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Analytical Simulation of Biocomposite Materials for Toyota Avanza Vehicle Cabin Lamp Light Covers Utilising Pandanus Tectorius Fibres with Epoxy Matrix as a Manufacturing Substitute to Cut Down on Plastic Waste

Kholis Nur Faizin[1*], Fredy Susanto[2], M. Shafwallah Al. Aziz[3], M. Chabib Nur Amin[4]
Politeknik Negeri Madiun
Corresponding Author: Kholis Nur Faizin kholis@pnm.ac.id

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A B S T R A C T

Biocomposites, made from an epoxy matrix and pandan fibre, offer a biodegradable alternative to plastic. Fabricated through manual layer lay-up, the material underwent stress propagation analysis using SolidWorks simulation and automotive testing. Results indicate that failure occurs in pure tension when stress exceeds 60% of the flexural strength (1.2 MPa) due to longitudinal fibre rupture. With a Young's modulus of 2×10^{10} N/m², tensile strength of 13.6 MPa, and Poisson's ratio of 0.31, the material exhibited safe performance under loads nearly four times its capacity. The factor of safety, while as low as 0.5 in critical areas, confirms t.

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INTRODUCTION

Plastic consumption has to be curbed right away since it harms the environment and costs money. Because plastic burns to release harmful gases, it contains dangerous particles. Because plastic is a lightweight material, it can help automobiles weigh less when employed. This lighter load may result in more fuel economy. While there are advantages to using plastic, it's vital to keep in mind that it contributes to pollution issues. Biocomposite is a substitute for biodegradable plastic.

Natural fibres are mixed with the matrix to create the biocomposite. Because of the many advantages of natural fibres and our continuous efforts to source superior natural fibres, we are able to develop products with less environmental impact.

Biocomposite materials have been the subject of numerous investigations. One of them makes use of natural fibre called pandan duri, also known as Adan fibre. This plant is widely distributed and does not present a health risk in Kresek Village, East Madiun. Pandanus tectorius leaf fibre is used to make biocomposite, according to research by Salahudin (2012). Because of its high mechanical qualities, resistance to different environmental factors, and affordable production costs, it is a good choice for interior car materials. Leaf material from Pandanus tecctorius is commonly utilised in handicrafts in Java. The leaves are easy to process and can be utilised as materials for crafts and furniture.

The findings of Dewi's research (2021) demonstrate that epoxy resin can boost the pandan leaf fibre utilised in this study's tensile strength, hardness, and abrasion resistance, making it a reinforcing material in the creation of composite materials. Epoxy resin is utilised to make the matrix. Epoxy resin gains 20% more tensile strength, 30% more hardness, and 40% more wear resistance. The purpose of this project is to build a light cover for the Toyota Avanza car cabin utilising a composite material made of Pandanus tectorius and reinforced with an epoxy matrix. The reason for this research that it is composed of sturdy mechanical materials and has impact-resistant chemical characteristics. high adhesive strength, solid shape, and chemical breakdown. This biocomposite material is produced using a moulding method that yields exact shapes and allows for the achievement of features that are otherwise impossible.

Aim and objectives

How can a replica of a Toyota Avanza car interior lamp cover be designed and computationally modelled utilising a pandanus tectorius composite material with an epoxy matrix?

Research purposes

Creating a pandanus tectorius composite material model using an epoxy matrix to imitate the light cover of a Toyota Avanza passenger compartment.

THEORETICAL REVIEW

Composite

Materials created by combining two or more materials are known as composite materials. The original (used) materials and these materials have differing mechanical characteristics. Reinforcement and filler (matrix) are the components of composite materials. The most popular kind of composite material on the market right now is fiber-reinforced composite. Although fibres are very elastic and have a high tensile strength, they cannot be employed in high temperatures. The matrix, on the other hand, is ductile and soft and forms bonds as it freezes. Hull and Clyne (1996) classified composites into three categories according to the type of matrix utilised, which are as follows:

a. Metal Matrix Composite (MMC)
   Metal Matrix Composite is a form of composite whose matrix is made of metal. Since 1996, this composite has been created. The Continuous Filament MMC type, which is utilised in the aviation industry, was the first composite that was investigated.
b. Ceramic Matrix Composite
   A kind of composite known as Ceramic Matrix Composite (CMC) has a ceramic matrix. Usually, oxide, carbide, and nitrite are utilised as reinforcement in CMC. One of CMC's manufacturing procedures is the Dimox method. In order to create a ceramic matrix around the filler area, a metal melt oxidation reaction is used in this method to make a composite.
c. Matrix of Polymers The most widely utilised matrix in the production of composite materials is composite polymer. Because of its reduced weight and increased durability, this matrix is utilised frequently. The two types of polymer matrices are thermosets and thermoplastics. While thermoplastics can be recycled, thermoset polymers cannot. Polypropylene (PP), Polystyrene (PS), Polyethylene (PE), and other thermoplastic polymers are frequently utilised.

Pandanus Tectorius

According to Kemeray's (2013) observations, the P. tectorius Park tree on Roswar Island has dark green, smooth-surfaced leaves that grow in an alternating spiral pattern. The leaves also bear thorns on both the left and right sides of the leaf. Anatomically, the leaves include a high density of epidermal cells per unit area and a comparatively large number of anomocytic stomata. The shrub Pandanus tectorius grows to a height of 3–7 meters and grows straight. This plant has multiple branches, and the base of the stem is surrounded by supporting roots. It has green leaves that are 4 cm wide and range in length from 90 to 150 cm. There is a pointed triangle at the leaf's tip. There are thorns on the lower layer of the mother leaf vein and the leaf margins. The complex, hanging fruit of the Pandanus tectorius plant is produced. The fruit is 2-6.5 cm in size and has a hard, stone-like feel. Pandanus tectorius, also referred to as the thorny pandan, is a coastal species. According to Mahlinda (2016), this pandan can withstand a wide range of coastal conditions, such as high salinity, constant wind gusts, peat, limestone, basalt, quartz sand, coral sand, and full sun. It prefers soil with a pH of 6 to 10.

Table 1. Pandanus Tectorius Taxonomy

Classification	**Term**
Kingdom	Plantae
Subkingdom	Tracheobionta
Superdivision	Spermatophyta
Division	Magnoliophyte
Class	Liliopsida
Subclass	Arecidae
Ordo	Pandanales
Family	Pandanaceae
Clan	Pandanus
Type	Pandanus tectorius

Epoxy Resin

Epoxy resin is a type of polymer that comes from the thermoset group. The molecular units that make up the dense network and the cross-linked network's length determine this resin's mechanical properties. Epoxy resin cannot melt, is temperature sensitive, is isotropic, and is not recyclable. Prior to solidifying, epoxy resin is a viscous liquid that resembles honey. Epoxy resin generally possesses the following characteristics:

a. Low viscosity
   Low viscosity liquids, such as epoxy resin and its hardener, allow for a small process system.
b. Minimal shrinking
   Low shrinkage of epoxy resin during hardening is a crucial characteristic.
c. High fracture strength
   The chemical formula of epoxy resin contains polar hydroxyl and ether groups. This resin works really well as an adhesive. The surface contact that forms between the liquid epoxy resin and the reinforcement is not disrupted during the hardening process since this resin has low shrinkage.
d. Superior mechanical qualities
   When compared to other resins, epoxy resin is more robust. This is because there has been little shrinkage, which reduces tensions that could erode the mechanical structure.

Table 2. Epoxy Properties

No.	Characteristic	information
1.	Density *(gr/cm^3)*	1,1-1,4
2.	Modulus Young (GPa)	3-6
3.	Poisson Ratio	0,38-0,40
4.	Tensile Strength	35-100

	(MPa)	
5.	Bending Strength (MPa)	100-200
6.	Maximum Strain(%)	1-6
7.	Coefficient of thermal expansion ($10^{-6}C^{-1}$)	60
8.	Thermal conductivity *(Wm^{-1} ^0C)*	0,1
9.	Maximum temperature (^0C)	50-300
10.	Depreciation (%)	1-2

Catalyst

A catalyst is a substance that can improve the speed of a chemical reaction without modifying or impacting the consequences of the reaction that occurs in the process. This implies that the catalyst will remain unchanged both during and following the reaction. The catalyst may change states during the reaction, but it will revert to its initial condition at the end of the catalytic cycle (Smith, Gerard V. & Ferenc Notheisz, 2000:2).

Cabin lamp cover

Another common term for an automobile's cabin light cover is a "ceiling light" or "sky light." This interior light, which is situated above the automobile's cabin, serves to illuminate the interior of the car at night or in dimly lit areas. This light's functions include lighting the cabin, assisting the driver and passengers in reading, navigating the space, and finding objects within the car. Typically, plastic is used to conceal the cabin light. The style and interior design of each car influence the design of this cover as well. Though sometimes there are fragile sections during the installation procedure, the strength and toughness are still inadequate. The construction has uneven mould feed in some places and overly thick in others. Insufficiently robust materials cannot bear the weight or force applied to them. Components may break, crack, or collapse as a result of this, causing structural failure. When a product is made using weaker materials, it could not be as sturdy or resistant to regular usage. This may lead to a product breaking down more quickly and needing to be fixed or replaced more frequently.

Hand lay up

Hand Lay Up is an open moulding technique used in the production of composites that works well for producing a wide range of composites on both a small and big scale. This method's benefit is that it uses a minimal amount of moulds to manufacture a large number of items at a low manufacturing volume. This approach is also highly ideal because it is very inexpensive, requires little processing, and can be manufactured in different sizes. This approach must be used in conjunction with the press moulding process to obtain a high fibre fraction. During the moulding process with this approach, the resin is in direct contact with the air until room temperature hardening takes place. In the meantime, a stopper must be used to regulate the volume fraction when employing the press moulding method. The most common applications for this technique are in composites with polyester and epoxy matrix types.

Simulation-Based Testing

Design planning and simulation are necessary in this research process to ensure that material manufacture proceeds smoothly and yields the best possible results. To determine the strength and quality of the material, simulation is required. SolidWorks 2020 is the program utilised.

SEM Test

The analysis technique known as scanning electron microscopy (SEM) is one used to describe the microstructure of materials. This technique provides high-resolution surface observations of the material using an electron beam. Among the many benefits of scanning electron microscopy (SEM) are its ability to create high-resolution images, see objects at extremely small sizes, observe objects at varying depths, and observe objects under a variety of situations. Research indicates that (Suardana, I.D.M. 2023). Concerning the Use of the SEM Method 14 (2), 1–10. An electron microscope bearing the JEOL JSM-6510LA brand is used for SEM testing. The types and brands of electron microscopes that are tested to gather information for the study findings in this title will be compared to this publication as a standard.

METHODOLOGY

Tools and Materials

Tools and materials are required for the manufacturing process to operate effectively, and their availability is required to make this study's application easier. The following list displays the equipment and supplies required for this study:

The foundation of the research process in this study is separated into four steps, which are as follows.

1. literature review
   The principles from earlier studies are furthered and scientifically investigated by literary studies. The exploration of sensor and control programming difficulties is the main goal of this literature study.
2. Composite manufacturing
3. Simulation Testing using Solidwork 2020 Software

Table 3. Tool list

No	Tool	Function
1	Mold	As a container used to print products

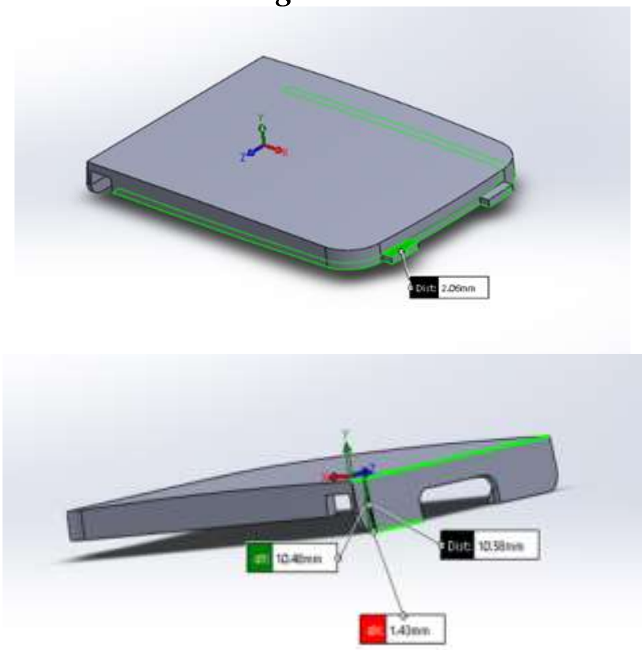
2	analytical scales	To weigh the mass of a material
3	Glass	As a cover for the mold
4	*Beakerglass*	Sebagai wadah yang digunakan untuk mengukur banyaknya volume bahan yang digunakan
5	Spatula	To move and level the matrix mixture
6	Sandpaper	To smooth out uneven products
7	Basin	For fiber soaking place
8	wire brush	To brush pandan leaves so the fiber can be taken
9	scissor	To cut the fiber after measurement.
10	ruler	To measure the length of the fiber to be used.
11	paintbrush	To smooth the mirror glaze when applied to the mold
12	glove	To protect hands from resin when mixing ingredients.
13	S*topwatch*	To calculate the time when carrying out the soaking process

The following materials will be used as study object material.
Table 4. Material list

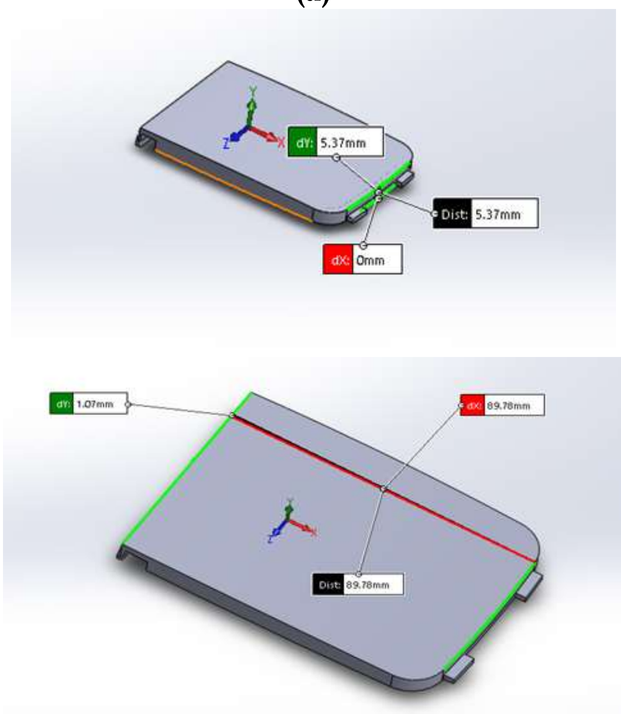
No	Materials	Function
1	*Pandanus tectorius* fiber	As a filler or reinforcement in the composite material created
	Resin *Epoxy*	As a matrix for binding fibres in composite materials
3	Catalyst	As a key component to quicken the resin's drying process
4	KOH 5%	To eliminate the lignin from the fibre of Pandanus tectorius
5	*Aquades*	to remove the fibre from the KOH mixture.
6	*Mirror Glaze*	to stop the sample from becoming

adhered to the mould.

Draught Concept and Data Gathering



(a)



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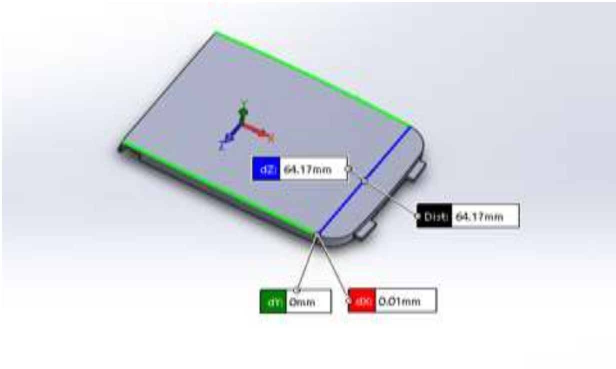

Fig. 1. Cover cabin lamp design

a) locker distance is 2, 06 mm, thickness is 1,47 mm
b) y axis distance is 5,7 mm, x axis distance is 89,78 mm
c) Z axis distance is 64,17 mm

RESULTS

This study was conducted in two stages: the design stage and the manufacturing stage. Figure 1 depicts the design of the cabin lamp cover. The design created with Solidwork software serves as the basis for the dimensions. The original mould images of the Avanza cabin lamp cover, figure 2.(a), (b), and (c), are contrasted visually and dimensionally with the design image below.

Fig. 2 a, b, c, the real biocomposite of tandanus tectorius cabin lamp cover

The process of getting fibre and basic ingredients, as well as the process of generating materials, are the numerous steps involved in creating lamp shades. Finding pandan leaves in the Madiun region, Indonesia, where there are still enough of them, is how get pandan fibre.

Lamp cover loading simulation results

The biocomposite model generated in Solidwork has the following mass results: 2.35782×10^{-5} kg, 1.2409×10^{-5} m^3, density of 1.9 kg/m^3, and weight of 0.000231066 N. Utilising Solidwork, the design outcomes offer a simulation of yield strength of 1.2×10^6 N/m^2 or 1.2 MPa, tensile strength of 1.36×10^7 N/m^2 or 13.6 MPa, and Young's modulus (Young's Modulus) of 2×10^{10} N/square meter.

According to Poisson's ratio of 0.31, the connection between stress and strain is determined by the material's stiffness. measurement of the amount of expansion or contraction a material experiences in a single direction in response to tension or vertical pressure. Mass or Density 1.9 kg/m^3 More mass is contained in a given volume at higher densities and vice versa. Similar to the modulus of elasticity (Young's modulus) in reaction to tensile or compressive stress, shear modulus 2×109 N/m^2 measures a material's stiffness in response to shear force.

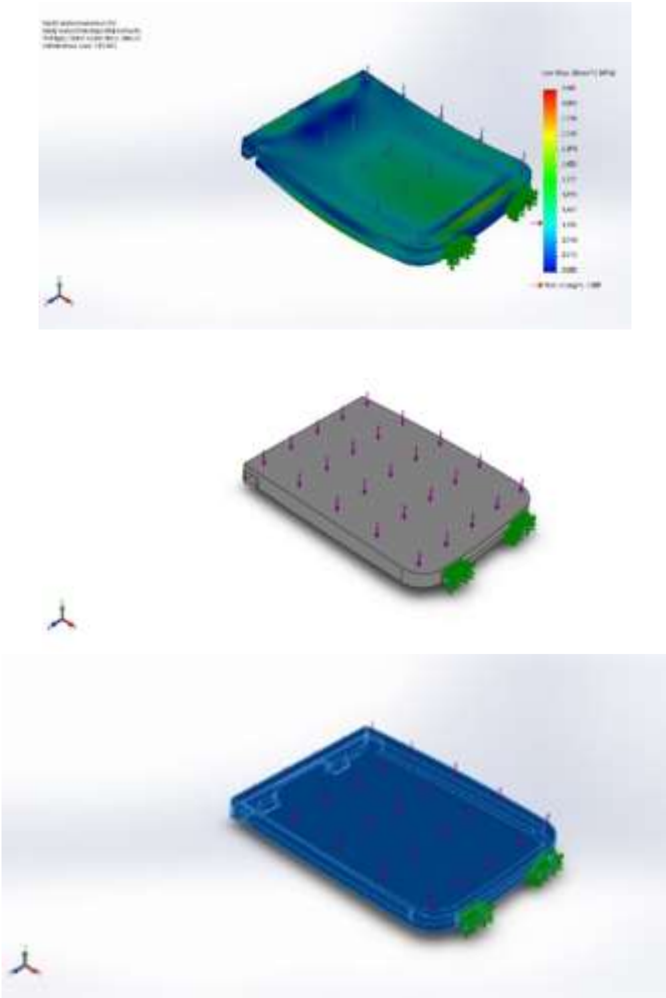

Fig. 3 The pressure exerted on the cabin light cover is equivalent to that of a human finger.

Figure 3 illustrates that force is a load that is applied to a structure or model. In a specific context, the load applied to a specific biocomposite model element is referred to as force. With a value of 20 N, this force is of the type "Apply normal force" and is applied to solid objects' surfaces (see to literature for details). A structure receives the application of a response force following the application of a compressive force. The response force for the reaction moment operating on the X axis is 0.235583 N, Y is 19.9949 N, and Z is -0.00130922 N when the structure is applied a compressive force. Next, 19.9963 N is the resultant result.

Vonmisses analysis

Figure 4 reckons that Von Mises stress is a tool used in structural analysis and materials engineering to assess the safety of a material or structure under a variety of loading scenarios. It does this by comparing the anticipated stress to a material's failure limit, such as its tensile or yield strength. Min: at Node 16247, 0.000 N/mm² (MPa); Max: at Node 1075, 4.461 N/mm² (MPa).

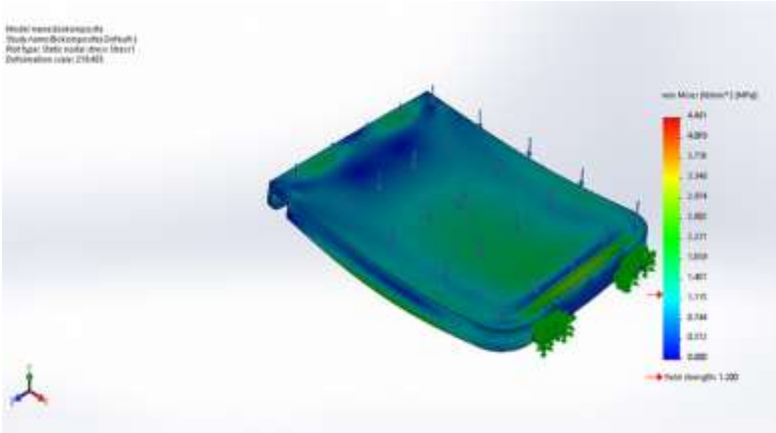

Fig. 4 Vonmisses Analysis

Displacement

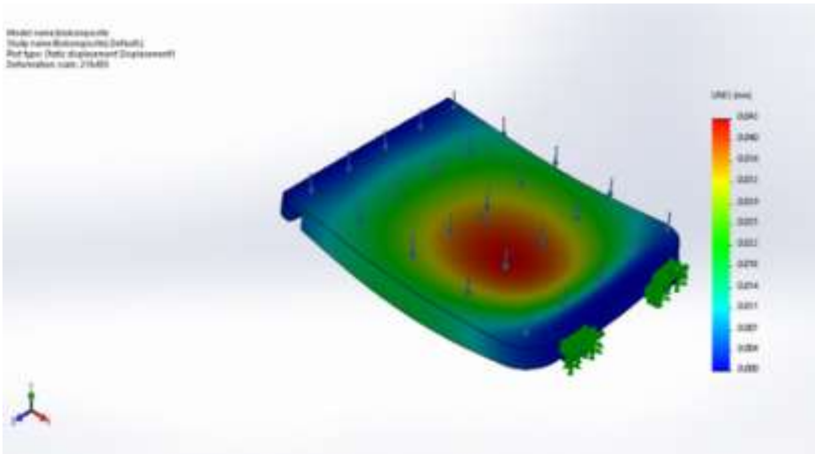

Fig. 5 Displacement Analysis

As a result, figure 5 reckons that Displacement In an analysis or simulation, enter the overall displacement or deformation of a structure or object. Maximum: 0.043 mm at Node 11178 and Minimum: 0.000 mm at Node 1. In actuality, stress-concentrating elements like tapers, notches, flanges, grooves, protrusions, etc. are frequently loaded into structural components and serve vital functions that cannot be eliminated. Abrupt alterations in these components lead to stress concentrations and impact the structure's overall functionality. Comparing the fatigue performance of specimens with rounded edges (low stress concentration) and sharp edges (high stress concentration) using finite element modelling. Stress concentration characteristics, including cavities, have a major influence on the beginning, progression, and stiffness deterioration of fatigue damage.

Strain

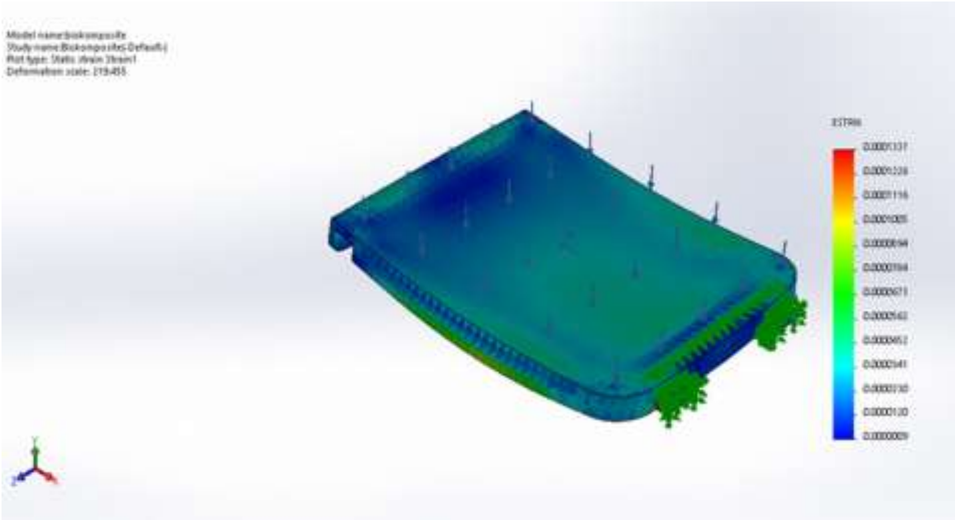

Fig. 6 Strain Analysis

The term "equivalent strain type" describes the kind of strain that is assessed in material engineering or structural analysis. Element 5038's min is 0.0000009, while element 5841's max is 0.0001337. Proven models were used in parametric investigations. Every model's flexural behaviour was looked at. When examining the impact of the lamp cover ratio, Figure 6 displays the deflection as a function of load on the flexural behaviour of the FE model. To support the lamp cover, it was molded using a thickness of 2 mm. The stiffness is greater for the Avanza cabin lamp cover has higher strength. However, the increase in stiffness does not correlate with the load. On the other hand, the graph shows the FE model load vs. mid-span deflection. Pandanus fiber reinforced plastic has increased flexural capacity. Failure theory is used to predict whether stress at a critical point in the specimen element will result in failure.

Safety Factor

To guarantee that the part or structure is strong enough. FoS minimum of 0.27 This shows that at some point in the structure, the applied load is almost four times more than the capacity of the material (because this location is at high danger of failure). Maximum FoS 5,403,626.50 shows that there is a significant margin of safety at some point in the structure where the material strength substantially exceeds the applied load.

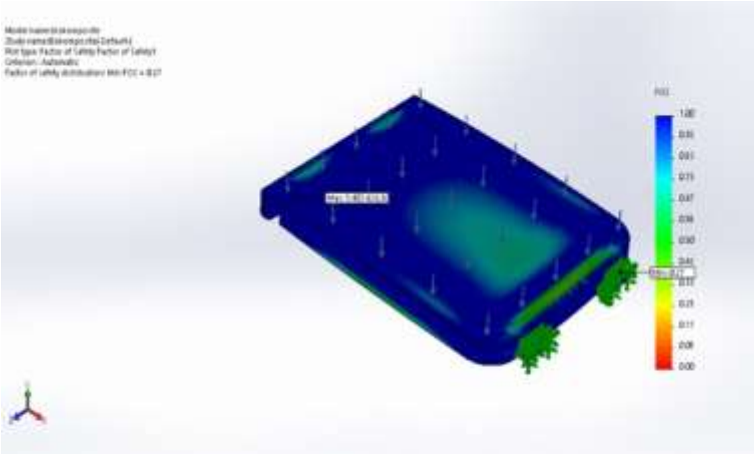

Fig. 7 Safety factor analysis

Scanning Electron microscope

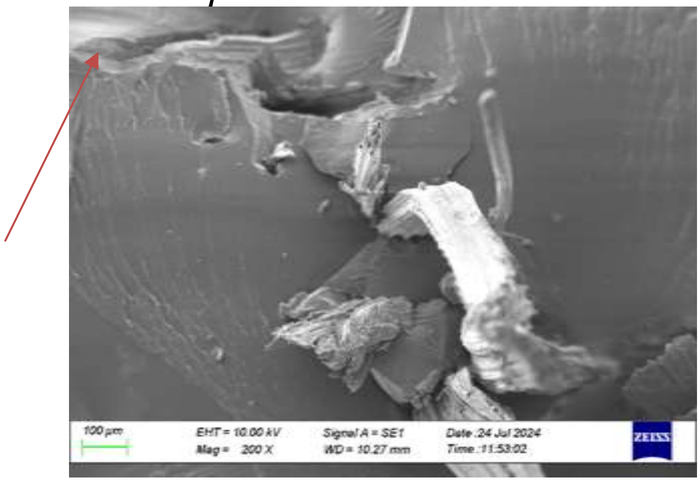

Fig. 8 200 micron SEM morphology

Figure 8 reckons the condition At 200 x micron magnification, a photo of the fracture on the cabin lamp cover specimen clearly demonstrates the location of the bond between the fibre and the matrix. The pull-out nature of the fibre fracture, along with its elongated contour, indicate the presence of strain and deformation in the fibre. A step-by-step fracture from the specimen's edge is seen in the matrix fracture, which is the beginning of a crack. Beginning with the opening, the fracture moves little by little. Additionally, there are indications of loose cracks from the fibres on the matrix, suggesting a strong link between the fibres and matrix.

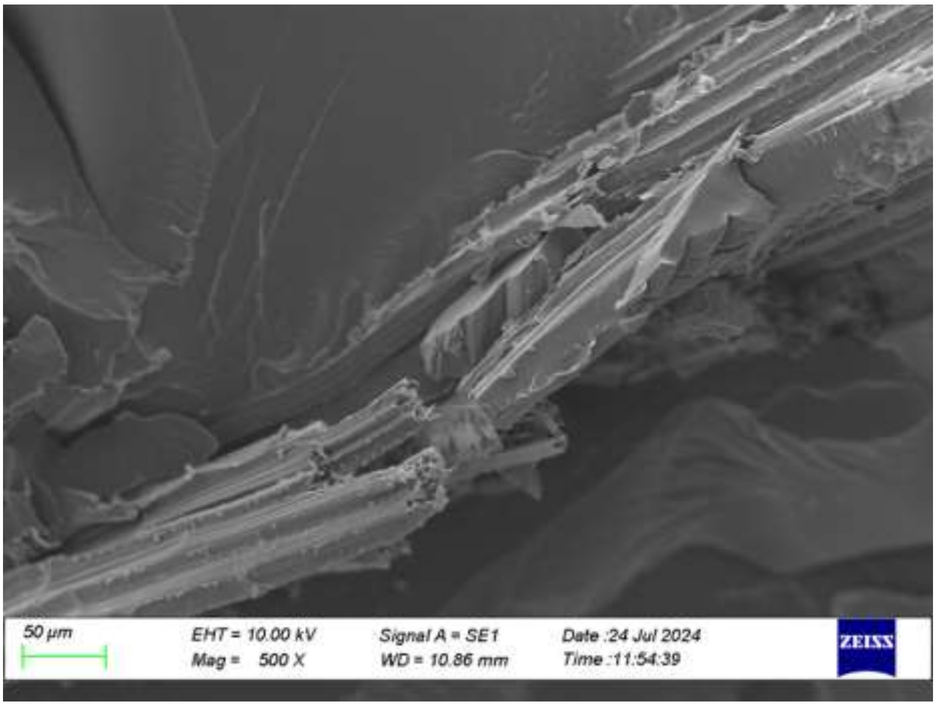

Fig. 9 500 micron SEM morphology

The initial surface conditions when microcracks occur are seen in Figure 9. It is evident that there is a dispersed impact on the test specimen's surface. This is because, in contrast to what often happens along the crack propagation, damage occurs at each point of the test specimen according to the local stress distribution even if it happens randomly because the composite laminate of the cabin cover light is inhomogeneous and anisotropic. characterised by metal, this state suggests that fibre composite material deterioration can happen alone or in conjunction with matrix cracks, fibre rupture, debonding, and delamination. The outermost layer of the specimen is made up of elongated fibres. The matrix attracts more stress than the fibres do due of its greater elongation, which causes surface cracks. This is corroborated by closely examining the surface roughness that was photographed under an optical microscope and subsequently subjected to image processing software analysis, as illustrated in the following figure. viscoelastic deformation of the resin occurs, but also the growth of micro cracks, supporting the redistribution of stress that causes fractures to propagate in the transverse direction to a specific critical level when the stress hits capacity, and the final collapse of the specimen occurs.

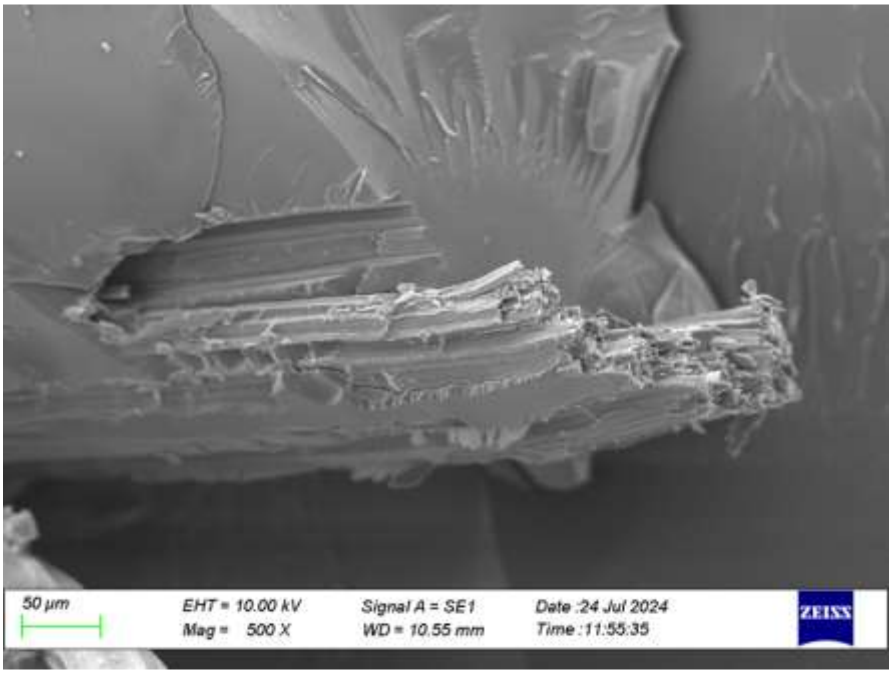

Fig. 10 500 micron SEM morphology on crack propagation

Figure 10 shows a plot of the applied stress level's impact on weariness. The fatigue life at extremely low loads is predicted by the SEM visual model, which also accurately depicts the experimental behaviour. This data confirms a recent discovery that the fatigue life rises with decreasing applied stress level. In other words, the rate of increase in fatigue life of composites made from pandan tectorius is higher than that of other fiber-based composites. The study's results show that the fatigue life of glass/vinyl ester materials increases significantly with a slight decrease in stress level.

DISCUSSION

The present study delves into the process of obtaining micro analysis and stress simulation of composite materials that could be substituted for the Avanza cabin lamp covers. The discussion's outcomes will be used to produce robust, fully biodegradable, and ecologically friendly products for commercialisation.

CONCLUSIONS AND RECOMMENDATIONS

1. The failure behaviour of the composite is influenced by the stress intensity. When the specimen was subjected to a stress of 60% of the flexural strength or less than its yield stress, or 1.2×10^6 N / m² or 1.2 MPa, it failed in pure tension due to longitudinal fibre rupture at a given stress of flexural strength or more than 20 Newtons.
2. The SEM visual analitis model used in this study has been able to mitigate the effects of tegangan rasio, maximum tegangan that is provided, frequency, and material properties that may accurately determine the colour of a cover photo in an opaque manner, even in high-quality photocopies. The maximum Tarik strength is $1{,}36 \times 10^7$ N/m², or 13,6 MPa, whereas the Young modulus is 2×10^{10} N/meter persegi. Strong substance

that establishes a connection between regangan and tegangan (ratio Poisson 0,31).

3. The calculated safety factor is relatively safe after being tested with a load that is applied approximately eight times more frequently than the material's capacity (since this material has a small chance of malfunctioning).FoS Maksimum 5.403.626,50, or 0.5% below level 1, indicates that in a few structural areas, there is a noticeable biru warning in the simulation.

FURTHER STUDY

Deep insight into the application of biocomposites for transportation is anticipated from this research. The findings can be utilised to create automobile replacement parts that are more affordable, ecologically friendly, and energy-efficient. Furthermore, the foundation for the creation of more sophisticated and effective material technologies in the future can be laid by this research.

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