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# ANALYSIS OF THE NATURAL COMPOSITE MATERIAL LAYERS INFLUENCE ON THE CANTILEVER'S STRUCTURAL PERFORMANCE

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***In this study, with their high strength-to-weight ratio, adaptability, and lack of corrosion, composite materials are widely used in aircraft construction and can be considered an acceptable metal substitute by all parties involved. Static load tests have been performed under identical conditions and stresses, but the layer sequence was changed. The Ansys workbench ACP-pre is utilized to analyze the data. Various deformations were found as a result of this. There are values of 14.265 and 0.1335 for the smallest z-direction deformation and for the overall strain in the composite 3 examples. Boundary conditions have been confirmed with 1,500 N as a resultant force with the static condition. The simulation results have been analyzed as a static condition. Four materials have been employed in different order to be investigated and these materials are Sisal, Pineapple, Jute, and Kenaf. The numerical results have been undertaken using the static structure of Ansys 16.1 Version tool. Geometry has been modeled and meshed using Ansys workbench. The model has been verified using convergence test. As the output, total deformation and von Mises stresses were investigated and explained accordingly. Numerical results stated that the maximum deformation due applied load was at the Z-axis. The maximum total deformation value is 1.254 mm and the minimum is 2.5 mm. Furthermore, von Mises stresses of the entire body have been calculated. The numerical results have shown the maximum result due to 1,500 N is 1.1 mPa. Eventually, the main aim has been achieved by employing total deformation and von Mises stresses accordingly***

***Keywords: natural fiber, natural composite, finite element method, static structure, cantilever***

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## 1. Introduction

In a variety of industries, such as automotive, aerospace, and defense, fiber-reinforced composites (FRCs) have been proved to have many applications and are gradually replacing traditional metallic structures [1]. Increasingly popular are long-term projects that don't hurt people or the environment, as people become more environmentally aware. Increasing environmental awareness will lead to a more environmentally friendly world [2].

It is possible to use natural fibers in composites that are stronger than synthetic fibers in some cases. Biodegradable natural fiber-reinforced composites are both low-cost and environmentally friendly [3]. The natural fiber component lignocellulose improves the matrix bonding of natural fibers. Examples of natural fibers that are non-abrasive, regenerative, lightweight, absorb $CO_2$ during growth, and use less energy to process are cotton, linens, and hemp [4, 5]. There are few fiber groupings that can match the combination of natural and synthetic fibers. They're easy to remove and affordable to use. Composite specimens produced from five different types of fibers were studied. These include natural fibers like kenaf and jute as well as synthetic fibers like polyester (carbon glass). They were able to perform a FEM analysis after combining these fibers. Various combinations can be mixed and matched. In order to do finite element analysis on the specimen, the Mechanical APDL ANSYS is utilized to apply a point load to it [6]. In the previous work, hybrid composites' deflection properties were examined under identical loading conditions. Hybrid composites may benefit in the long term from this. A high-quality composite material could potentially be used to create a high-resistance material [7].

Natural fiber-reinforced polypropylene composites were explored using the film stacking compression molding process (sisal, kenaf, hemp, jute, and coir). The mechanical properties of various natural fiber composites were evaluated and compared. Glass-reinforced open-literature polypropylene composites have similar properties to polypropylene composites [8]. The modulus and tensile strengths of composites made from sisal, kenaf, and hemp are all very similar. Kenaf, on the other hand, appears to outperform hemp in terms of its impact qualities. Increasing the mass fraction of the fibers can improve the impact strength, modulus, and ultimate tensile stress of kenaf-reinforced polypropylene composites. The impact strength of coir fiber composites is higher than that of kenaf and jute, despite the inferior mechanical qualities [9].

The new natural fiber was used in a polyester resin matrix to study the tensile, dielectric, and flexural properties of composite materials. Fiber composites were made from fibers that had been manually treated and reset. Newer composite materials, such as kenaf fiber and bamboo fiber, offer qualities that are similar to those of current composites. Composites should have total fiber fraction volumes of 0.37 and 0.39 for tensile and flexural/dielectric testing, respectively. Flexural strength is superior to that of the kenaf composite and comparable to that of the sisal fiber composite in a volume percentage of fibers. Dielectric strength improves with increasing volume percentage in comparison to kenaf, sisal and bamboo composite fibers. Using weaving patterns and random orientation [10]. The previous study investigated the mechanical properties of kenaf hybrid polyester composites [11]. To make the composites, plain and twill weave patterns were used. The flat weave performed better than the twill weave in all composites. When compared to random-oriented composites, the strongest gains in mechanical strength were seen in single weave hybrid composites. Since load is transferred from fiber to fiber, the stress at the composite interface will be reduced. However, NaOH and sodium lauryl sulfate treatments, on the other hand, aim to improve interfacial bonding between the two surfaces in order to boost mechanical strength.

## 2. Literature review and problem statement

In earlier investigations, composite materials poisoning of water bodies is a major health hazard. When heavy metals are ingested by fish or humans at the top of the food chain, they can accumulate in the body and offer the greatest health risk [12]. It has been found that the biological processes of respiration, metabolism, and biosynthesis all contain nickel, one of the numerous heavy metal ions, which is vital nutrition for living creatures. Thus, the moderate levels of Ni(II) ions supply critical trace nutrients, but excessive amounts can be dangerous. Waste effluents frequently contain harmful metals like nickel and zinc, which implies that each country's governing body may have a responsibility to rigorously comply with discharge and exposure restrictions [13]. Toxicological effects on the respiratory system have been connected to the extensive use of Ni(II) in industrial applications such as rechargeable batteries, electrochromic devices, supercapacitors, electroless nickel plating technology and precursor for catalysts in chemical reaction [14]. A novel material for selective detection and elimination of Ni(II) in environmental, industrial, culinary and biological samples is appreciated.

In order to remove heavy metals from polluted water and prevent their harmful effects on the environment, human health, and the ecosystem [15], numerous remediation procedures have been devised. Due to the secondary pollution they produce and the fact that they do not eliminate metal residues, standard remediation approaches such as chemical precipitation and flocculation are ineffective [16]. In addition to ion exchange and solvent extraction, other methods for removing metal ions from water include reverse osmosis, distillation, and adsorption [17]. Due to its unique selectivity by the functional groups of the adsorbent material, however, the adsorption approach is preferable [18]. Metal ion adsorption can be improved by using ligand-functionalized composite hybrid materials. Many of these substances are simple to create, simple in operation, produce a small amount of residue, significantly recover pollution, may be repurposed without losing any functional group or case cavity [19]. Because of their large surface area and ability to alter their surface, composite materials are more effective than standard micro (macro) solid supports.

Natural frequencies decrease and the mode shape shifts when a structure has a crack, according to the literature [20]. Natural frequency data from vibration-based non-destructive techniques, such as modal analysis, can be used to identify the location and depth of a discovered crack in a structure. The detection of cracks in beam constructions has gained a lot of interest from the scientific world. Fracture mechanics approaches [21] depicted a crack as a zone of local flexibility. A crack's depth can be determined by measuring changes in natural frequencies, which can be used in a variety of designs. The broken beam problem was addressed using FEM and Newton-Raphson methods [22]. The broken beam's native frequencies were discovered using the Transfer Matrix Method (TMM) [23]. Inverse crack detection was addressed. A beam with many transverse cracks has a more complicated dynamic response than a beam with just one transverse crack [24].

Several studies on multiple-cracked beams have been done recently because of the likelihood of several cracks in the elements of engineering constructions such as beams and the possibility of their destruction quickly [25]. Structures containing many cracks, like beams, rotors, and pipelines were among Sekhar's primary research targets. Detection of many cracks in more sophisticated beams has recently become a fascinating topic of study for scientists. Combining TMM and wavelet analysis, crack detection in a stepped cantilever beam was investigated. They used peak wavelet coefficients to locate the crack, and then TMM to determine the depth of the crack. Detection of transverse cracks in a stepped beam was the focus [26]. They used a torsional spring to mimic the fracture and created three graphs, one for each of the crack's three inherent frequencies. The crack's position was determined by the junction of three graphs. It was found that utilizing the energy approach and an analytic strategy based on the Rayleigh-Ritz method could detect many cracks in a multi-stepped beam. Most vibration-based approaches require a two-step procedure to determine the location and depth of a crack since the natural frequencies of a cracked beam are affected by both the location and size of the crack. The position and size of the cracks can be used as design variables in a crack detection optimization problem [27]. Recent years have seen a substantial rise in the use of optimization techniques to detect damage. Genetic optimization was used to determine the depth and position of a generated fracture.

If a fracture exists, it alters the natural frequency and the mode shape of a structure. Non-destructive methods, such as modal analysis, can be used to identify the location and depth of a discovered crack in a structure using natural frequency data. Beam crack detection has been extensively studied in the literature. To model a crack, fracture mechanics were used. In order to find cracks in various structures, they created a spectral approach that correlated break depth with changes in natural frequencies.

Today's manufacturing industries rely heavily on the utilization of banana fibers in the production of commercial components. Composite materials such as carbon fiber, ceramics, and epoxy resin can all be likened to it. The development of microbe composite materials has so been accelerated in an effort to lessen environmental impact. As a result, thermoset plastic-based organic resources have become widely used in a variety of human endeavors ranging from automotive parts to home appliances to recreational items to maritime apparel. Reinforced in a polymeric-based matrix has recently been made using banana, jute, coconut, cotton, and fibers [28]. Natural fiber composites were recommended above glass composites because of their environmental friendliness, little influence on the environment, and inexpensive fabrication costs [29]. If you want to create a composite with cellulosic, natural fibers are a fantastic option. Researchers examined fiber structure, total carbohydrate, and microfibril angle to regulate mechanical properties [30]. Particular modules were revealed by conducting a weathering test on the fabric fiber composites [31]. Banana composite material with polymer composites has also been the subject of various studies. Young's modulus, fracture toughness, hardness, absorption, and steaming absorption are all produced through the chemical preparation of banana fiber composites. The tensile strength of polyester banana composite material was found to be around 60 MPa with 30 mm fiber length [32] and 50 % fiber mixing. With glass and banana fibers, polystyrene matrix and composite materials can be formed more quickly and easily than with other fibers. Several investigations [33] have shown that banana fiber is compatible with thermoset polymers. There was no systematic parametric study for natural fiber-polymer composites in prior literature.

It has been suggested that composite materials could be used in the wing construction because of the advancements in commercial aircraft design. The first commercial implementations of this topic explored in the European Project ALCAS are now taking place with A350 XWB, which features the basic construction of the torsion box of wings made of carbon-fiber composite (Advanced Low Cost Aircraft Structures, Sixth Framework Programme) [34]. Because of the anisotropic nature of the composite material and the geometric complexity of these elements, Finite Element models (FE) are frequently employed in conjunction with experimental testing (tests) to validate the models that are developed. But it's expensive to use these FE models during the design phase to change the stacking sequences of the laminates. Simplifying analytical beam models has therefore been an important research area. There are a large number of studies on anisotropic thin-walled beam models in the literature. Several books have been written on this subject, and they have provided an overview of a wide range of beam concepts. Silvestre and Camotin [35] have uncovered stability issues with arbitrary orthotropic materials, and Schardt offered the Generalized Beam Theory as a framework to address these issues. For the analysis of composite beams, the Exact Beam Theory was employed. Using the Vlasov Theory, the structural response of a two-cell composite rotor blade was examined under bending and torsion loads to provide experimental support for the theoretical predictions. A Vlasov-type modified first-order shear deformation theory was devised to assess the dynamic response of open-profile sections. A torsional load is placed on a cantilever I-beam, and this theory is used to determine how it will behave. For thin-walled open or closed section composite beams with arbitrary layups, an explicit formulation for the stiffness matrix was developed.

## 3. The aim and objectives of the study

The aim of the study is to investigate the performance of the composite cantilever structure based on the order of layers.

To achieve this aim, the following objectives are accomplished:

– to investigate the total deformation due to applied load;

– to investigate the effect of von Mises stresses on the cantilever structure.

## 4. Materials and methods

### 4. 1. Object of study

In this paper, four types of organic fibers are explained for the purpose of creating composite materials. The structural analysis is carried out using Ansys' ACP-pre Workbench. Composites could be made by altering the sequence in which they were assembled, but maintaining the same requirements and loads that are common to composites. Using the findings of this study, composites that are identical to the original product can be developed that are stronger. Finding out how a composite can be formed requires using the right model for the material design in the first place. Composite paper is made by laminating kenaf, jute, pineapple, and sisal fibers five times. Particularly, the influence of the natural composite material layers on the performance of the cantilever structure will be examined and tested accordingly.

### 4. 2. Boundary conditions

Mechanical properties of the Ansys ACP mechanical pre were being evaluated with this specimen. The specimen is 20 mm wide and 200 mm long. The literature [28] contains a wide variety of material characteristics. The left and right ends of this sample were removed after it was opened to 0 degrees. The laminate had a thickness of 0.25 mm, and there were four layers total in the design. In addition, the entire specimen has a thickness of 1 mm. Fig. 1 illustrates how the spacers should be used in practice. When all of the preceding conditions are met, the composite direction ($-y$) is applied with a force of 1,000 N. The composite fixed end and the force direction are presented in Fig. 2. There is no DOF in any direction in this composite.

The geometry of the current study has been performed using a design modeler in Ansys software. Fig. 2 showed the boundary conditions where it is supported from the side and free from the other side.

### 4. 3. Modeling and mechanical properties

In engineering research, numerical simulations are used extensively because of their low cost, reliability, and ease of use qualities. Modern computer simulation techniques are increasingly in demand due to their versatility. The ACP Workbench 19, a highly specialized procedure for processing composite materials, also makes use of numerical simulation.

For example, the ability of ANSYS ACP 19 to develop strength in a variety of directions is really good. In ANSYS ACP 19, orthotropic properties were assigned. Laminate development will become more user-friendly once a matrix is included. The facility must confirm the reliability of the composite analysis tests in order to avoid using an experimental approach. ANSYS Design Modeler 19 and Ansys Mesh were used to develop the test sample's basic design and to discretize the tensile test sample. It is used for the internal structural analysis of matrix and fiber in composite numerical analysis rather than the laminate analysis of laminated structures. The properties of fibers are shown in Table 1.

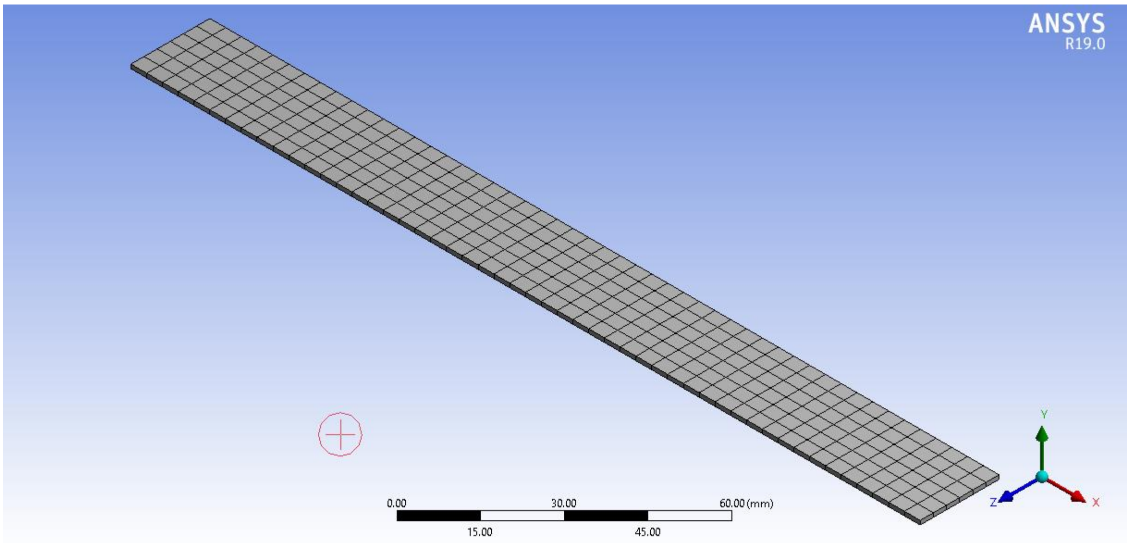


Fig. 1. Geometry and mesh of the cantilever structure

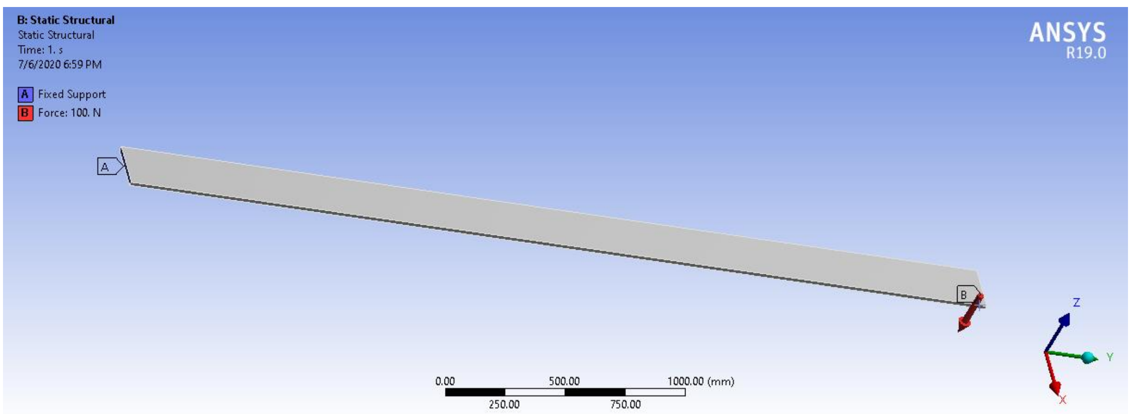


Fig. 2. Boundary condition based on the force direction

Table 1

Mechanical properties of natural fibers

| Properties | Sisal | Pineapple | Jute | Kenaf |
|---|---|---|---|---|
| E (GPa) | 704 | 1,025 | 501 | 651 |
| Poisson's ratio | 0.311 | 0.369 | 0.39 | 0.299 |
| Density (kg/m$^3$) | 1,361 | 1,290 | 1,103 | 1,299 |

In this research, four natural composite materials have been employed and fabricated accordingly. The mechanical properties of these materials have been collected accordingly. For the simulation purpose, the modulus of the velocity, Poisson's ratio along with density have been calculated.

**4. 4. Convergence test of the composite cantilever structure**

An ANSYS 16.1 pre-processing tool called vibration response has been used to simulate the sandwich structure. In this study, a local mesh model was generated. Linear loads are sufficient for the current type of components. Fig. 3 shows the results of seven possible solutions, each with a different number of pieces, all with the same applied load of 100 N. On the basis of the results of the simulation. With 11,564 components, the curve becomes horizontal at a total deflection of 0.32 mm. In this experiment, the mesh model was shown to be converging.

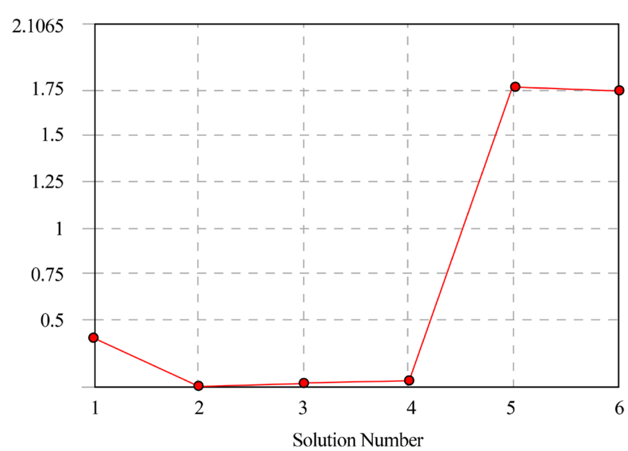


Fig. 3. Convergence test of the cantilever model in terms of Total Deflection

The geometric model has been converged and performed using structural analysis in ANSYS software. Wherein this case six attempts have been tested numerically. The main indicator for the best solution is total deformation.

## 5. Results of research of the influence on the cantilever's structural performance

**5. 1. Total deformation due to the applied load of the cantilever structure**

On successful completion of the discretization procedure, ACP Ansys was used to complete critical phases such as fiber construction, component assignment and rosette generation, orientation set-up initialization and fold grouping, and solid model construction. Fabric design is all about enhancing and categorizing mechanical qualities. The rosette allows for fiber guidance and canted arrangement. Using this method, a laminate is oriented in the appropriate way. As part of the modeling process, students worked together to refine the angles and thicknesses of their folds. By employing a solid model to connect the fibers in the matrix, the laminate will be created in the end. As a static structural analysis tool, Ansys will be able to help FEM. External charge operation was made possible because of this framework's static structure (Fig. 4). As the test sample, a cantilever chain is subjected to tensile loads of 1,500 N on one end and 1,500 N on the other. All of the strain energy, deformation direction, and total deformation have been plotted and indicated in a static structural system following post-processing.

There are a number of ways to describe the fibers' composite character, using numbers like «Pineapple», «Sisal», «Jute», etc. The final composite rating is shown in Table 2.

According to Fig. 3 through 6, test specimens that have anomalies on the side are depicted (kenaf, jute, sisal, and pineapple). Fig. 7 depicts the strain in the test specimen's accumulated energy.

Table 2

Composite order

| Composite No. | Layup order |
|---|---|
| First layer | 1 |
| Second layer | 2 |
| Third layer | 3 |
| Fourth layer | 4 |

Compared to the other composites, compound 1 has the least amount of distortion in both the $x$ and $y$ axes, while composites 2 and 3 have the least amount of deformation in both directions, as shown in Table 3. Composite 1 has a larger energy density as well.

Table 3

Deformation due to load

| No. | $x$ | $y$ | $z$ | Total deformation |
|---|---|---|---|---|
| First layer | –11.3 | –0.3 | 21.1 | –2.35 |
| Second layer | –12.33 | –0.4 | 22.2 | 1.254 |
| Third layer | –34.11 | –0.45 | 15.35 | –0.56 |
| Fourth layer | –24.23 | –0.465 | 15.1 | –0.90 |

Total deformation has been considered for the four trials for three axes. The maximum deformation was due to the $z$-axis for the previous trails. Fig. 4–7 show the total deformation at all axis.

Numerical results stated that the maximum deformation due to the applied load was at the $Z$-axis.

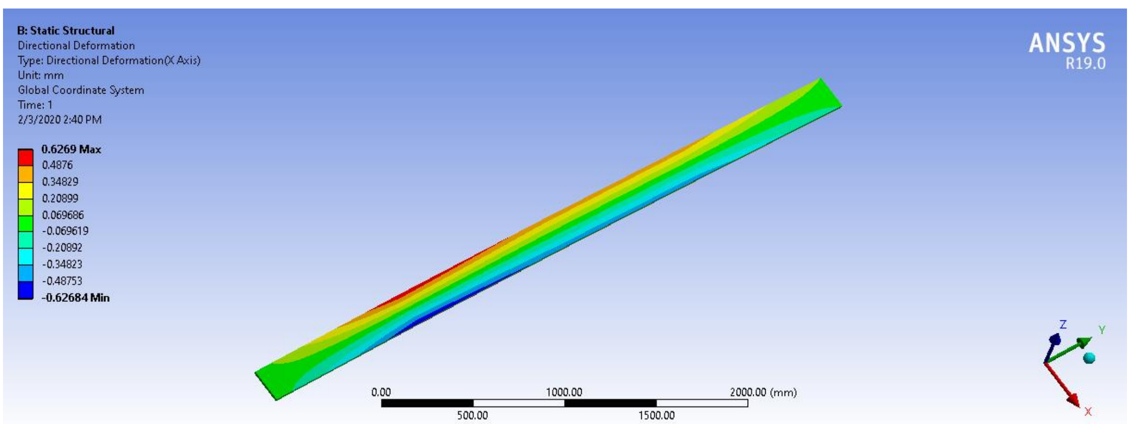


Fig. 4. Effect of the $X$-directional deformation

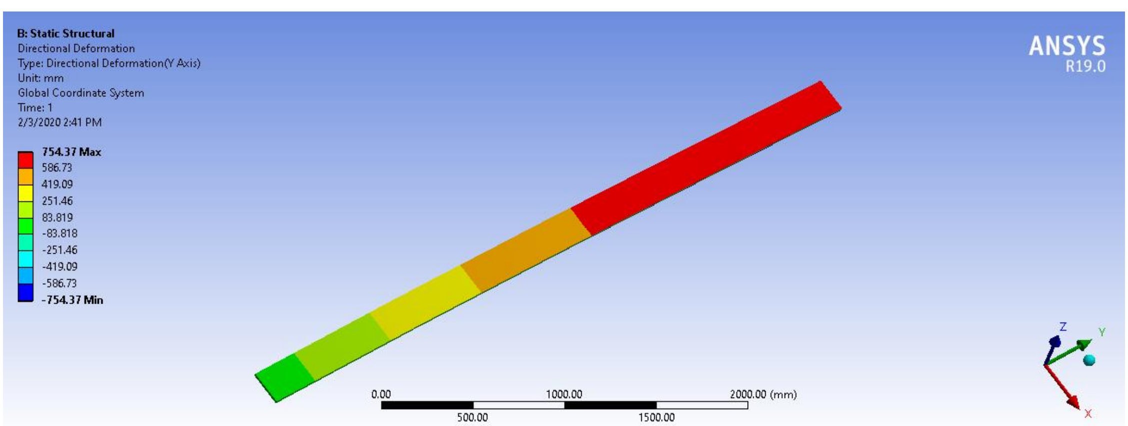


Fig. 5. Effect of the $Y$-directional deformation

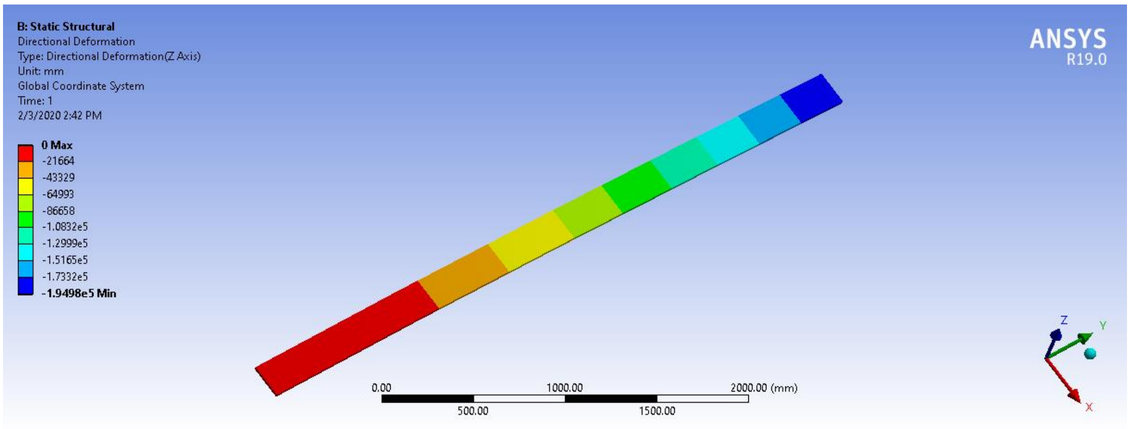


Fig. 6. Effect of the *Z*-directional deformation

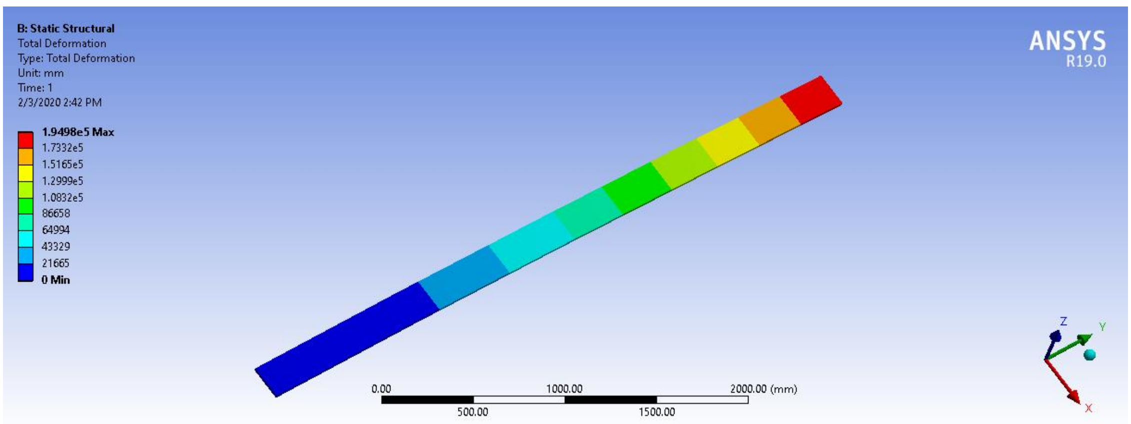


Fig. 7. Results based on the total deformation

The maximum total deformation value is 1.254 mm and the minimum is 2.5 mm.

**5. 2. Effect of von Mises stresses due to applied load of the cantilever structure**

The cantilever structure's ability to withstand various loads has been evaluated using von Mises stress.

Fig. 8 shows the results of four different composite layers being evaluated in this study.

The impact of von Mises stress due to the applied load of 1,500 N was calculated numerically using Ansys software.

The results showed the maximum strain value of 1.18 MPa on the top structure.

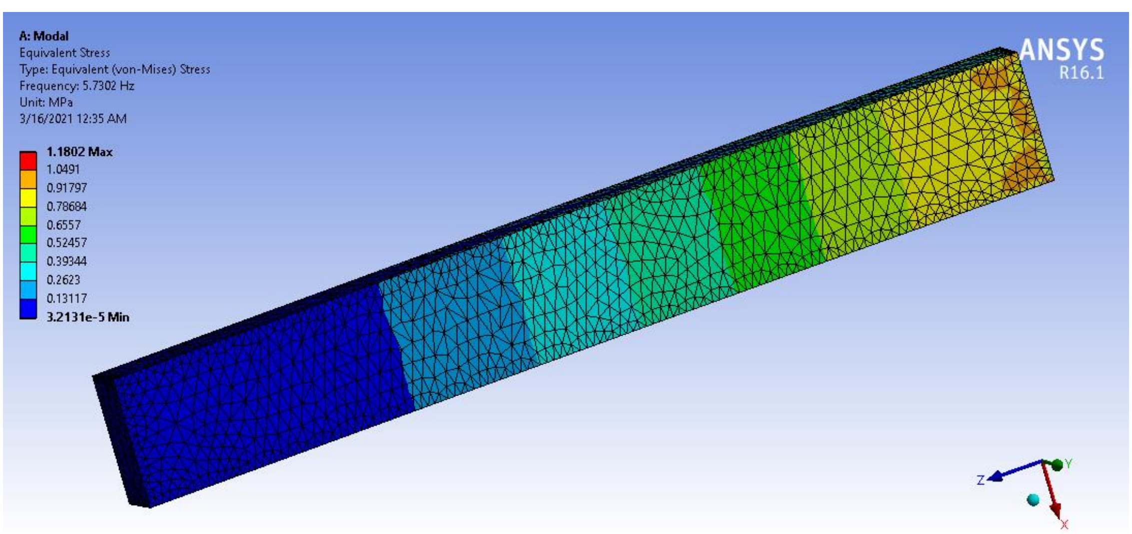


Fig. 8. Von Mises stresses

## 6. Discussion of the influence on the cantilever's structural performance

The results showed the effect of the layers on the mechanical performance of the cantilever structure of the composite materials. Numerical analysis has been considered to solve the issue based on the total deformation and von Mises stress. The simulation results have stated that the maximum total deformation is 1.254 mm as shown in Fig. 7. As well, von Mises stress has been obtained due to applied force and the maximum value of the stress is 1.18 MPa as shown in Fig. 8. Sections 5. 1 and 5. 2 have shown a comprehensive overview of the material layers influence on the cantilever's structural performance. The finite element method was considered to investigate the impact of the load on layers of the composite material of the cantilever structure. These results have been converged using the static structure tool in ANSYS software.

This study is limited to the four trials of the results with four kinds of materials Sisal, Pineapple, Jute, and Kenaf with 1,500 N as applied load. The output of the simulation process is limited to the two main factors, total deformation and von Mises stresses.

There are disadvantages that have been faced while setting up the process of pre-processing numerical simulation in the mesh setting, boundary conditions, and number elements. These issues can be fixed in the future by choosing different materials with the same boundary condition. The same boundary condition can be applied with other software like ABAQUS software.

## 7. Conclusions

1. The total deformation with a three-axis has been investigated and analyzed accordingly. The numerical results have stated that the deformation has maximum values at the *Z*-axis. Eventually, the maximum total deformation of the entire body of the structure is 1.254 mm.

2. Von Mises stresses have been calculated for the entire body of the cantilever structure. It has been calculated due to an applied load of 1,500 N, the numerical results stated that the maximum stress is 1.18.

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