FINITE ELEMENT ANALYSIS OF ENSET FIBER COMPOSITE MATERIAL

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ABSTRACT: Enset fiber, a naturally abundant and low-cost material, offers promising potential as a sustainable reinforcement in composite applications. This study presents a comparative evaluation of Enset fiber reinforced composite (EFRC) and glass fiber reinforced composite (GFRC) under identical fiber orientation, volume fraction, and loading conditions using ANSYS Composite Prepost (ACP) and ANSYS Workbench. The composites were analysed for their flexural, tensile, impact, and modal responses. Simulation results reveal that EFRC develops lower stress magnitudes to resist the applied loads, indicating better load-bearing efficiency. Specifically, EFRC develops a tensile stress of 4.7098 MPa, while GFRC develops 5.0518 MPa under the same loading conditions. In the flexural analysis, the stress in EFRC is 32.289 MPa, whereas GFRC shows a higher value of 43.893 MPa. Similarly, in the impact test, EFRC records a stress of 11,736 MPa, compared to 26,462 MPa for GFRC. Moreover, modal analysis shows that EFRC has lower natural frequencies in all vibration modes, reflecting favourable damping characteristics and reduced stiffness. These findings indicate that EFRC performs more efficiently by developing less internal stress under equivalent loading, which can be advantageous in structural applications requiring energy absorption and vibration control. Considering its mechanical performance, environmental benefits, and cost-effectiveness, Enset fiber presents a viable alternative to synthetic fibers like glass in the production of lightweight and sustainable composite materials. Further experimental studies focusing on durability, moisture resistance, and fiber-matrix interface optimization are recommended to support the broader implementation of Enset fiber composites in real-world engineering applications.

Keywords: Enset fiber reinforced composite, Mechanical performance, ANSYS simulation, Sustainable materials

ENSET ELYAFLI KOMPOZİT MALZEMENİN SONLU ELEMANLAR ANALİZİ

ÖZ: Doğal olarak bol bulunan ve düşük maliyetli bir malzeme olan Enset lifi, kompozit uygulamalarda sürdürülebilir bir takviye malzemesi olarak önemli bir potansiyel sunmaktadır. Bu çalışma, Enset lifi takviyeli kompozit (EFRC) ile cam lifi takviyeli kompozitin (GFRC) aynı lif yönelimi, hacim oranı ve yükleme koşulları altında ANSYS Kompozite Prepost (ACP) ve ANSYS Workbench yazılımları kullanılarak karşılaştırmalı değerlendirmesini sunmaktadır. Kompozitler eğilme, çekme, darbe ve modal tepkileri açısından analiz edilmiştir. Simülasyon sonuçları, EFRC'nin uygulanan yükleri karşılamak için daha düşük gerilmeler geliştirdiğini ve bunun da daha iyi yük taşıma verimliliğine işaret ettiğini göstermektedir. Özellikle, aynı yükleme koşulları altında EFRC 4.7098 MPa çekme gerilmesi geliştirirken, GFRC 5.0518 MPa değerine ulaşmaktadır. Eğilme analizinde EFRC'de oluşan maksimum gerilme 32.289 MPa iken, GFRC bu değeri 43.893 MPa olarak göstermektedir. Benzer şekilde, darbe testinde EFRC 11.736 MPa'lık bir gerilme üretirken, GFRC 26.462 MPa seviyesine ulaşmaktadır. Ayrıca, modal analiz sonuçları EFRC'nin tüm titreşim modlarında daha düşük doğal frekanslara sahip olduğunu, bunun da daha iyi sönümleme özellikleri ve daha düşük rijitlik anlamına geldiğini ortaya koymaktadır. Bu bulgular, EFRC'nin eşdeğer yükler altında daha düşük iç gerilmeler geliştirerek daha verimli bir mekanik performans sergilediğini ve bu durumun enerji sönümleme ve titreşim kontrolü gerektiren yapısal uygulamalarda avantaj sağlayabileceğini göstermektedir. Mekanik performansı, çevresel faydaları ve ekonomik oluşu göz önüne alındığında, Enset lifi, cam gibi sentetik liflere sürdürülebilir bir alternatif olarak hafif kompozit malzeme üretiminde önemli bir adaydır. Dayanıklılık, nem direnci ve lif-matris ara yüzey etkileşimi gibi konularda yapılacak ilave deneysel çalışmalar, Enset lifi kompozitlerinin gerçek mühendislik uygulamalarında daha yaygın kullanılmasına katkı sağlayacaktır.

Anahtar Kelimeler: Enset lifi takviyeli kompozit, Mekanik performans, ANSYS simülasyonu, Sürdürülebilir malzemeler

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1. INTRODUCTION

Scientists and researchers are working to find more environmentally friendly materials these days in an effort to lessen our reliance on synthetic fibers and their derivatives [1-2]. Since sustainability is fast becoming a global priority across many industries, the composites industry is moving closer to manufacturing green composites. Composites made of natural fibers have gained attention from significant industries like building, automotive manufacturing, and packaging [3]. Because of its significant mechanical qualities, ease of availability, low cost, and partial or complete biodegradability, false banana fiber-reinforced composites are an interesting subject for further research [4]. Sustainable lightweight materials and composite constructions can be made from natural fibers derived from agricultural waste [5]. Because of their special qualities and versatility, composite materials are being utilized in applications more and more.

The use of natural fibers allows for the reduction of environmental effect because of their naturally renewable nature and the lower energy required for their manufacturing and processing (4 MJ/kg of natural fiber compared to 30 MJ/kg of glass fiber or 130 MJ/kg of carbon fiber) [6]. Although the potential of these natural fiber composite materials is believed to be just 10%, their application in the building and automotive industries is growing [7]. Compared to conventional materials such as steel and aluminium, natural fiber-reinforced polymer matrix composites offer superior specific performance relative to cost, making them an attractive option for structural applications [8][9].

Enset fibers are derived from the pseudostems and leaves of the plant Enset ventricosum, which is also referred to as an Enset or false banana [9]. Because of their versatility in creating fabrics, ropes, baskets, and other items. However, only a small portion of the material is used in these applications, and a significant amount of these wastes remain unusable [10]. These fibers have been employed historically in many places, especially in East Africa. The Enset (Enset ventricosum) plant grows wild in numerous countries and is also found in sub-Saharan Africa. It is the principal crop of an indigenous African system that is sustainable and resistant to drought [11]. In addition, it is utilized as a decorative, for building materials, to produce fiber, as animal feed, and for medical purposes.

Plant fiber called Enset fiber is taken from the plant's pseudostem and leaf sections. Fibers from the plant's fallen-sheath sections and leaf stalks may be extracted and used since it is sufficiently robust and flexible for a variety of uses [12]. The Enset plant which is depicted in Figure 1 below, is the source of the Enset fibers.

Batu and Lemu used varying Poisson ratios to examine the impact of this ratio on the mechanical behavior of the composites and came to the conclusion that the FEA results are unaffected by variations in the Poisson's ratio of the fibers [14]. Therefore, it was found that the value of the poison's ratio had no discernible impact on the computed findings when the micromechanics model was applied. The Poisson ratios v = 0.175 for false banana fibers, 0.35 for epoxy resin, and 0.22 for glass fibers were applied in this analysis.

Using Design-Expert software, Balcha D et al. analyzed Enset fiber from ten different breeds and performed a tensile test on the material which is presented under Figure 2. Additionally, the effects of the length of the 5% Na-OH surface treatment and the position of the fibers along and across the plant pseudostem were examined. According to the test results, there is no significant difference in rupture stress between the fibers from ten different Enset breeds. Nonetheless, there is a notable variance in strain across the fibers from ten Enset breeds, with Dego fiber exhibiting the highest strain prior to failure. After a full day of treatment, surface-treated fibers had increased elastic modulus and rupture strength. There was negligible variation in elastic modulus across and along the stem. Enset fiber results in the following: rupture stress, elastic modulus and strain: 360.11 ± 181.86 MPa, 12.80 ± 6.85 GPa, and 0.04 ± 0.02 mm/mm, respectively. These findings demonstrate that Enset fiber can be utilized as an alternative to other natural fibers in composite applications, and it is equivalent to fibers from abaca, bananas, and sisals [5].

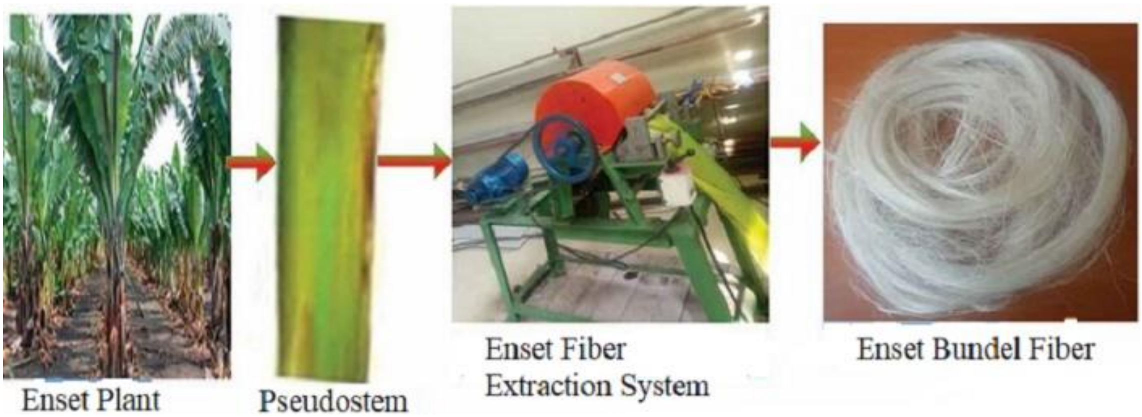


Figure 1. Extraction of Enset bundle fibers from Enset plant Pseudostem [13].

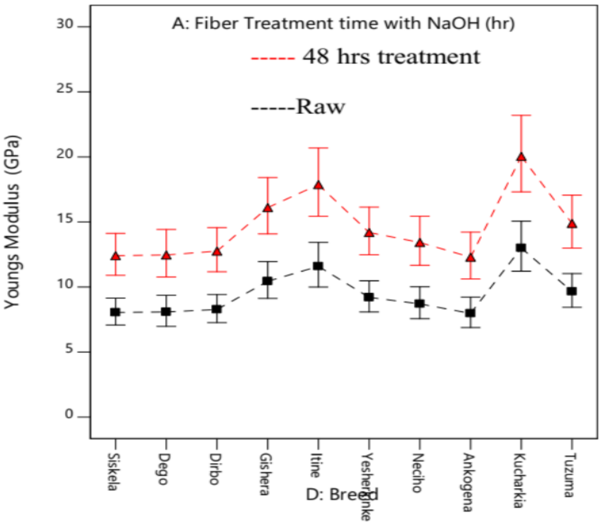


Figure 2. Young's Modulus against treatment and breed Rupture [5]

Abdela A. et al. [15] used digital image correlation and optimal experiment design to demonstrate the properties of a single Enset fiber under strain. They made use of an Enset fiber sample that was 10 cm long and was adhered to a sand paper casing using TIPIX to create speckle formation. A pyrometer is used to measure fiber density in order to estimate cross sectional area. After that, a predetermined load has been introduced gradually till failure. Additionally, pictures are captured with the lime camera during the elongation. Every point's response is combined with analog data to create a correlation, which is then examined further to ascertain the fiber's characteristics utilizing correlated solution software (Vic2D). The outcome has also been supported by the use of the bundle test. According to their research, the fiber has the following characteristics: density: 1.4 g/cm3, strength: 67 MPa–923 MPa, mean strength: 647 MPa, and E modulus: 12 MPa–69 MPa, mean E modulus: 46 MPa. They came to the conclusion that the manual fiber extraction process used to extract the pulp is the main cause of the lowest value in the range [15]. Assuming that the fiber is extracted by machines rather than by hand, the maximum values are used for analysis in this research.

Composites with various forms of reinforcement can reduce weight by 15% to 40% in addition to providing other desirable properties for the industrial application such as automotive sector, like corrosion resistance, low thermal conductivity, high specific strength, and design flexibility[17] [17]. In recent decades, there has been an increasing need for the global automakers have sparked a weight-saving revolution because to increased fuel economy and decreased environmental effect [17]. In the meantime, the cost goal control and simple recovery elevate the standard even higher for automobile choice of materials and structural layout. As a result, the replacement of traditional automobile materials like cast iron and it is shown that steel combined with cutting-edge lightweight materials is a successful tactic producing a significant decrease in the just created automobiles [18].

The study of Enset fiber-reinforced cement composites has increased recently. According to Abuye and Molla's [19] investigation, combining 20% of Enset fiber with gypsum produced the best results. This increased the gypsum resin's water absorption and enhanced its tensile, flexural, and impact capabilities. In order to enhance the mechanical and physical qualities of natural fiber-reinforced composites, false banana fibers may be a viable option. To increase the mechanical and physical qualities, an attempt has been made to create the composite material utilizing Enset fiber and gypsum resin [20]. The mechanical performance of aligned Enset ventricosum fiber reinforced cementations composites, and in particular the influence of the fiber volume fraction on the composite's flexural performance, were evaluated by Dejene and Geletaw in relation to the false banana fiber's suitability as a reinforcement in cement and polymer-based composites. As the fiber content of the Enset ventricosum fiber-reinforced specimens grew, so did their post-cracking stiffness, toughness, and flexural strength. Their findings hold promise for the creation of a green composite based on Enset-ventricosum fiber for construction sector [4].

Temesgen et al. [23] examined the mechanical characteristics of a green composite made of bioresin and Enset woven cloth, showing notable increases in tensile strength. Feyissa and Gudayu [24] optimised processing parameters to increase tensile strength in their biopolymer-reinforced Enset fibre green composite packaging films made from starch. Pectinase enzyme treatment considerably enhanced fiber-matrix interaction, according to Abraha's [25] analysis of the effects of various surface treatments on Enset fiber-reinforced polylactic acid composites. The potential of integrating natural fibres for improved performance was further highlighted by research by Abdela et al. [16] which assessed the impact of hybridisation and treatment on the mechanical properties of Enset and Sisal hybrid composites.

Understanding the mechanical behaviours of natural fibre composites and improving their applications have been greatly aided by recent developments in finite element modelling (FEM). For example, Biniyam Ayele Abebe et al.[26] study on Enset fiber-reinforced composite vehicle bodies uses ANSYS ACP to simulate crash scenarios and compare performance with glass fiber composites. The results show that Enset composites offer better energy absorption and lower stress transmission during high-speed impacts (120–200 m/s), with a notable reduction in stress from 19.866 GPa (glass fiber) to 6.707 GPa (Enset fiber) at 120 m/s. This highlights Enset fiber's potential as a sustainable, safer alternative in automotive applications. similarliy, Arfan et al. [27] used ANSYS to perform three-dimensional finite element analysis on composite panels reinforced with coconut inflorescence stem fibre that were exposed to static loading. The investigation improved knowledge of the material's fracture behaviour by shedding light on issues such as stress intensity and crack growth beginning.

Enset fiber reinforced composite material analysis still has a gap, even after a lot of research comparing the mechanical performance of different natural fibers to synthetic fibers was conducted. Tensile, flexural, impact, and vibration properties of Enset fiber reinforced composites have not received much attention in previous research. The objective of this study is to perform a comprehensive analysis of these mechanical characteristics for Enset fiber and to compare them with those of glass fiber reinforced composites. Enset fiber composites' tensile strength, flexural strength, impact resistance, and vibration damping characteristics are evaluated in this study using ANSYS.

2. FINITE ELEMENT ANALYSIS

For the finite element analysis of the false banana (Enset) composite material that is applicable for the construction and industrial sectors instead of the glass fiber composite material need to be analysed on the ANSYS software suite includes a module called ANSYS Composite Prepost (ACP) that is especially made for composite material analysis. The ACP model was done by considering the arrangement of the fiber is considered to be 0^0 / 90^0 woven fabric for both Enset and existing glass fiber composite material which is shown in Figure 3.

For the finite element analysis of the thickness to be considered as 4mm for the composite materials, and there was four layers with thickness of 1mm, that means 0.5mm fiber ply and 0.5mm thickness of epoxy risen ply was modeled. For all forms of analysis performed on this paper, the two-dimensional plate model's overall dimensions are taken into consideration as 300 mm in length and 300 mm in width.

2.1 Methodology

In this paper, composite materials reinforced with Enset fiber are thoroughly studied and simulated. As shown in Figure 4 beginning with a review of the literature to find out more about the mechanical and physical properties of Enset fiber as well as its material characteristics had been performed. A simple rectangular surface geometric model was done for modelling a composite on ACP. The composite structure was designed and analysed using this model in ANSYS Composite Pre-Post (ACP). To assess the composite model's performance under various loading scenarios, a number of simulations in ANSYS Workbench had been performed. In the last stage, the simulation results are compared to evaluate the performance and possible uses of the Enset fiber composite, emphasizing its benefits and drawbacks in comparison to glass fiber composite material.

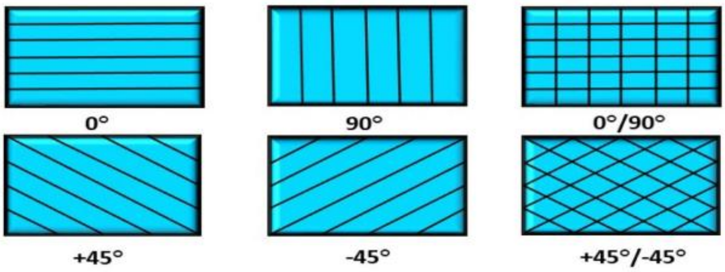


Figure 3. Orientation of fiber [21]

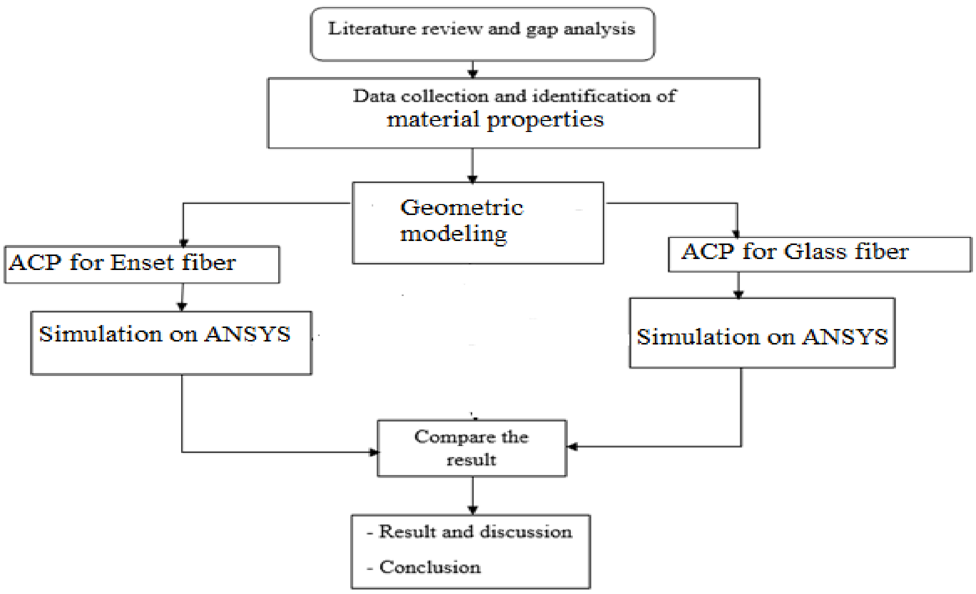


Figure 4. General work flow of the research

2.2.1. Material setup

The material properties of Enset fiber, epoxy resin, and glass fiber were modelled into the ANSYS engineering material model. Material properties including Young's modulus, yield stress, and Poisson's ratio and also density of each material was obtained from the literature and are presented under Table 1 and in part one of this paper. These properties were defined to ensure accurate simulation of the mechanical behaviours of the composite structure. Proper assignment of these values is essential for reliable stress and deformation analysis in ANSYS.

2.2.2. Geometrical modelling

For finite element analysis the specimen is model as a flat plate as shown in which dimension is assumed as 300mm width and 300mm length. After the layers of the false banana and epoxy risen is to be 4mm thick.

2.2.3. Create fabric

The Enset fiber was arranged as the stiffener of the epoxy resin in 90-degree arrangement with in the thickness of 0.5 mm and the woven fabrics. The orientation of the direction of the Enset fiber is 90 and the matrix is 0-degree arrangement.

2.2.4. Modeling of the ply and the composite

The epoxy risen and the fiber were converted layers of 1 mm thickness and then later on the four layers 2 layers of fiber and 2 layers of epoxy risen are modelled as shown in Figure 5 and then it was imported to the ANSYS structural analysis to analyze the flexural strength according to the vonmises stress, total deformation and total strain, as well as the tensile and impact analysis done according to the vonmises stress, total deformation and total strain.

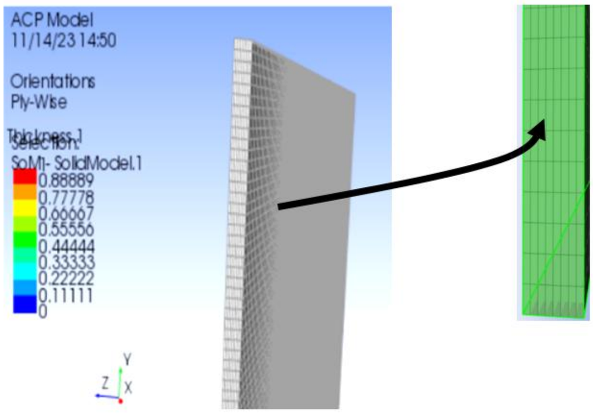


Figure 5. 3D modelling of composite plate

2.2.5 Mesh sensitivity analysis

Mesh convergence analysis in ANSYS evaluated the interaction between von Mises stress and mesh size, as seen in *Figure 6*. Larger mesh sizes initially displayed notable differences in stress levels, suggesting a lack of detail. These differences diminished as the mesh was adjusted. The graph of von Mises stress against mesh size smoothed at a mesh size of 0.5 mm, indicating convergence of the solution. At this mesh size, the von Mises stress was 4.7 MPa, suggesting that additional mesh refinement would not materially change the outcome. This indicates that the stress distribution in the model may be accurately and effectively represented with a 0.5 mm mesh size.

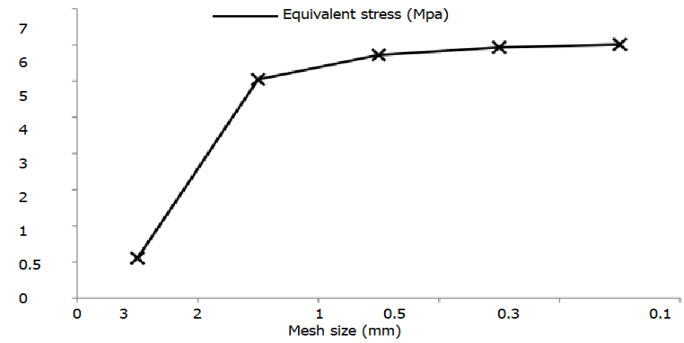


Figure 6. Mesh convergence

2.2.6. Boundary conditions and load applications

- Boundary conditions of tensile and flexural analysis

For both flexural and tensile strength analyses, as given in Figure 7 a force of 1.5 kN is applied. In the flexural strength analysis, the composite plate is modeled as a fixed–fixed beam, with the load applied at the mid-span. For the tensile strength analysis, the plate is modeled as a bar subjected to a uniaxial tensile load of 1.5 kN at one end, while the opposite end is fully constrained.

- Boundary conditions of crash and Modal analysis

For the impact and modal analysis, a 300 mm × 300 mm flat composite model reinforced with Enset and glass fibers is utilized, with all edges fully constrained as presented under Figure 8. The impact is simulated by a high-velocity bullet striking the centre of the composite plate at a speed of 900 m/s. In the case of the modal analysis, no external load is applied, as the objective is to determine the natural frequencies and corresponding mode shapes under free vibration conditions. For this simulation, the rectangular plate is modeled with all edges simply supported.

Table 1. Mechanical properties of materials used in the simulations [16][29][30]

Material Type	Density (kg/m^3)	Modulus of Elasticity (MPa)	Poisson's Ratio	Yield Stres (MPa)
Enset fiber	1400	19650	0.2	600
Glass fiber	2580	73000	0.25	3445
Epoxy resin	1350	90	0.35	50

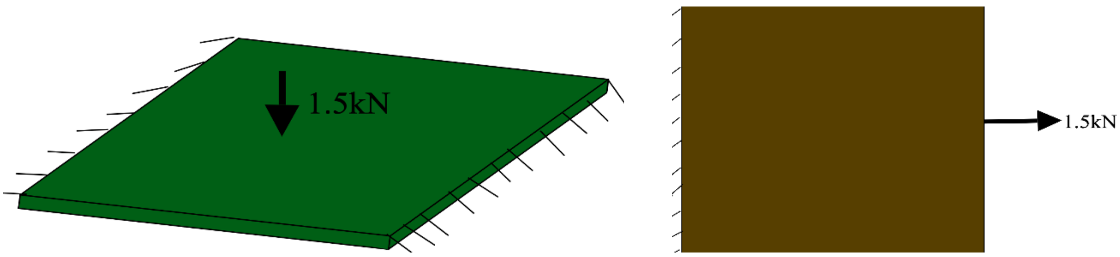


Figure 7. Boundary conditions of tensile flexural (a) and tensile (b) analysis

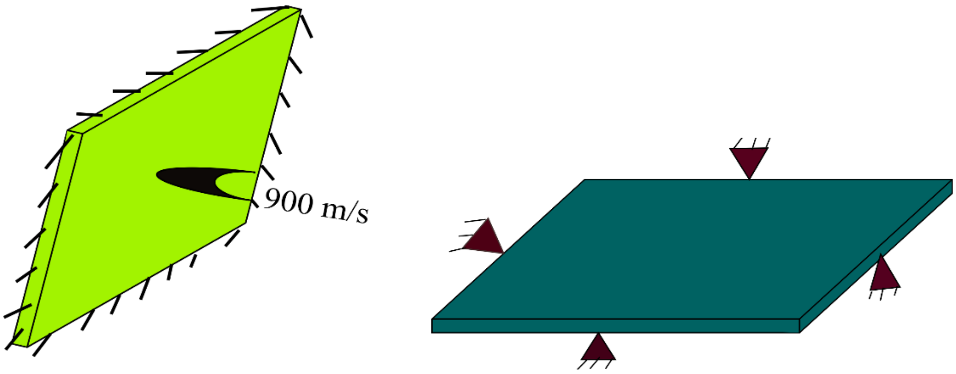


Figure 8. Boundary conditions of crash (a) and Modal (b) analysis

3. RESULT AND DISCUSSION

3.1. Flexural analysis

The total deformation of the epoxy risen Enset fiber reinforced plate in comparison with the epoxy risen glass fiber reinforced plate depicted in the Figure 9. The maximum deformation of the epoxy risen Enset fiber reinforced plate is 2.525 mm and the maximum total deformation of epoxy risen glass fiber reinforced plate is 0.9276mm. From the analysis's outcome the two distinct materials have different stiffness and elasticity values, which affect how they deform when subjected to the same load. When a bending load are applied to an Enset fiber reinforced material, this material experiences more substantial deformations. Comparatively speaking to a glass fiber-reinforced composite material, the Enset fiber-reinforced composite material can deform more under the same load because it may be less stiff or more elastic. That mean the composite material reinforced with Enset fiber is more flexible or pliable.

According to the analysis result for equivalent strain depicted in Figure 10 reinforced material using Enset fiber has greater ductility or flexibility of the material which is indicated by its larger strain values. Before failing, ductile materials can experience significant plastic deformation. This could be advantageous in situations when a material must absorb energy through deformation, like in designs intended to withstand impacts.

The epoxy-risen Enset fiber reinforced plate's equivalent stress for flexural analysis is compared to the epoxy-risen glass fiber reinforced plate shown in Figure 11. The maximum equivalent stress of a glass fiber reinforced epoxy-risen plate is 43.893MPa, while the maximum equivalent stress of an Enset fiber reinforced epoxy-risen plate is 32.289MPa. The results of the analysis show that, considering the same loading and boundary conditions, the Enset fiber composite materials have lower stress levels. In the design context, the material resulting a lower stress value is more preferable it mean that those materials might be utilized without substantially affecting the stress response for the particular loading conditions taken into consideration.

3.2 Tensile analysis

For the tensile analysis of the deformation of the epoxy risen Enset and glass fiber reinforced material is depicted in and as it can be seen on the colorful results the deformation of the new Enset fiber composite material is 2.8483mm and the deformation for the glass fiber composite material is 1.1427 mm. When 1500N tensile load is applied at the edge of the material the new materials have a considerable deformation which is not much different from the existing material.

Similar to the deformation, the strain is shown in Figure 13 below. The strain of the glass fiber is shown on the right side, while the reinforced material with enset fiber is shown on the left. As a result, similar to the deformation, the strain of the new material is given a very close value; the strain of the new material is 0.00023969, while the strain of the existing material is 0.0000692. The outcome indicates that both materials are undergoing comparable levels of deformation or strain under the specified loading circumstances.

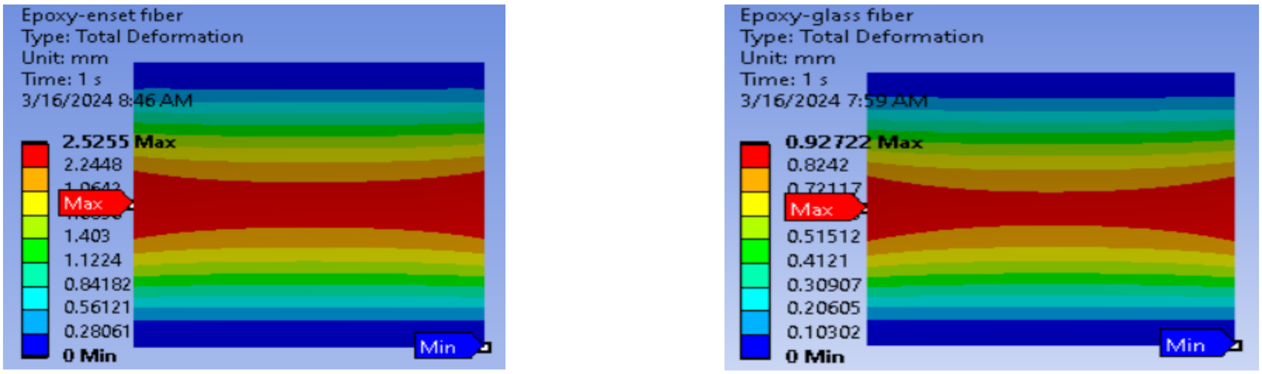


Figure 9. flexural deformation of the new and existing materials

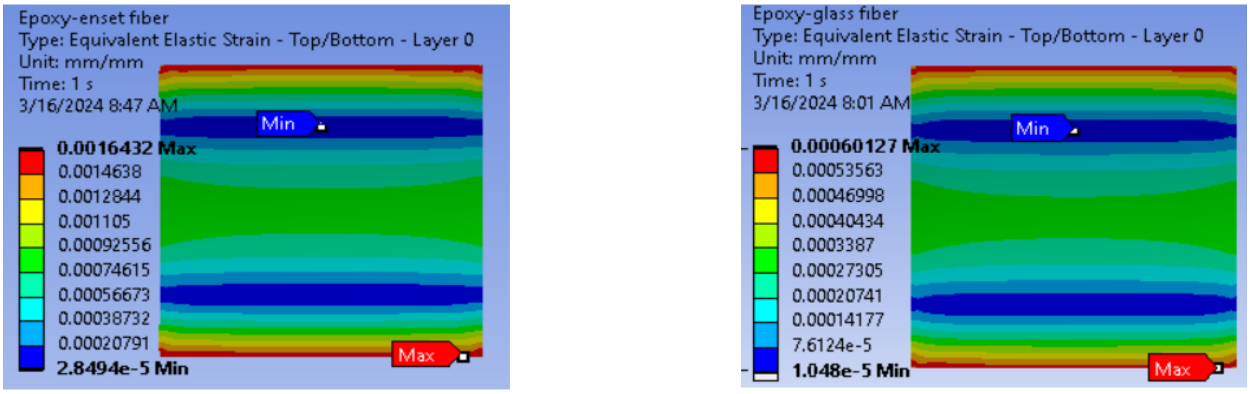


Figure 10. flexural strain of the new and existing materials

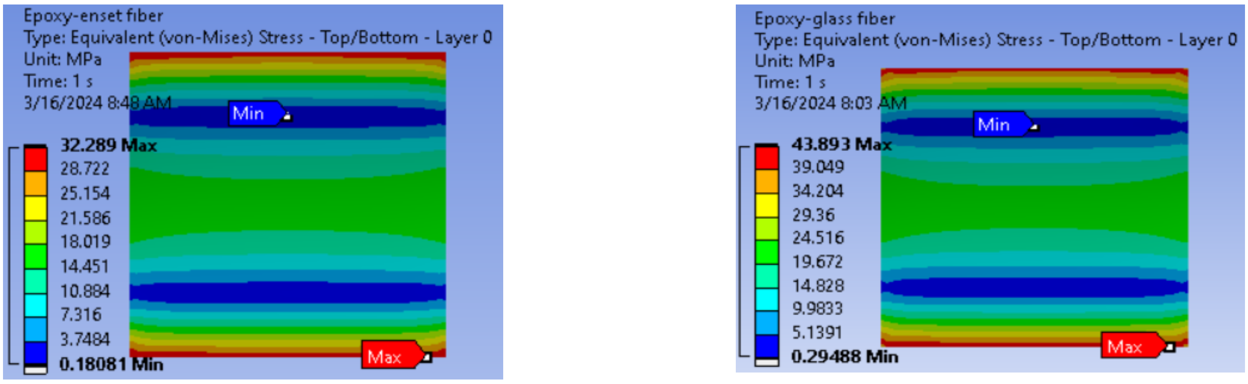


Figure 11. flexural stress of the new and existing materials

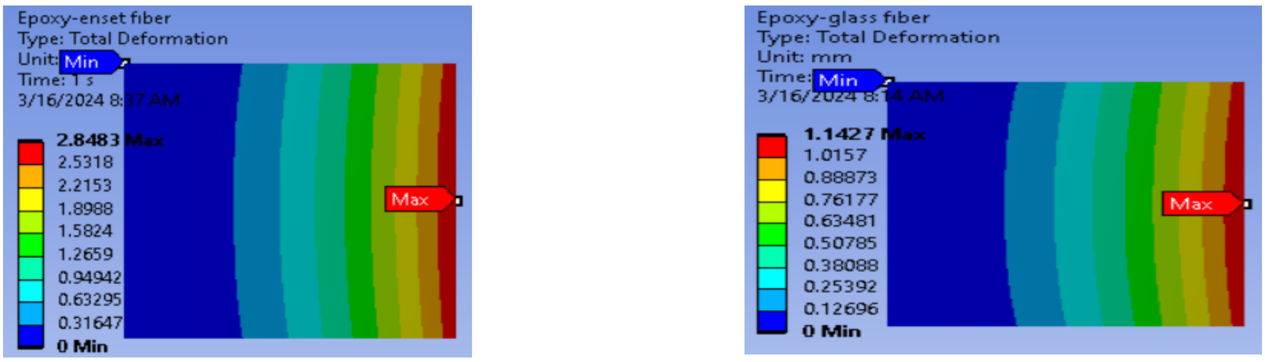


Figure 12. tensile deformation of the new and existing materials

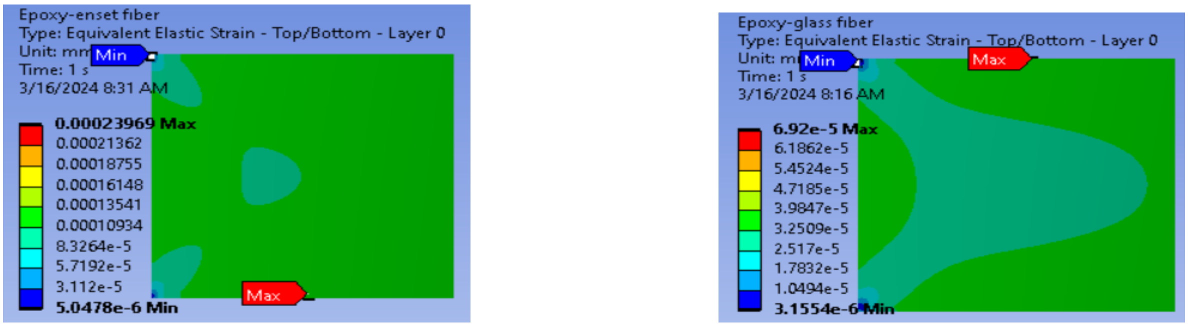


Figure 13. tensile strain of the new and existing materials

Additionally, the stress produced in the newly created epoxy-risen Enset fiber reinforced material is shown on the left, and the stress induced in the glass fiber-based existing material is shown on the right side of Figure 14, with corresponding values of 5.0513 MPa and 4.7098 MPa. Comparatively more stress is generated in the glass fiber used presently than in the new epoxy-risen Enset fiber reinforced materials.

3.3 Explicit dynamics impact analysis

When a structure is exposed to abrupt, high-energy events like collisions or explosions, impact analysis is very helpful in understanding how the structure responds. An Enset and glass fiber reinforced composite 300 mm by 300 mm flat model is used for the impact test. The bullet struck the composite model's core at a high speed of 900 m/s. There is a detailed discussion of the outcomes in terms of strain, stress, and directional deformation which is shown in Figure 15. Compared to glass fiber composite material, the Enset fiber composite exhibits larger directional deformation and strain. However, the Enset fiber composite material has an equivalent stress of 11736 MPa, which is significantly less than the glass fiber composite material's 26462 MPa. Glass fiber is weaker and more likely to break suddenly, according to the simulation findings. Glass fiber could not be able to absorb as much energy in an impact, which could result in a catastrophic failure. Enset Fiber, on the other hand, has superior energy absorption properties and can be more ductile. This makes it appropriate for applications where controlled deformation is a goal because it can lead to a more progressive failure.

3.4 Modal analysis

By using ANSYS finite element analysis software modal analysis on the newly identified Enset fiber composite material and the existing glass fiber composite material offers various advantages when comparing these materials. For each material, the natural frequencies of its vibration modes can be identified by modal analysis. It helps to identify how the two materials react to dynamic stresses and pinpoint possible areas for improvement by comparing their natural frequencies. Mode shapes are a description of the vibration patterns that a material or structure exhibits. Modal analysis can provide information about these modes. By comparing the mode forms of the glass fiber composite with the Enset fiber composite, one can determine how differently they behave structurally and evaluate how well they operate in different conditions.

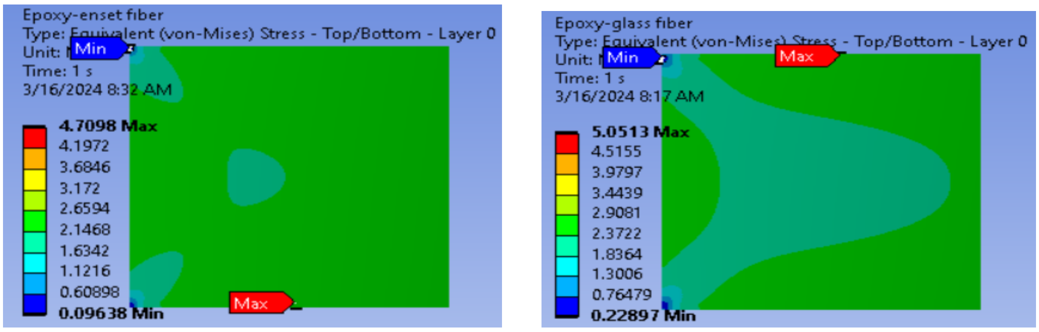
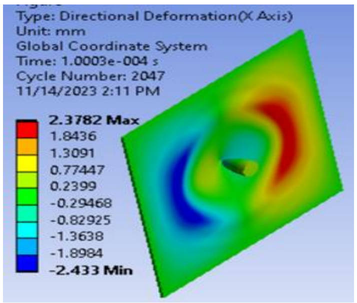
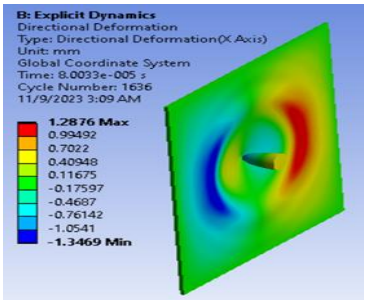


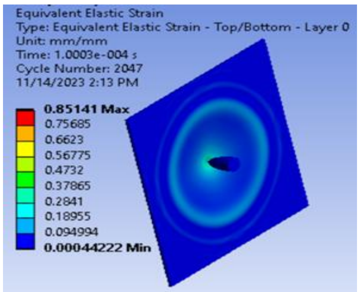
Figure 14. tensile stress of the new and existing material



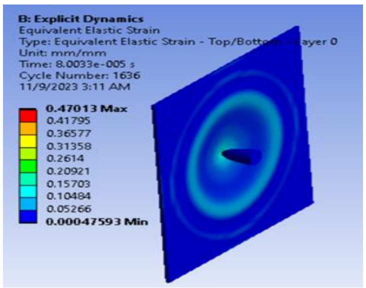
Directional deformation for Enset fiber



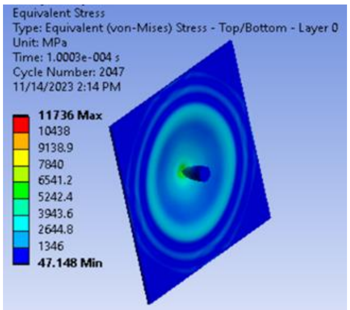
Directional deformation for glass fiber



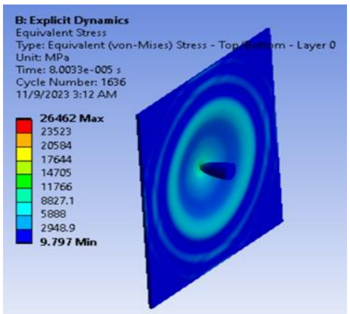
Equivalent strain for Enset fiber



Equivalent strain for glass fiber



Equivalent stress for Enset fiber

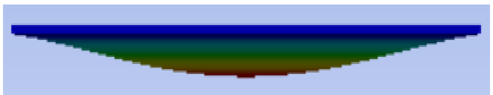


Equivalent stress for glass fiber

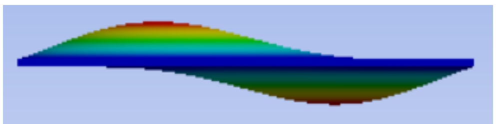
Figure 15. impact analysis result for both material

Mode shape and Frequencies for Enset fiber reinforced composite

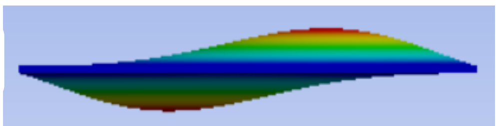
Mode-I
f=219.84Hz



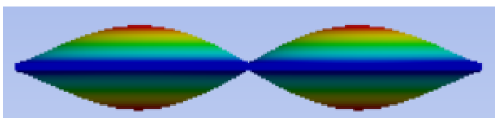
Mode-II
f=440.98Hz



Mode-III
f=440.98Hz

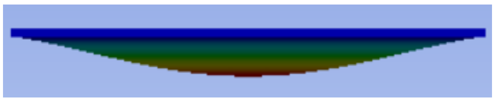


Mode-Iv
f=709.66Hz

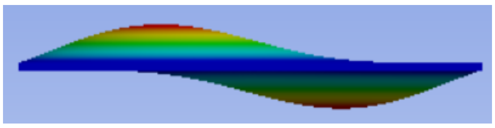


Mode shape and frequencies for Glass fiber reinforced composite

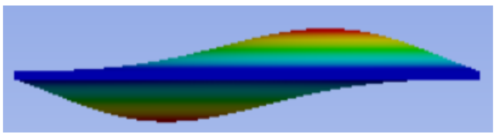
Mode-I
f=313.84Hz



Mode-II
f=627.45Hz



Mode-III
f=627.45Hz



Mode-Iv
F=1010.6Hz

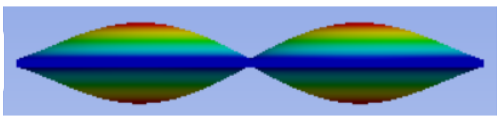


Figure 16. Modal analysis result for both material

As seen in Figure 16 when Enset fiber and glass fiber composite materials are compared using modal analysis, Enset fiber composite material yields a lower frequency value across all mode shapes, indicating a number of benefits for the material. Smaller frequency values are often indicative of stronger stiffness in a material. Increased stiffness can improve the integrity and stability of a structure by reducing deflections and deformations under dynamic stresses. Increased stiffness is frequently correlated with a better ability to withstand fatigue and dynamic loading circumstances. Smaller frequency values increase a material's strength and resilience by reducing its susceptibility to resonance and vibration-induced fatigue failures. Enset fiber reinforced composite material is a desirable alternative to the existing glass fiber composite material for a variety of engineering applications because it has lower frequency values across all mode forms, which suggests enhanced the dynamic performance, durability, and efficiency.

A numerical study using ANSYS was conducted to determine the mechanical properties of the new material based on its tensile, flexural, impact and modal analysis result. The results showed that the new material experienced a good performance over the existing synthetic glass fiber composite material. Based on this investigation, the newly developed material known as Enset fiber reinforced composite material has emerged. Glass fiber reinforced composite material can be replaced with Enset fiber reinforced material, which offers competitive performance.

4. CONCLUSION

In this study, ACP and ANSYS Workbench was utilized to model and analyze the numerical data of the newly developed epoxy-risen Enset fiber reinforced composite material and the existing glass fiber reinforced composite material. Using the same fiber orientation and fiber volume on ACP and the same boundary and loading circumstances on ANSYS workbench; the mechanical properties test such as flexural, tensile, impact and vibration analyses were conducted. Stress, deformation, strain and frequency levels are compared between the two distinct materials. Taking consideration of the analysis outcome, following conclusion are drawn.

Analysis results shown that Enset fiber reinforced composite material gives a very good properties which are very competent with the existing composite material. According to the tensile analysis, stress created for the same loading conditions on Enset fiber reinforced composite material (4.7098MPa) and glass fiber reinforced composite material (5.0518 MPa). Compared to the new epoxy-risen Enset fiber reinforced materials, comparatively higher stress is generated in the glass fiber that makes the new material better. According to flexural characteristics, the maximum equivalent stress of an epoxy-risen plate reinforced with glass fiber is 43.893MPa, whereas the maximum equivalent stress of a plate reinforced with Enset fiber is 32.289 MPa. These values also makes the new material have better performance. While compared to impact stress, the Enset fiber composite material has an equivalent stress of 11736 MPa, which is substantially less than the 26462 MPa of the glass fiber composite material. Enset fiber composite material yields a lower frequency value across all mode shapes, this indicating that it will be a very good alternative in the area of vibration reduction. Enset fiber reinforced composite material produces excellent results in all analysis results and it is a material that is highly competitive with glass fiber reinforced material.

Like other natural fiber-reinforced materials, enset fibre composites have significant limitations, including poor matrix-fiber interfacial bonding, high moisture absorption, and decreased long-term durability, all of which can eventually affect mechanical performance and dimensional stability. Because fibre stretching and degradation can occur in a variety of environmental situations, these problems are especially important. To increase the dependability of Enset fibre composites in structural applications, future research should concentrate on developing fibre surface treatments, investigating hybrid composite techniques, and carrying out long-term durability investigations. The overall findings affirm the potential of Enset fiber reinforced composite as a strong and sustainable alternative to conventional glass fiber composites, particularly in applications where reduced stress response and vibration sensitivity are critical. Its favourable performance under tensile, flexural, impact, and modal conditions highlights its suitability for use in structural panels, automotive components, and vibration-damping systems. The material's lower stress development under identical loading not only indicates improved efficiency but also suggests potential for enhanced durability and energy absorption. To further validate its practical applicability and long-term reliability, future studies should focus on experimental evaluation of its environmental resistance, aging behaviours, and fiber–matrix bonding characteristics under real-world service conditions.

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