Numerical Analysis of Fiber Reinforced Composite For Tensile and Bending Strength

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Abstract

In this paper, the numerical analysis is done on the glass epoxy composite material and Tsai-Wu and Tsai-hill failure theories are applied to analyze the composite. Finite Element Methods are used to analyze the tensile and bending strengnth by applying the different boundry conditions. The experimental results and theoretical results are compared for different tests like tensile test, bending test, and compressive test.

Keywords: Composite laminate, Finite Element Methods, Tsai-wu,Tensile strength, glass Epoxy.

1.1 Introduction

For as long as years, due to their mechanical properties and quality, the engineering materials are replaced by fiber-reinforced composite materials over a large portion of the engineering applications.A composite material structure comprising at least two or more macroscopically identifiable Constituent (basically matrix and reinforce) material/component/element that working together to perform significantly better in different applications.[1]Desired parameter/property of composite material is like high strength, high-temperature stability, environmentally sustainable. composite mainly has a matrix that gives the material desired shape and another one is reinforcement which gives the strength to the material. Today the world is growing very fast and to develop these smart materials which can work properly. The important and optional designs of engineering applications concentrate on the be-reason of the composite materials for the lightweight and also the high quality or resistance of these composite materials. The carbon filaments are probably the hardest fiber among all the accessible natural and manufactured fiber strings.[2] This is why the carbon fiber strands are used to model applications such as shuttles, ships, cars,common structures like bars, beam and different games types of gear like rackets and some more.

Experimentation

The sample was prepared to examine the mechanical properties and various property of the material. In this study the different concentration of epoxy and glassfiber used as given in table 1.[3]

Table 1. Weight % of epoxy, glass fiber and clay.

Sr. No.	Sample code	Fiber orientation	Number of layers	Weight fraction %		
				Epoxy	Glass Fiber	Cloisite 30B
1	GF-0	[0°/45°/90°]	3	67	33	0
2	GF-1	[0°/45°/90°]	3	59.67	39.71	0.62
3	GF-2	[0°/45°/90°]	3	59.23	39.53	1.24
4	GF-3	[0°/45°/90°]	3	58.94	39.20	1.86
5	GF-4	[0°/45°/90°]	3	58.13	38.82	3.05
6	GF-5	[0°/45°/90°]	3	58.11	38.80	3.09

In this paper glass fiber and epoxy resin is used and these fibers mechanical property is given in table 2 and table 3.[4]Glass fiber gives the highest strength quality and stiffness everything being higher for all strands. High-temperature execution is especiallyremarkable aimed at glass strands. Significant disadvantage to PAN-based strands is high cost, which makes the base material very expensive and concentrated assembling development. Filaments of glass fiber can the reason for galvanic consumption when utilized alongside metals.

Table 2. Mechanical properties of glass fiber

Properties	**Glass fiber**
Density	1.7(g/m^3)
Tensile modulus	40 GPa
Thickness	0.2 mm
Weight	200 GSM
Elongation	1.6%
Tensile strength	550 MPa

[10]

Table 3. Mechanical properties of epoxy resin

Properties	**Epoxy resin**
Flashpoint	185℃
(ISO 12058-1)Viscosity at 25℃	1200-1400 mPa s
(ISO 1675)Density at 25℃	1.1 - 1.2 (g/cm^3)

[6]Different testing is done the material like tensile test, compressive test and flexural testas shown in the figure 1, 2 and 3.

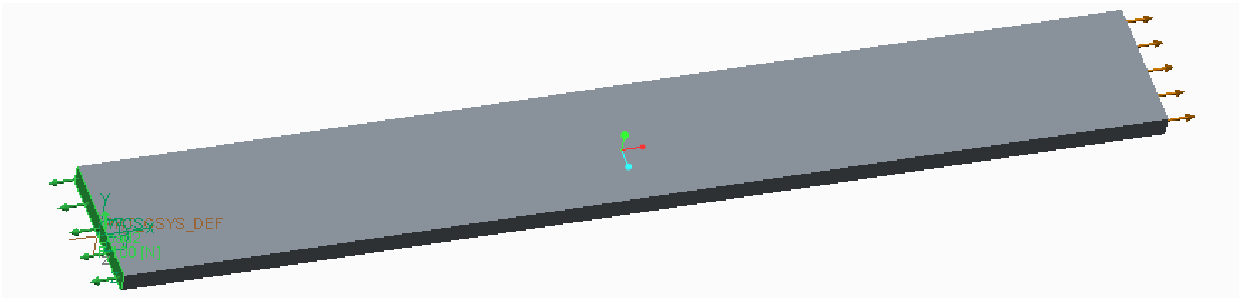

Figure 1. Tensile testing in composite material

The tensile strength and compressive strength are being determined by using the Universal testing machine for the materials. In this work universal testing machine used for design, tension, compression and compliance measurement of the material for experimental results.[7]

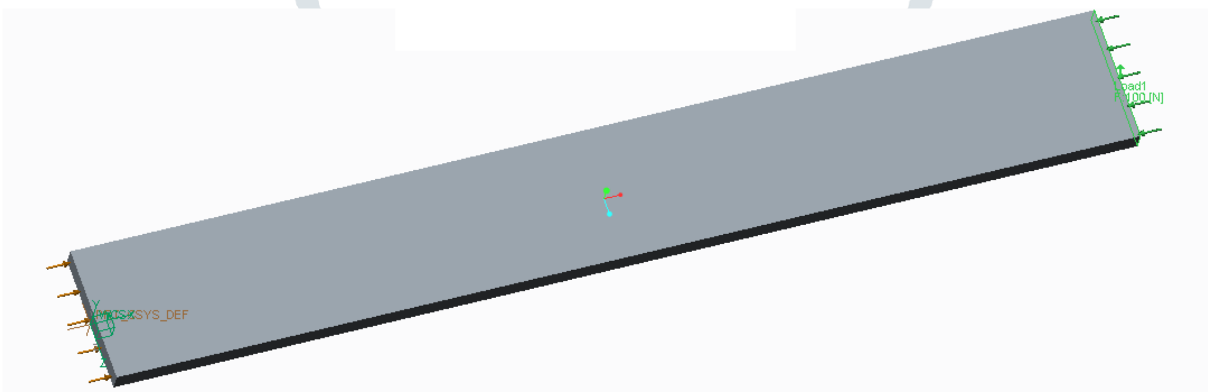

Figure 2. Compressive testing in composite material

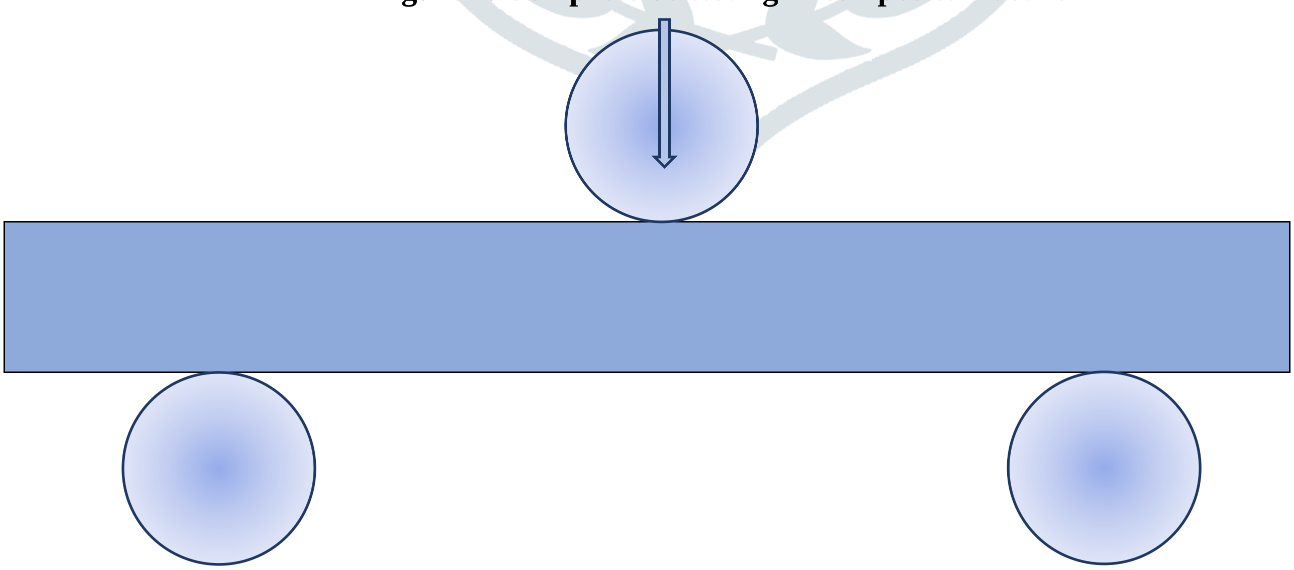

Figure 3. Flexural testing in composite material

Boundary condition is applied as discussed and the testing of these materials is done by using failure theory. Two failure theories are applied like one is Tsai-Wu and Tsai hill which are are reduced for 2D orthotropic Lamina. These failure theories are discussed below.[8], [9]

$$F_1\sigma_1 + F_2\sigma_2 + F_3\sigma_3 + F_4\sigma_4 + F_5\sigma_5 + F_6\sigma_6 + F_{11}\sigma_1^2 + F_{22}\sigma_2^2 + F_{33}\sigma_3^2 + F_{44}\sigma_4^2 + F_{55}\sigma_5^2 + F_{66}\sigma_6^2 + 2F_{12}\sigma_1\sigma_2 + 2F_{13}\sigma_1\sigma_3 + 2F_{23}\sigma_2\sigma_3 \le 1$$

Let the where, be σ_{1t}, σ_{1c}, σ_{2t}, σ_{2c}, σ_{3t}, $\sigma_{3c}$are the failure strength be in the three directions of anisotropy in uniaxial stress and compression.Then the terms of the orthotropic Tsai–Wu failure criterion are

$$F_1 = \frac{1}{\sigma_{1t}} - \frac{1}{\sigma_{1c}}\ ;\ F_2 = \frac{1}{\sigma_{2t}} - \frac{1}{\sigma_{2c}}\ ;\ F_3 = \frac{1}{\sigma_{3t}} - \frac{1}{\sigma_{3c}}\ ;\ F_4 = F_5 = F_6 = 0$$

$$F_{11} = \frac{1}{\sigma_{1c}\sigma_{1t}}\ ;\ F_{22} = \frac{1}{\sigma_{2c}\sigma_{2t}}\ ;\ F_{33} = \frac{1}{\sigma_{3c}\sigma_{3t}}\ ;\ F_{44} = \frac{1}{\tau_{23}^2}\ ;\ F_{55} = \frac{1}{\tau_{31}^2}\ ;\ F_{66} = \frac{1}{\tau_{12}^2}$$

Other terms like F_{12}, F_{12}, F_{23} are determined using the failure strengths in equiaxial tension areσ_1, σ_2, σ_{b12}, σ_1, σ_3, σ_{b13}, σ_2, σ_3, σ_{b23}. [14]

$$F_{12} = \frac{1}{2\sigma_{b12}^2}\left[1 - \sigma_{b12}(F_1 + F_2) - \sigma_{b12}^2(F_{11} + F_{22})\right]$$

$$F_{13} = \frac{1}{2\sigma_{b13}^2}\left[1 - \sigma_{b13}(F_1 + F_3) - \sigma_{b13}^2(F_{11} + F_{33})\right]$$

$$F_{23} = \frac{1}{2\sigma_{b23}^2}\left[1 - \sigma_{b23}(F_2 + F_3) - \sigma_{b23}^2(F_{22} + F_{33})\right]$$

One of the phenomenological product failure hypotheses is the Tsai–Hill failure criterion,[10], [11] which is commonly used for anisotropic composite materials with varying stress and compression strengths. The criterion of Tsai-Hill predicts failure when the laminate failure index exceeds 1.The Tsai-Hill criterion is based on an energy theory with interactions between stresses. Ply rupture appears when

$$\left(\frac{\sigma_{11}}{X_{11}}\right)^2 - \left(\frac{\sigma_{11}\sigma_{22}}{X_{11}^2}\right) + \left(\frac{\sigma_{22}}{X_{22}}\right)^2 + \left(\frac{\sigma_{12}}{X_{12}}\right)^2 \le 1$$

Where,

X_{11} is the allowable strength of the ply in the longitudinal direction of 0º.

X_{22} is the allowable strength of the ply in the transversal direction of 90º.

X_{12} is the in-plane shear allowable strength of the ply between the longitudinal and the transversal directions.

Testing and Discussions

For the tensile test, the examples arranged for the test were having a gauge length of 150 mm with a start position of 250 mm. For the flexural test, the width of the example was 7 mm and the thickness was 2 mm. The tensile test was performed on the samples arranged from glass fiber reinforced epoxy with nano clay in Ansys software. The three-point flexural test was performed on tests with various nano clay.The theoreticalanalysis is done using the same composite material and the same property as preferred in this paper. Testing is done on the Ansys workbench software. All the results of theoretical analysis and experimental analysis are compared to check how much difference is coming from both the results. Figure 4 shows the tensile strength test results and figure 5 is showing the compression in composite material and figure 6 is showing the bending strength results of the glass composite material. All the same, property is taken for the analysis and we get these results.

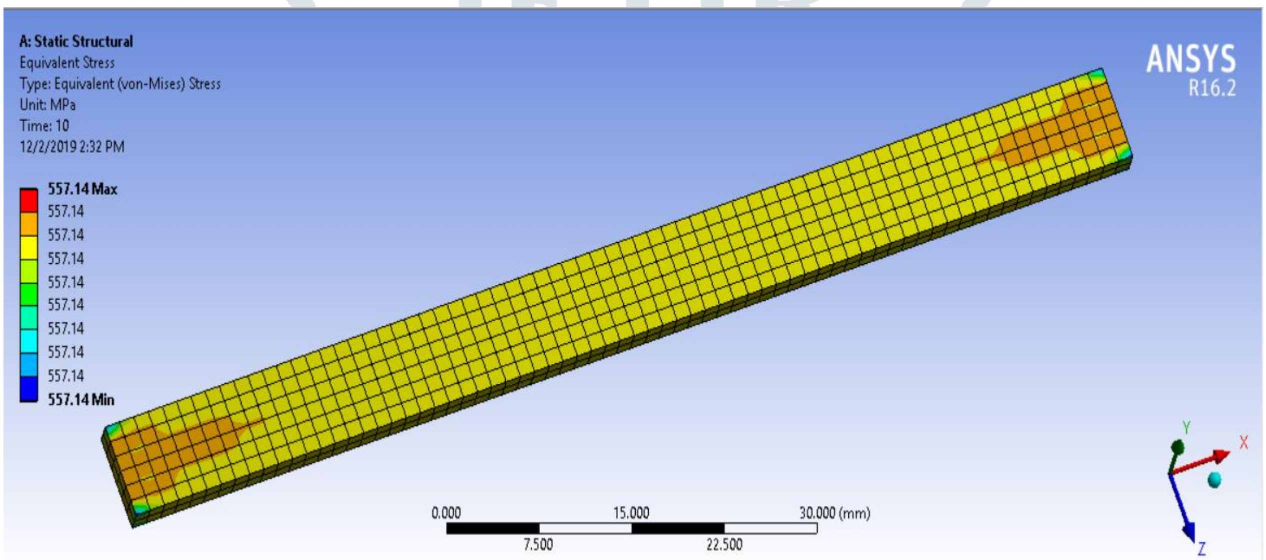

Figure 4. Tensile strength of the composite material

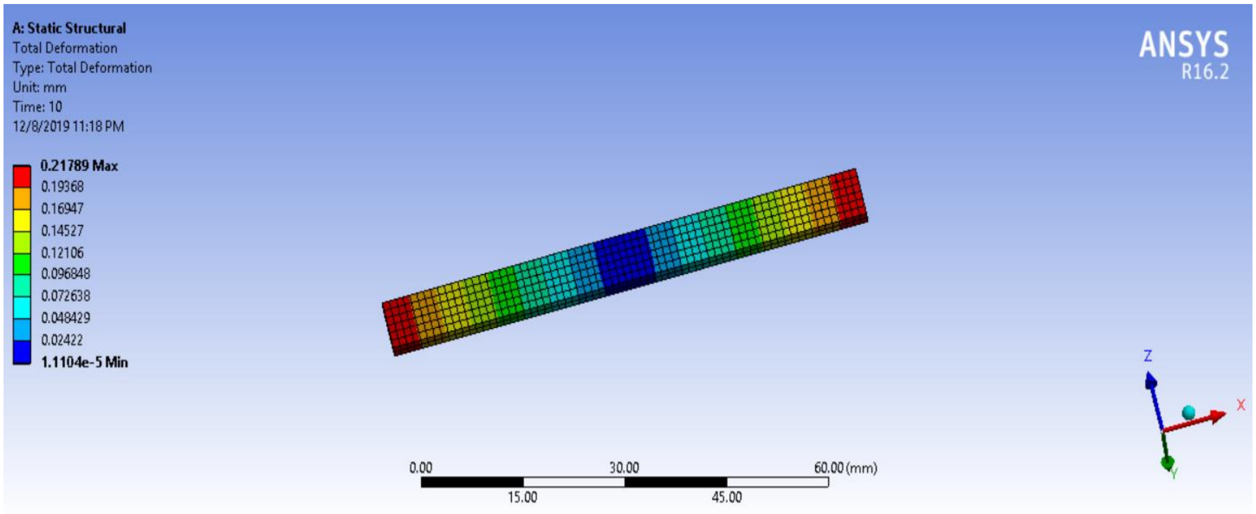

Figure 5. Deformation in composite in compressive load

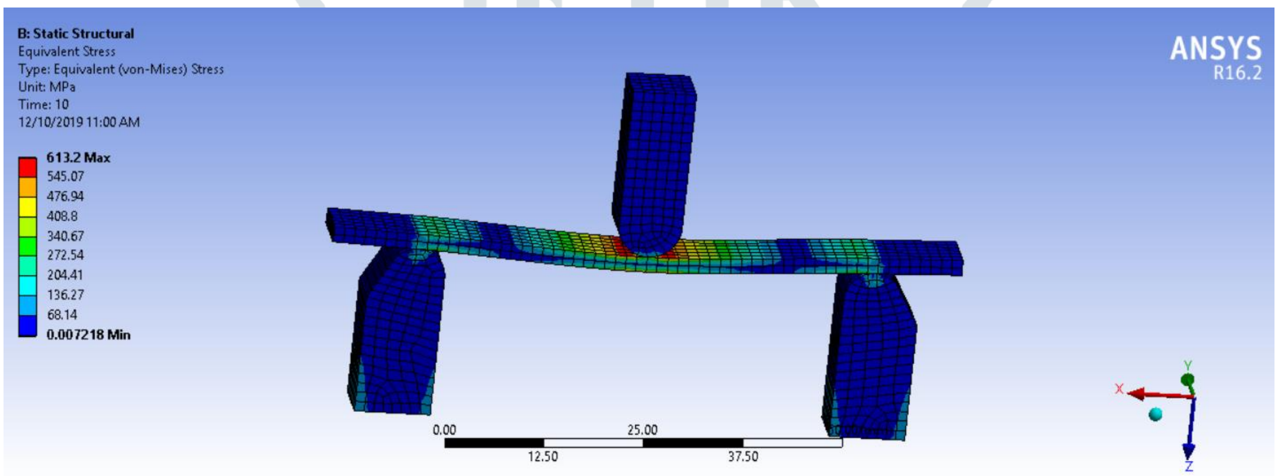

Figure 14. Bending strength of the composite material

Conclusion

From the theoretical analysis is done on the Ansys software using Tsai-Wu and Tsai-hill failure theory and the tensile strength comes 357.12 MPa and the tensile came out according to experimental study is around 340 MPa and deformation in the plate is .11879 mm. After comparison,the results concluded that experimental and theoretical results are nearly the same. The deformation is quite the same as the conventional results and concluded that with consideration of all the theoretical results and experimental results the study of all the results are matched and this composite material can be used in different real-life applications.

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