matrix resin in the alternative fashion, whereas the second model is assumed to have aluminium reinforcement in the middle portion of the composite sheet. It will have fibres and resin matrix alternately, but aluminium is supposed to be placed centrally. After considering every dimension of the natural fibre sheet panel, the design is carried out using SolidWorks software. The 2D and 3D models of the design are presented in Figures 1 and 2.

4.1. Model 1 (Fully Natural Fibre). Composite fibre with fully natural fibre and resin is shown in Figure 1.

4.2. Model 2 (Natural Fibre with Al-3003). The features used for 3D modelling are Solidworks extrude and cut extrude options. The 3D models and 2D models are shown in Figures 3 and 4.

5. Analysis

The analysis of the composite fibre model is conducted using ANSYS. The analysis of the natural fibre is divided into two sections: natural fibre with epoxy composite and natural fibre with aluminium reinforcement. The analysis is done for the forced load condition where the composite sheet is subjected to 2500 N load. The results obtained by the analysis of the various natural fibres will help to find out the most suitable material for the window panel of the car. The procedure for the analysis is described below.

5.1. Engineering Data. For performing the analysis on the natural fibre composite sheet, the engineering data regarding the materials and their properties must be known. In this project, all the data regarding the analysis of the composite sheet are noted as mentioned before. After inputting the engineering data, meshing is carried out.

5.2. Meshing. The meshing of the composite sheet model is to discretize the model into small elements. After the design is completed using SolidWorks software, the model is imported to ANSYS. The meshing nodes and elements are edited to make the entire analysis process as accurate as possible. This composite model has 4080 elements and 30575 nodes. The mesh of the composite fibre is shown in Figure 5, and the details of mesh are shown in Figure 6.

5.3. Boundary Value Conditions. Horizontal load of 2500 N is applied to the top middle section of the fibre composite sheet. Fixed support is applied at the left end of the composite sheet. Same load condition is applied for model 2 as well. After setting up the boundary conditions, the data are processed and the results are obtained in terms of elastic or

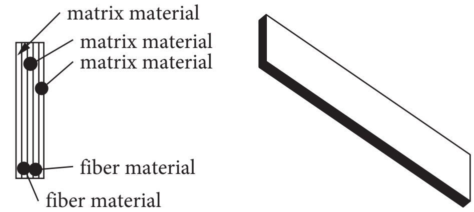


Figure 1: Composite fibre with fully natural fibre and resin.

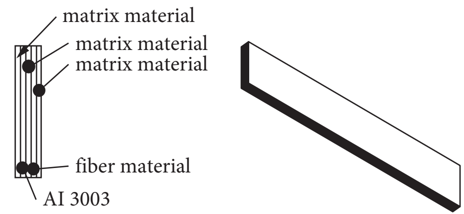


Figure 2: Composite fibre with aluminium reinforcement.

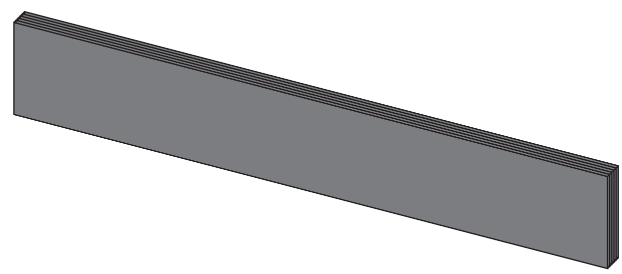


Figure 3: 3D model of the composite fibre sheet.

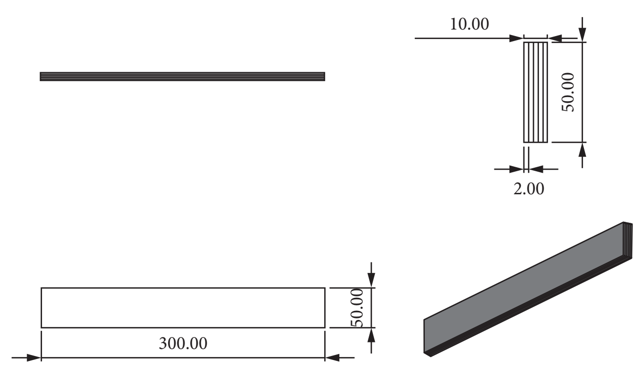


Figure 4: Detailed view of the composite fibre sheet.

equivalent strain, deformation, equivalent stress, and shear stress. The boundary condition of the analysis for the forced load condition is shown in Figure 7.

6. Results

The boundary conditions are followed by the results in the form of different parameters. The engineering data used for the analysis of the project are mentioned in the previous sections. The variables are obtained in the form of results which are deformation, stress, and strain, respectively. The analysis for model 1 will predict the behavior of every selected natural fibre under the application of impact force.

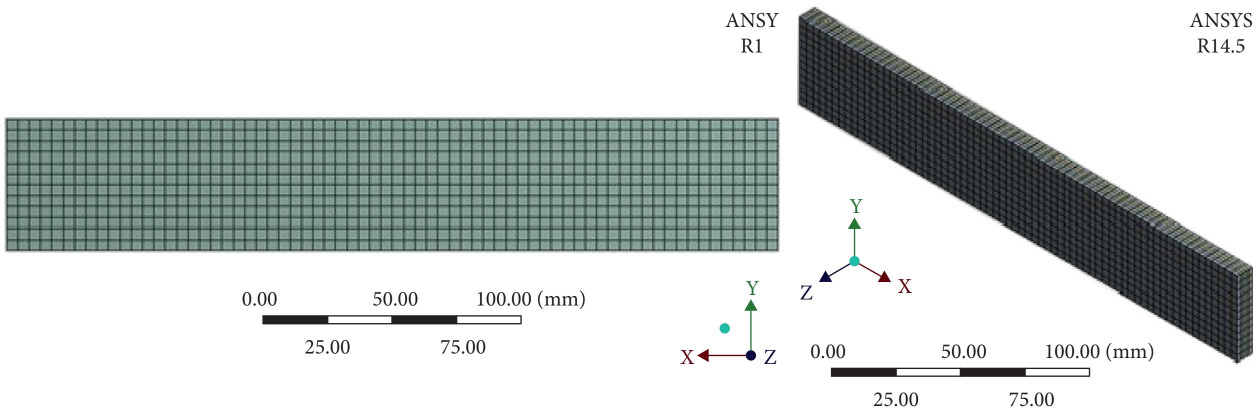
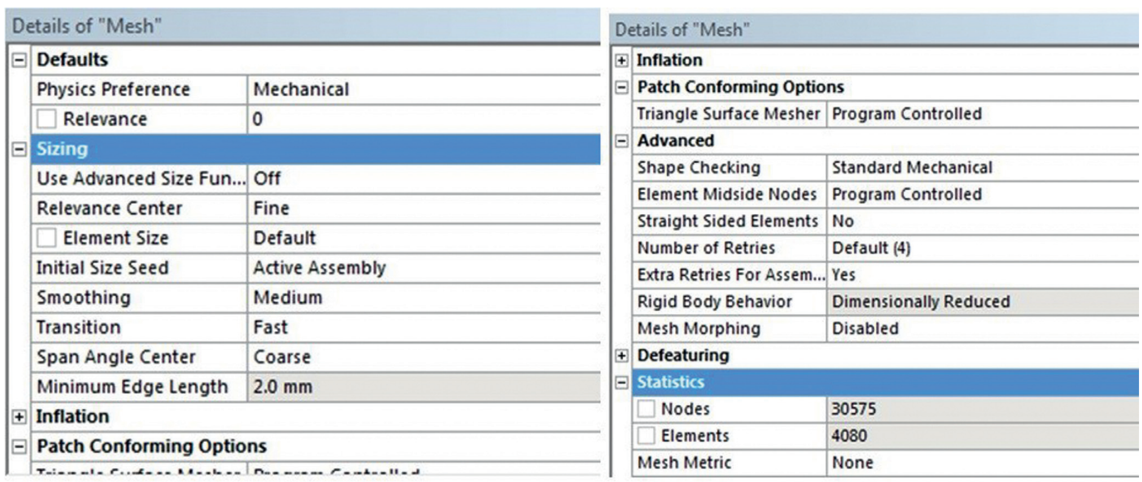


Figure 5: Mesh of the composite sheet.



Details of "Mesh"	
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Fun...	Off
Relevance Center	Fine
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	2.0 mm
Inflation	
Patch Conforming Options	

Details of "Mesh"	
Inflation	
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Advanced	
Shape Checking	Standard Mechanical
Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Extra Retries For Assem...	Yes
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Defeaturing	
Statistics	
Nodes	30575
Elements	4080
Mesh Metric	None

Figure 6: Details of the mesh.

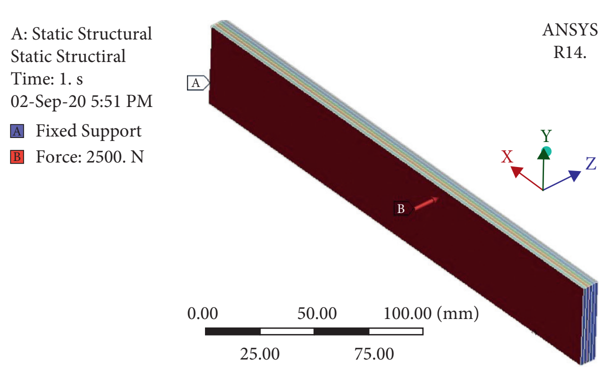


Figure 7: Boundary condition for forced load.

The analysis of model 2 will help to determine the behavior of aluminium and natural fibre due to the application of force.

6.1. Model 1 (Fully Natural Fibre). The findings from ANSYS for model 1 are presented in Figures 8–23.

6.2. Model 2 (Natural Fibre with Al-3003). The findings from ANSYS for model 2 are presented in Figures 24–39.

The analysis made on flax, jute, sisal, and leather is shown in the images above. All the parameters, namely, total deformation, equivalent stress, equivalent strain, and shear stress, are identified for every material. The pattern of variable results is identical for model 1 and model 2.

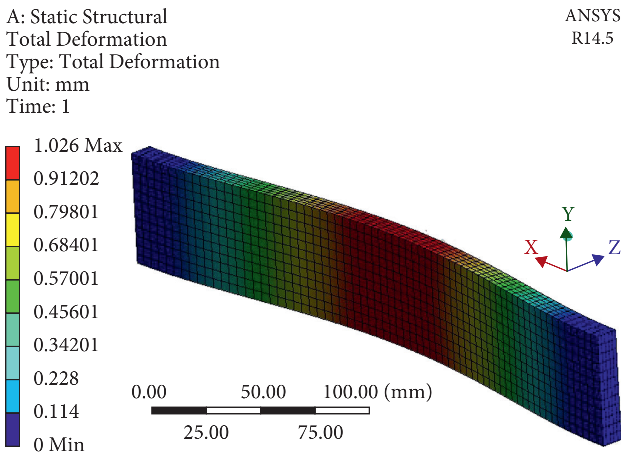


Figure 8: Total deformation—flax (model 1).

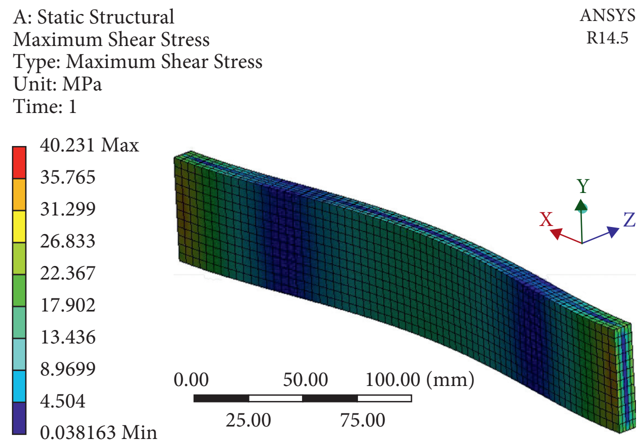


Figure 11: Max shear stress—flax (model 1).

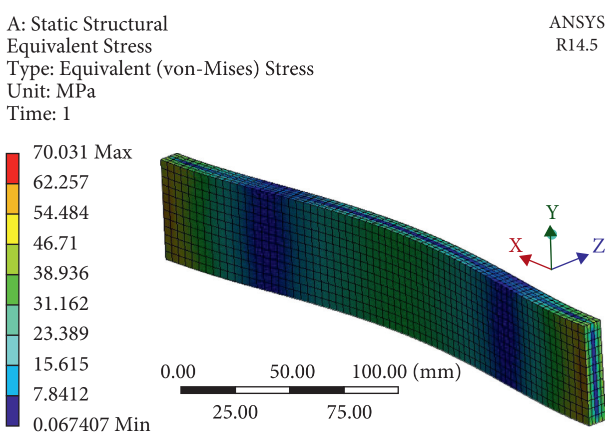


Figure 9: Equivalent stress—flax (model 1).

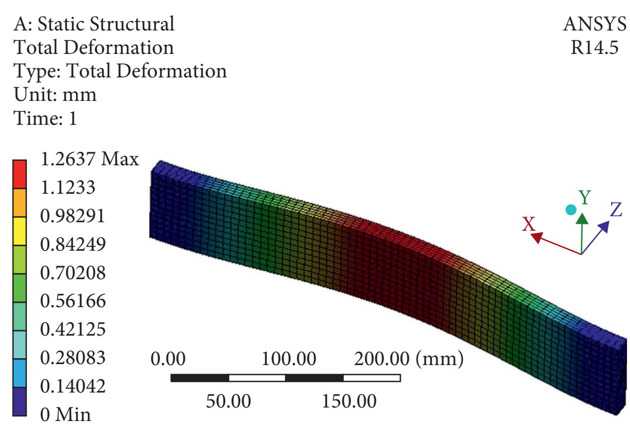


Figure 12: Total deformation—jute (model 1).

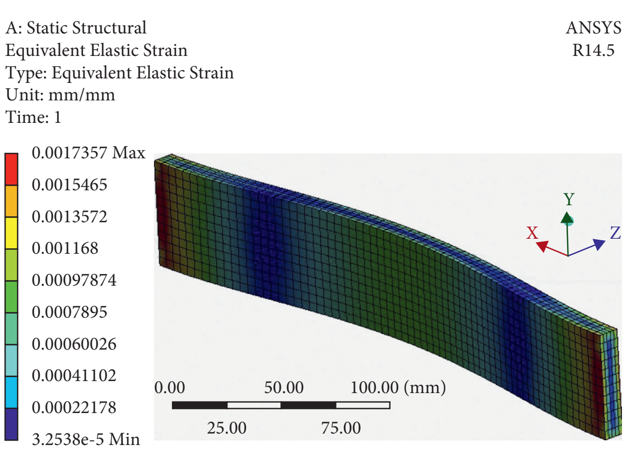


Figure 10: Equivalent strain—flax (model 1).

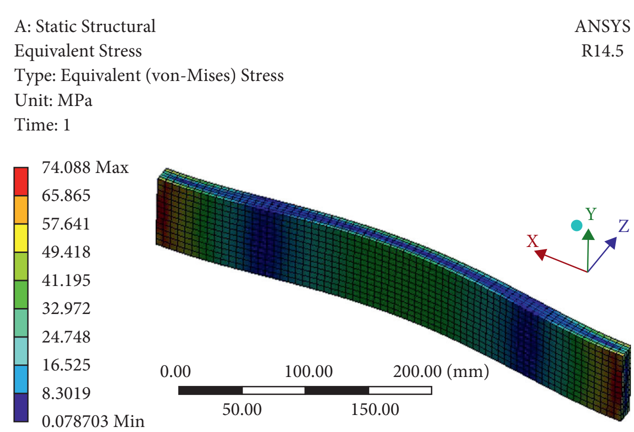


Figure 13: Equivalent stress—jute (model 1).

However, the values for both models vary due to difference in additional reinforcement. Having aluminium-3003 as the central reinforcement has helped to reduce the deformation, stress, and strain, respectively. Using aluminium as the central reinforcement was more effective compared to the fully natural fibre reinforcement. The deformation of the composite sheet shows the highest displacement of the material in the middle section and decreases gradually towards the ends of the sheet. Equivalent stress, however, is higher at the ends and middle portion of the sheet. Also, the

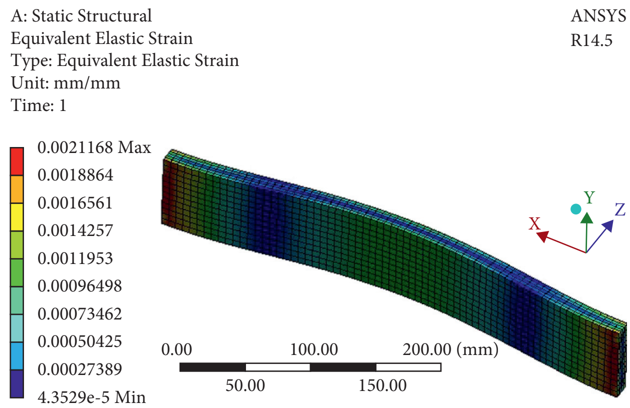


Figure 14: Equivalent strain—jute (model 1).

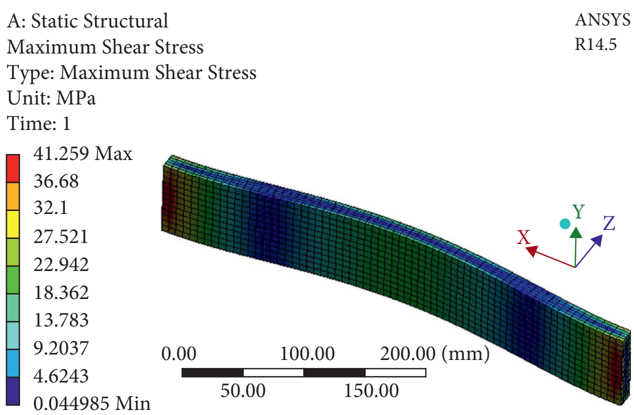


Figure 15: Max shear stress—jute (model 1).

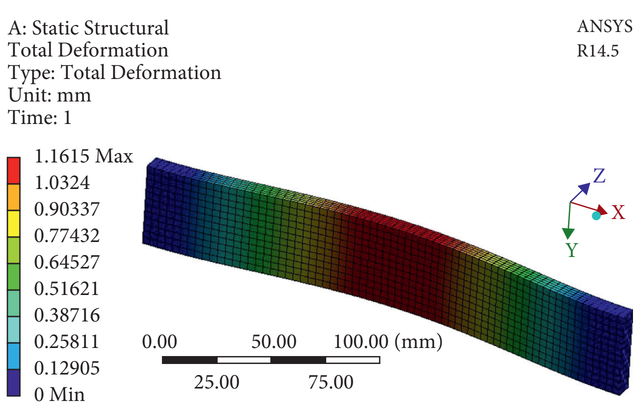


Figure 16: Total deformation—sisal (model 1).

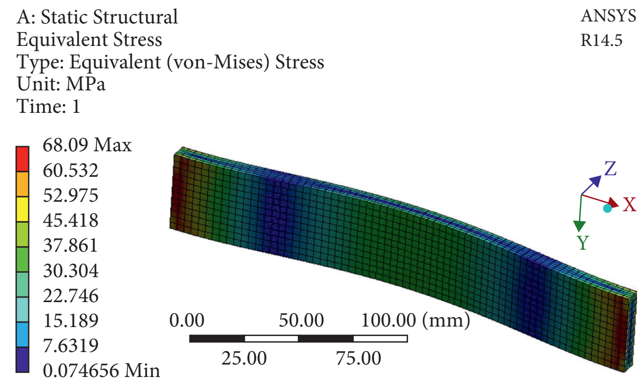


Figure 17: Equivalent stress—sisal (model 1).

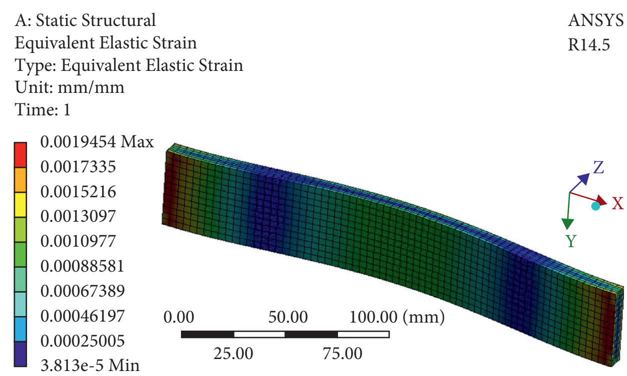


Figure 18: Equivalent strain—sisal (model 1).

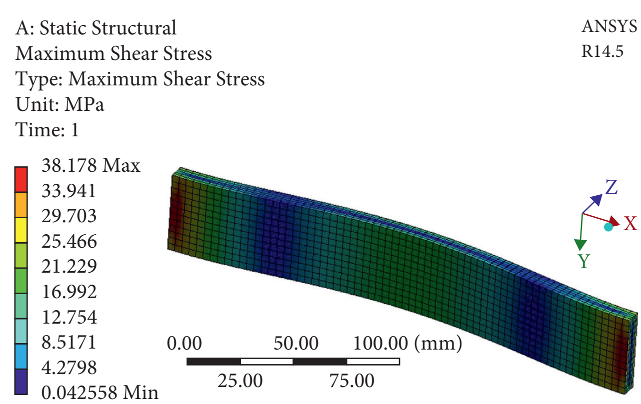


Figure 19: Max shear stress—sisal (model 1).

equivalent strain follows the same pattern as the equivalent stress. Max shear stress is observed in the middle and at the ends. From the results, it is evident that the leather showed the highest value for deformation, strain, and stresses. Flax and sisal had moderate to low values of deformation, strain, and stress, which is desirable in the construction of window panel.

The cumulative vector number of the displaced physical structures refers to the total deformation resulting from ANSYS. The elastic strain is the ratio of material distortion to the original shape. Shear stress is the stress caused by equal and opposite tangential forces within the material section. The von Mises equivalent stress is applied to find out if the ductile material having isotropic nature will yield when it is loaded. The results of variables for model 1 and model 2 are presented in Tables 7 and 8.

Figures 40 and 41 show the graphical representation of the results for model 1 and model 2.

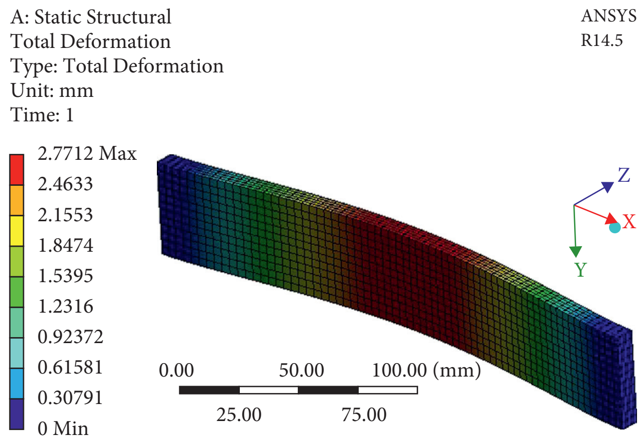


Figure 20: Total deformation—leather (model 1).

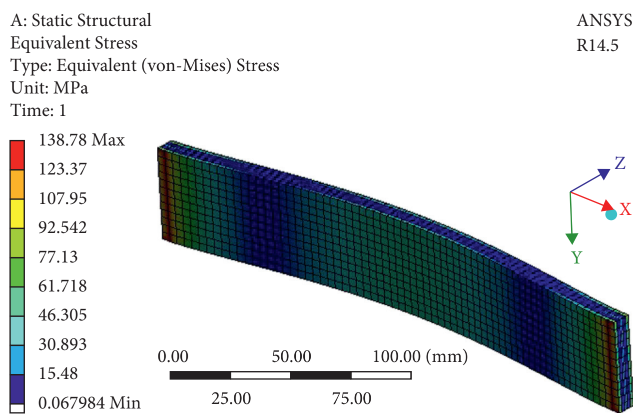


Figure 21: Equivalent stress—leather (model 1).

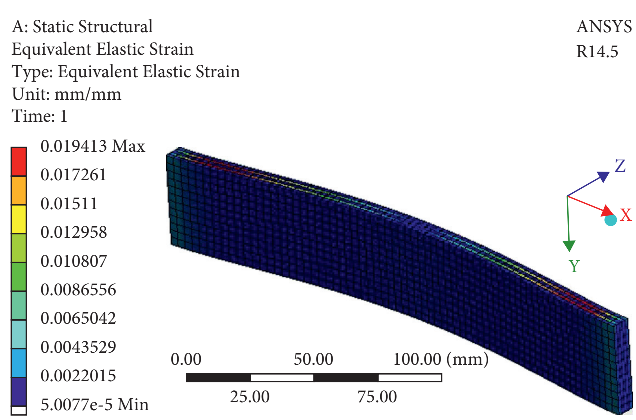


Figure 22: Equivalent strain—leather (model 1).

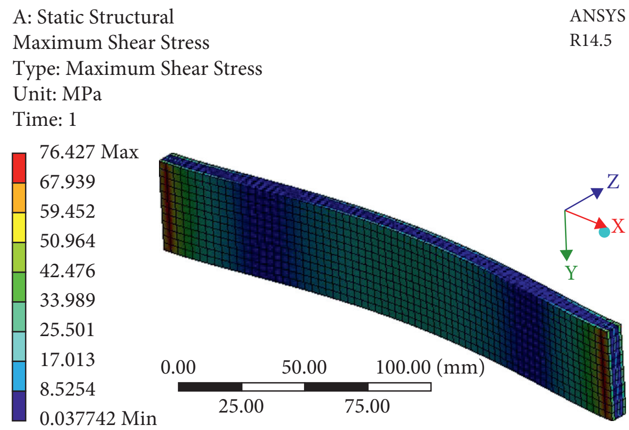


FIGURE 23: Max shear stress—leather (model 1).

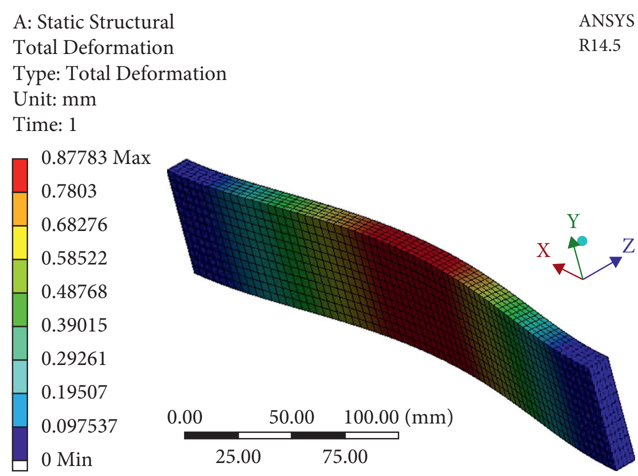


FIGURE 24: Total deformation—flax (model 2).

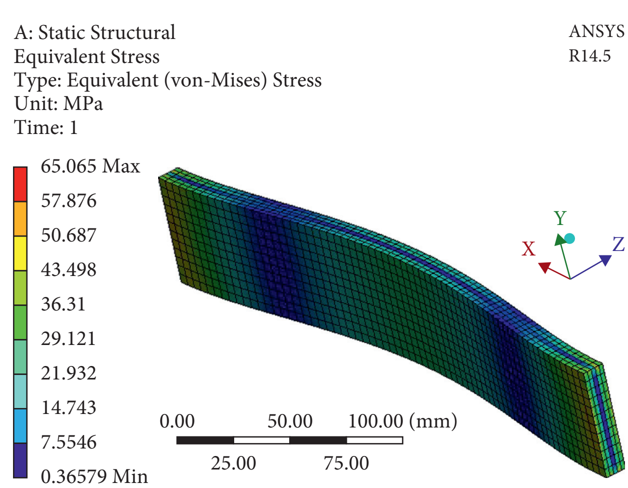


FIGURE 25: Equivalent stress—flax (model 2).

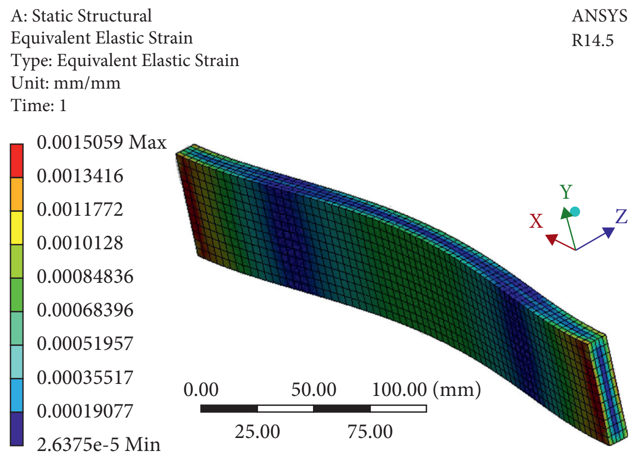


FIGURE 26: Equivalent strain—flax (model 2).

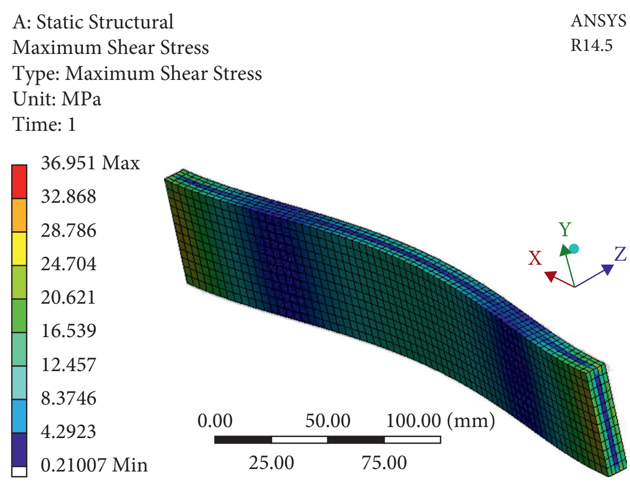


FIGURE 27: Max shear stress—flax (model 2).

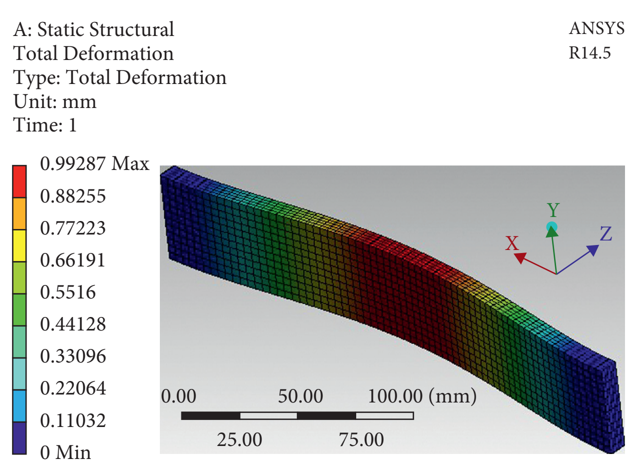


FIGURE 28: Total deformation—jute (model 2).

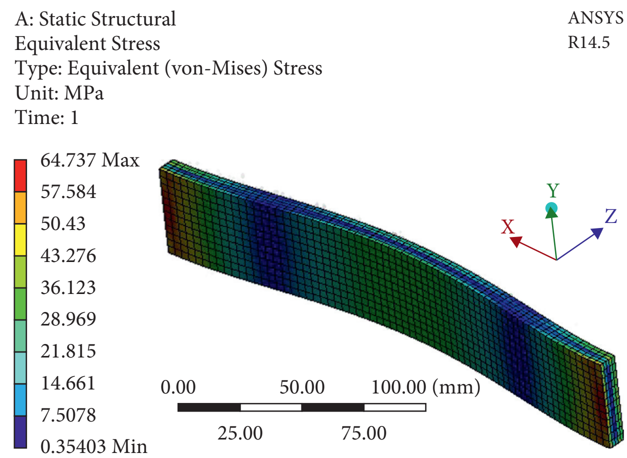


Figure 29: Equivalent stress—jute (model 2).

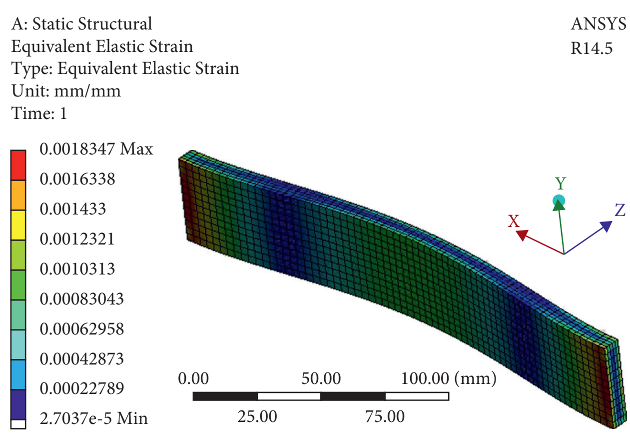


Figure 30: Equivalent strain—jute (model 2).

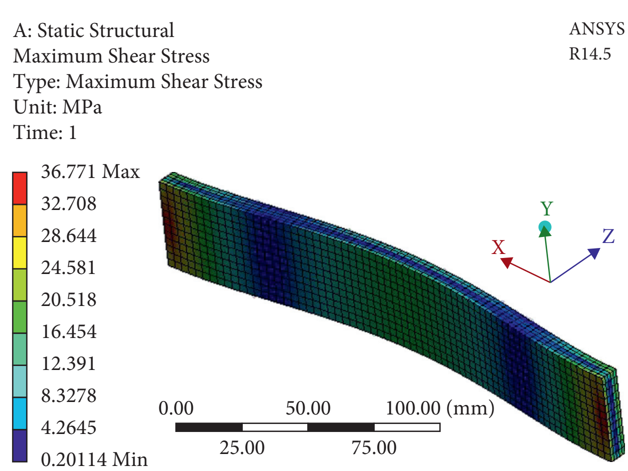


Figure 31: Max shear stress—jute (model 2).

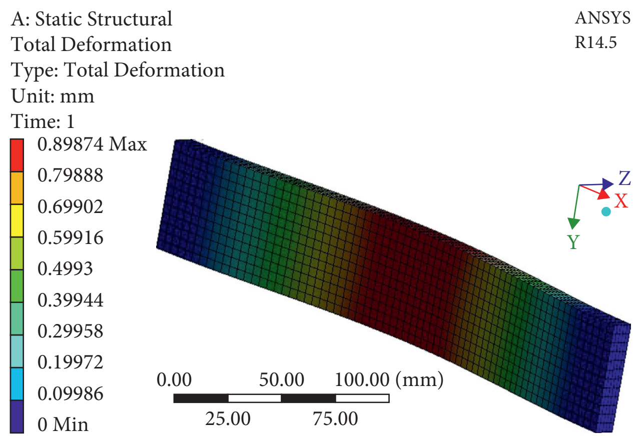


Figure 32: Total deformation—sisal (model 2).

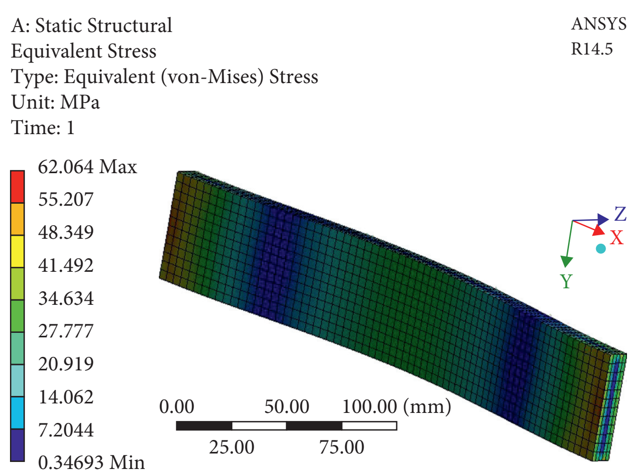


Figure 33: Equivalent stress—sisal (model 2).

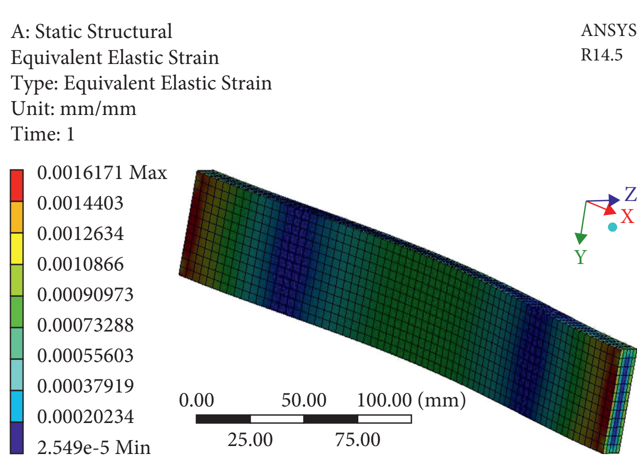


Figure 34: Equivalent strain—sisal (model 2).

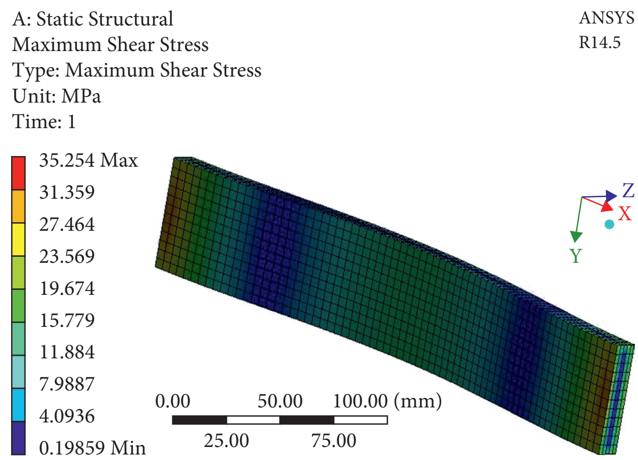


FIGURE 35: Max shear stress—sisal (model 2).

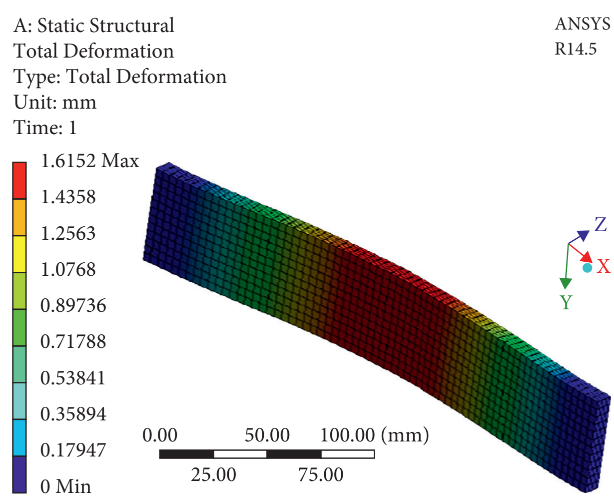


FIGURE 36: Total deformation—leather (model 2).

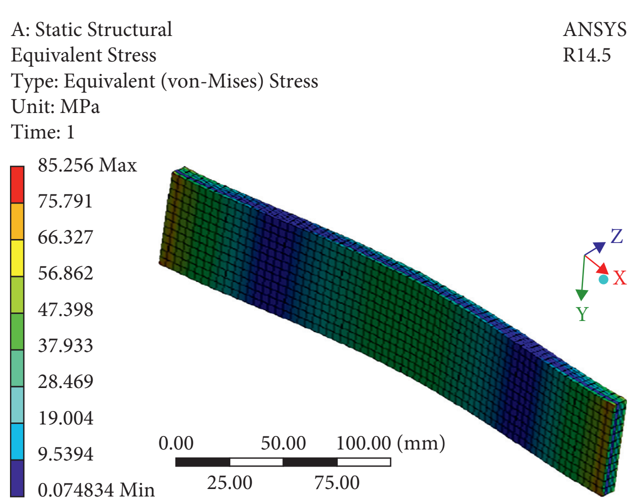


FIGURE 37: Equivalent stress—leather (model 2).

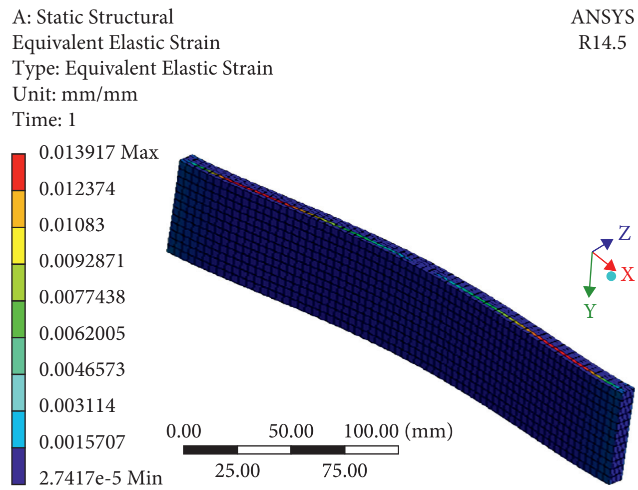


Figure 38: Equivalent strain—leather (model 2).

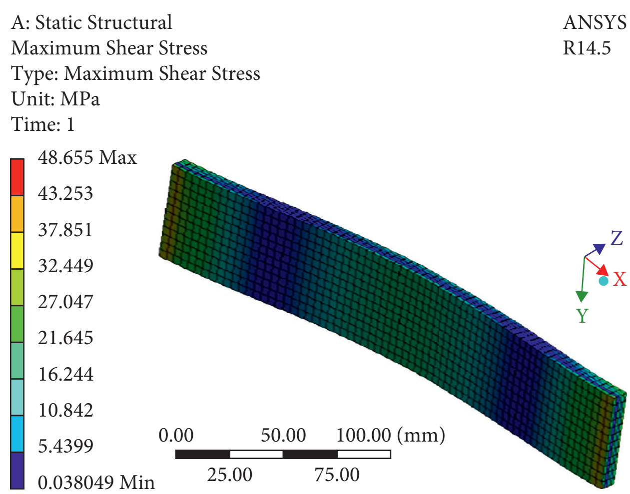


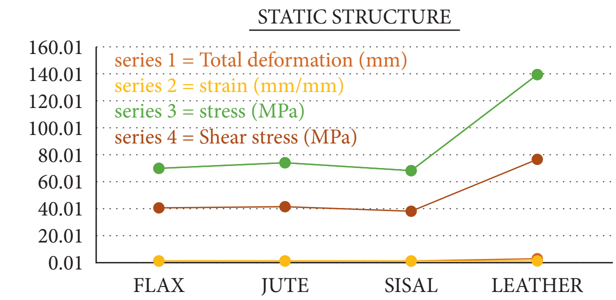
Figure 39: Max shear stress—leather (model 2).

Table 7: Model 1.

No.	Material	Total deformation (mm)	Equivalent elastic strain (mm/mm)	Equivalent stress (MPa)	Shear stress (MPa)
1	Flax	1.026	0.001735	70.03	40.231
2	Jute	1.2637	0.002116	74.088	41.259
3	Sisal	1.1615	0.001945	68.09	38.178
4	Leather	2.7712	0.01941	138.78	76.427

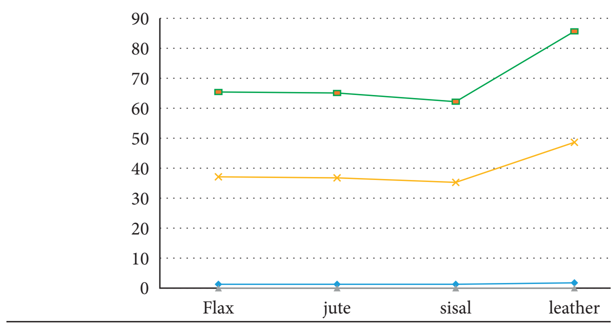
Table 8: Model 2.

No.	Material	Total deformation (mm)	Equivalent elastic strain (mm/mm)	Equivalent stress (MPa)	Shear stress (MPa)
1	Flax	0.87783	0.00150	65.065	36.951
2	Jute	0.99287	0.0018347	64.747	36.771
3	Sisal	0.89874	0.0016171	62.064	35.254
4	Leather	1.6152	0.01391	85.256	48.655



	FLAX	JUTE	SISAL	LEATHER
Series1	1.026	1.2637	1.1615	2.7712
Series2	0.001735	0.002116	0.001945	0.01941
Series3	70.03	74.088	68.09	138.78
Series4	40.231	41.259	38.178	76.427

FIGURE 40: Graphical representation of model 1 results.



	Flax	jute	sisal	leather
total deformation	0.87783	0.99287	0.89874	1.6152
equivalent stress	65.065	64.747	62.064	85.256
equivalent strain	0.0015	0.0018347	0.0016171	0.01391
max shear stress	36.951	36.771	35.254	48.655

FIGURE 41: Graphical representation of model 2 results.

7. Conclusion

The results from the analysis are obtained in terms of deformation, tension, and strain for the composite beam. The tests are compared, and the most suitable fibre with the best overall characteristics is found. The ANSYS results show that flax and sisal have better mechanical properties compared to jute and leather. Leather is deemed to be unsuitable for door panels because of its high deformation and induced stresses. Based on the characteristics of deformation, flax is the best material, but sisal, on the other hand, has the lowest stresses. Hence, flax can be used for the production of door panels of the automobile.

This project is successful in the execution of design and analysis of natural fibres. The material study and analysis dictate the suitability of natural fibres in the automotive sector. The analysis results show that natural fibres can be used as an alternative to other high-strength synthetic fibre materials. The natural fibres are found to be safe and suitable for use in the automotive industry.

The natural fibre composite industry is a promising field whose continuous growth is inevitable. With the regulations made by the EU for the emission and recycling of waste, the natural fibre used in the automotive industry is picking up the pace. With the growing concerns over the environmental protection and sustainable development, natural fibres are promising resources which can be utilized in a variety of industries to promote environmental awareness.

There is a significant lack of research on the field of natural fibre composite materials. Properties of various types of natural fibre having different types of alignments are difficult to predict, and hence research studies are needed to find out the behavior of various natural fibres. There is a need to accurately address the moisture and porosity present in natural fibres. Research studies can be carried out to determine the effect of moisture on natural fibre materials [33–35].

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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