Mechanical Properties of Okra Fiber Reinforced Composites Using Fem

[I]James Paul.K, [II]Sd.Abdul Kalam
[I]PG Scholar, PVP Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India
[II]Associate Professor, PVP Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India

Abstract

The micromechanical analysis plays a very important role in the composite materials. These studies explore average mechanical properties of composites materials with good accuracy. The properties of any composite material depends on the constituents, loading, geometry, inter phase region and environmental conditions. The proposed work focuses on the evaluation of properties of the fiber reinforced composite material with different volume fraction under different loading conditions. The 3D finite element model with governing boundary conditions has been developed from the unit cell of square pattern of the composite to evaluate engineering constants like, longitudinal modulus (E1), transverse modulus (E2), major Poisson's ratio (v12) and minor Poisson's ratio (v21) of the fiber reinforced composite for different fiber volume fractions considering uniform and random distribution of reinforcement. The predictions of the present work are validated with analytical expressions. The present work will be useful to predict the engineering constants of uniform and random distribution of FRP composites subjected to longitudinal and transverse loading.

Keywords

Mechanical properties, Fiber, Composite materials, Finite element method, FRP composites

I. Introduction

Engineering materials are classified into three broad categories; metals, ceramics and polymers. Composites are combinations of two or more materials from one or more of these categories. One of the phases is usually discontinuous, stiffer, and stronger and is called reinforcement, whereas the less stiff and weaker phase is continuous is called the matrix. The combination results in superior properties not exhibited by the individual materials. Mostly the properties of interest in composites are the mechanical properties. A composite material is composed of reinforcement (fibers, particles, flakes, and/or fillers) embedded in a matrix (polymers, metals, or ceramics). The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. The key parameters of interest in fiber reinforced composites are specific strength and specific modulus. Specific strength is defined as the ratio of tensile strength to the specific gravity. Specific modulus is defined as the ratio of modulus of elasticity to the specific gravity. The fiber reinforced composite can be a tailor made, as their properties can be controlled by the appropriate selection of the substrata parameters such as fiber orientation, volume fraction, fiber spacing, and layer sequence. The required directional properties can be achieved in the case of fiber reinforced composites by properly selecting fiber orientation, fiber volume fraction, fiber spacing, and fiber distribution in the matrix and layer sequence. As a result of this, the designer can have a tailor-made material with the desired properties. Such a material design reduces the weight and improves the performance of the composite. Shokrieh and Ghanei Mohammadi (2010), Lei et al. (2012) and Syam Prasad et al. (2013) have developed predictive models for the uni-directional short fiber-reinforced composites and investigate the distribution effect of the short fibers. Sreedhar Kari et al. (2007), have developed predictive models for micromechanical analysis of fiber reinforced composites with various types of constituents. Harald Berger et al. (2007), Srivastava et al. (2011), Anurag Bajpai et al. (2012) and Marek Romanowicz (2013) have developed the material properties of spherical particle reinforced composites for different volume fractions upto 60%. Dragan Kreculj (2008), stresses in the models from uni- directional carbon/epoxy composite material are studied using Finite Element Method (FEM), can be used in order to predict stress distribution on the examined model.

In this paper the material properties are predicted for the uniform distribution of fiber reinforced composites and random distribution of fiber reinforced composites. The engineering constants E_1, E_2, ν_{12}, ν_{21}, ν_{13}, ν_{23} are determined for both the cases and are compared with the rule of mixtures and Halphin-Tsai criteria.

II. Methodology

The present research work deals with the evaluation of engineering properties by the elastic theory based on finite element analysis of representative volume elements of fiber reinforced composites. The fibers are arranged in the square array which is known as the uni-directional composite. And this uni-directional fiber composite is shown in figure 1.

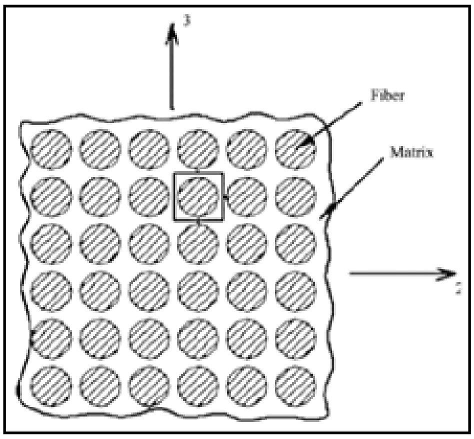

Fig. 1 : Concept of Unit Cells

It is assumed that the fiber and matrix materials are linearly elastic. A unit cell is adopted for the analysis. The measure of the volume of fiber relative to that total volume of the composite is taken from the cross- sectional areas of the fiber relative to the total cross-sectional area of the unit cell. This fraction is considered as an important parameter in composite materials and is called fiber volume fraction (V_f).

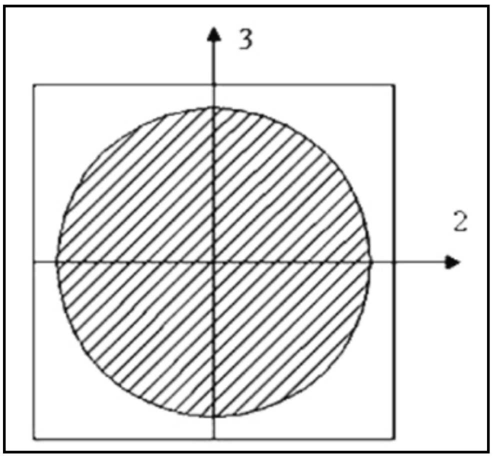

Fig. 2 : Isolated Unit Cells of square packed array

Finite Element Model

In the study of the Micromechanics of fiber reinforced materials, it is convenient to use an orthogonal coordinate system that has one axis aligned with the fiber direction. The 1-2-3 Coordinate system shown in Figure 3 is used to study the behavior of unit cell. The 1 axis is aligned with the fiber direction, the 2 axis is in the plane of the unit cell and perpendicular to the fibers and the 3 axis is perpendicular to the plane of the unit cell and is also perpendicular to the fibers. The isolated unit cell behaves as a part of large array of unit cells by satisfying the conditions that the boundaries of the isolated unit cell remain plane.

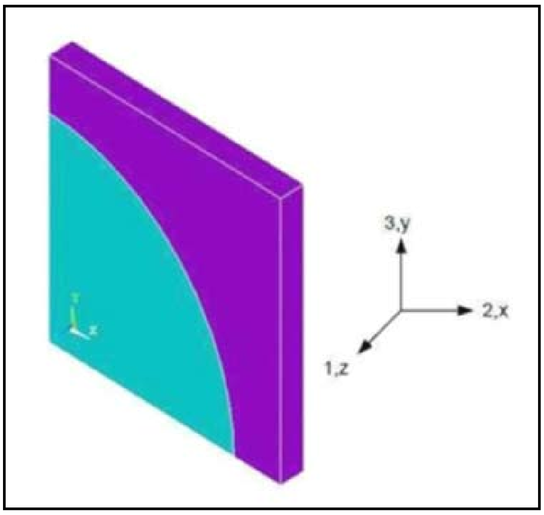

Fig. 3 : One fourth portion of Unit cell

Due to symmetry in the geometry, material and loading of unit cell with respect to 1-2-3 coordinate system it is assumed that one fourth of the unit cell is sufficient to carry out the present analysis. The 3D Finite Element mesh on one fourth portion of the unit cell is shown in Figure 4.

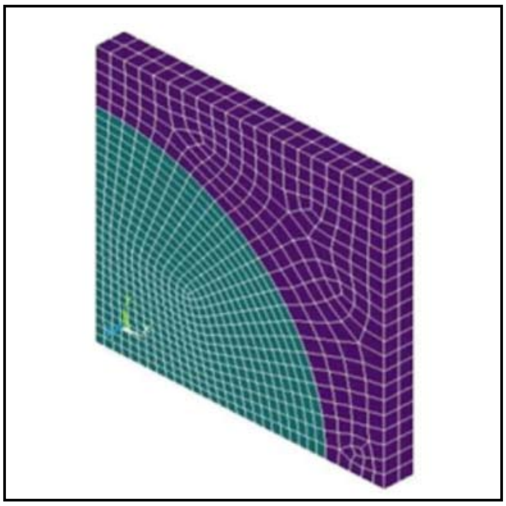

Fig. 4 : Finite Element Mesh Model

Geometry

The dimensions of the finite element model are taken as:
X = 100 units,
Y = 100 units,
Z = 10 units.

The radius of fiber is calculated is varied to the corresponding fiber volume.

Element Type

The element SOLID 20 node 186 of ANSYS V15.0 used for present analysis is based on a general 3D state of stress and is suited for modeling 3D solid structure under 3D loading. SOLID 20 node 186 is a higher-order version of the 3D 20-node solid element that exhibits quadratic displacement behavior. It can tolerate irregular shapes without as much loss of accuracy. SOLID186 elements have compatible displacement shapes and are well suited to model curved boundaries. SOLID186 has plasticity, creep, stress stiffening, large deflection, and large strain capabilities. The element has 20 nodes having one degree of freedom, i.e., temperature and with three degrees of freedom at each node: translation in the node X, Y, Z directions respectively.

Boundary Conditions

Due to symmetry of the problem, the following symmetric boundary conditions are used:
At $X = 0, U_x = 0$
At $Y = 0, U_y = 0$
At $Z = 0, U_z = 0$

In addition, the following multi point constraints are used.

- The U_x of all the nodes on the area at X=100 is same.
- The U_y of all the nodes on the area at Y=100 is same.
- The U_z of all the nodes on the area at Z=10 is same.

Analytical Solution

The mechanical properties of the lamina are calculated using the following expressions of Theory of elasticity approach and Halphin- Tsai's formulae. Young's Modulus in the fiber direction and transverse direction are calculated through

$$E_1 = {}^{\sigma_1}/_{\varepsilon_1}$$

$$E_2 = {}^{\sigma_2}/_{\varepsilon_2}$$

Major poison's ratio $v_{12} = {}^{-\varepsilon_2}/_{\varepsilon_1}$
Where;

$\sigma_1 = Stress\ in\ x - direction$

$\sigma_2 = Stress\ in\ y - direction$

$\varepsilon_1 = Strain\ in\ x - direction$

$\varepsilon_2 = Strain\ in\ y - direction$

Rule of Mixtures

Longitudinal young's modulus:

$$E_1 = E_f V_f + E_m V_m$$

Transverse young's modulus:

$$E_2 = E_f V_f + E_m V_m$$

Major Poisson's ratio:

$$v_{12} = v_f V_f + v_m V_m$$

III. Results

In the present work finite element analysis has been carried out to predict the engineering constants of uniform and random distribution fibers in fibre reinforced particulate composite. The results obtained are validated with the results obtained by Rule of Mixtures and Halpin-Tsai.

Uniform distribution of fiber (okra) in an FRP composite:
The variation of different engineering constants of a uniform distribution of okra fiber/Epoxy composite with respect to the different volume fractions is shown.

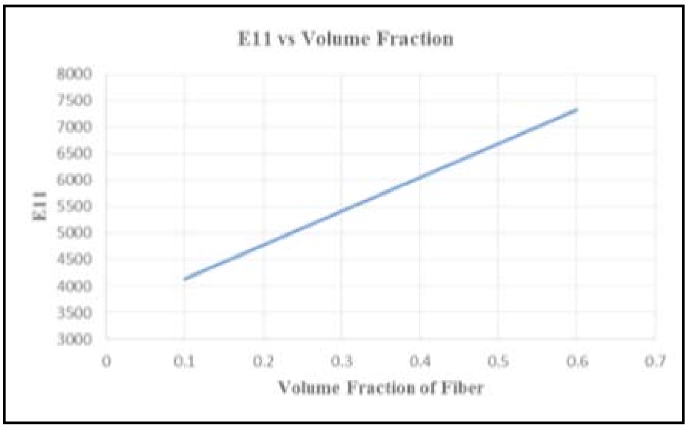

Fig. 5 : Variation of E_1 with fiber volume fraction

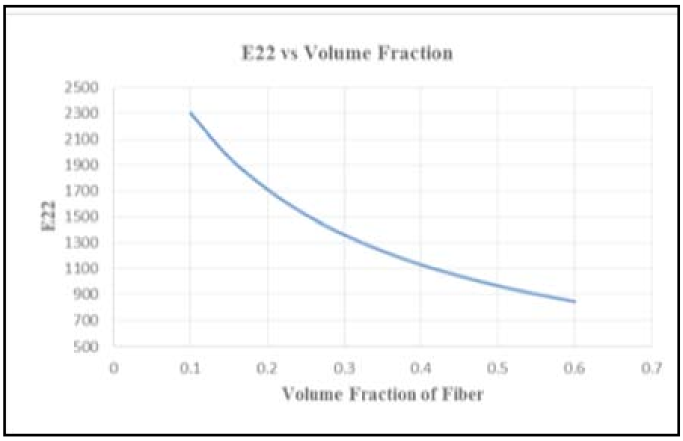

Fig. 6 : Variation of E2 with fiber volume fraction

The variation of longitudinal Young's modulus (E_1) with respect to volume fraction of fiber is observed. The response of E1 of composite material is increasing in linear manner with the variation of fiber content (V_f). This is due to the improvement in stiffness of resulting composite material (Figure 5).The variation of Transverse modulus (E_2) following the same trend as that of longitudinal modulus but in nonlinear way (Figure 6). The longitudinal Poisson's ratios v_{12} and v_{13} are yielded same response and their magnitude is decreases as the stiffness of composite material increases (Figure 7). The transverse Poisson's ratio v_{23} is decreased sharply up to 40% V_f later no significant change is observed (Figure 8). The transverse Poisson's ratio v_{23} showed different response compared with other Poisson's ratios. It is low at lower volume fractions and maintained steady response with the increment of volume fraction (Figure 9).

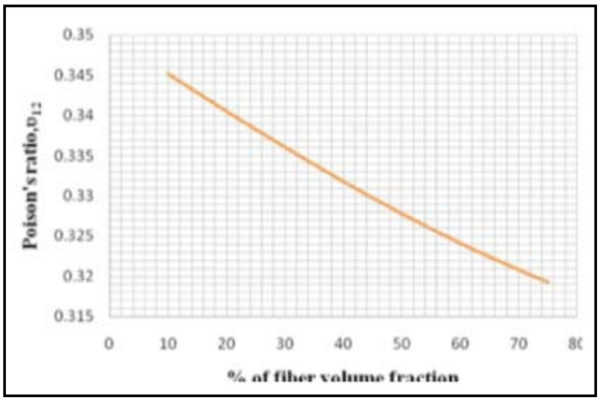

Fig.7 : Variation of v_{12} with fiber volume fraction

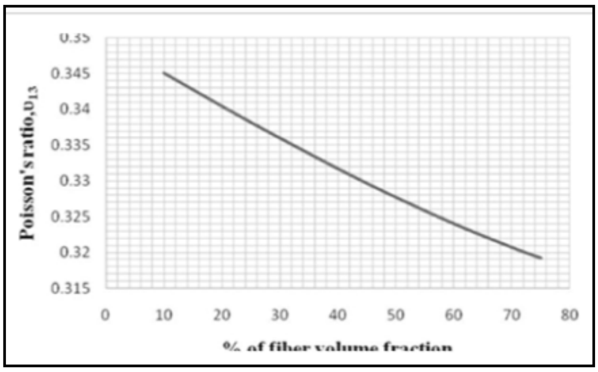

Fig. 8 : Variation of v_{13} with fiber volume fraction

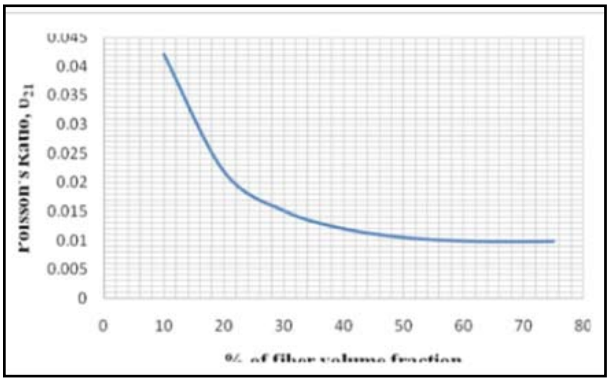

Fig. 9 : Variation of v_{21} with fiber volume fraction

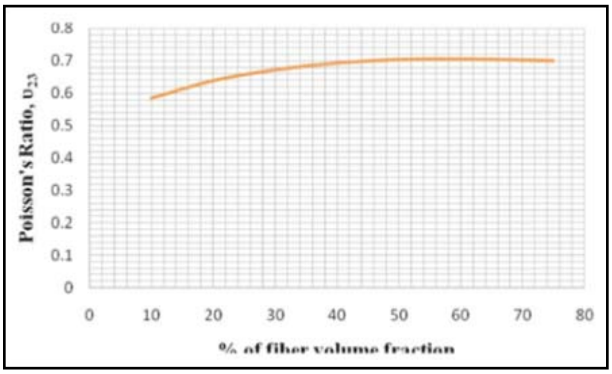

Fig. 10 : Variation of v_{23} with fiber volume fraction

IV. Conclusion

The finite element method is very useful tool to extract the average properties of composite materials. The influence of reinforcement distribution in mechanical properties of composite material is presented by adopting finite element method and micromechanics approach. Compared with uniform distribution, the random distribution of Okra fiber is significant in terms of mechanical properties particularly in transverse properties.

AcknowledgEment

I'm very thankful to PVP Siddhartha institute of Technology and Sd. Abdul kalam sir for providing me with facilities to complete my work.

References

[1]. *Shah, Shyamkumar, et al. "Effect of coal ash as a filler on mechanical properties of glass fiber reinforced material." International Journal of Applied Engineering Research, ISSN: 0973-4562.*

[2]. *N. Hameed, P. A. Sreekumar, B. Francis, W. Yang and S. Thomas, "Morphology, Dynamic Mechanical and Thermal Studies on Poly(styrene-co-acrylonitrile) Modified Epoxy Resin/Glass Fibre Composites" Composites Part A, Vol. 38, No. 12, 2007, pp. 2422- 2432.*

[3]. *Cs. Varga, et al. "Improving the Mechanical Properties of Glass-Fibre-Rein- forced Polyester Composites by Modification of Fibre Surface" Materials and Design, Vol. 31, 2010, pp. 185- 193.*

[4]. *Saha, Nirmal, and Amar Nath Banerjee. "Stress relaxation behaviour of unidirectional polyethylene-glass fibres PMMA composite laminates" Polymer 37.20 (1996): 4633-4638.*

[5]. *Matteson, Robert, and Roger Crane. "Flexural Testing of Steel Wire Composite Beams Made with Hardwire (trademark) Unidirectional Tape" no. Nswccd-65-tr 2003/48. Naval surface warfare center carderock div bethesda md, 2003.*

[6]. *Pandya B.N. and Kant T., "Finite element analysis of laminated composite plates using a higher order displacement model" Composite Science and Technology, 32 (1988): pp. 137-155.*

[7]. *Kant T. and Swaminathan K., "Analytical solutions for the static analysis of laminated composite and sandwich plates based on a higher order refined theory" Composite Structures, 56 (2002): pp. 329-344.*

[8]. *Soltani P., Keikhosravy M., Oskouei R. H. and Soutis C., Studying the tensile behaviour of GLARE laminates: A finite element modeling approach, Appl Compos Mater" 18 (2011): pp. 271-282.*

[9]. *Attallah, K. M. Z., J. Q. Ye, and H. Y. Sheng. "Threedimensional finite strip analysis of laminated panels" Computers & Structures 85.23 (2007): 1769-1781.*

[10]. *Bhar, A., S. S. Phoenix, and S. K. Satsangi. "Finite element analysis of laminated composite stiffened plates using FSDT and HSDT: A comparative perspective" Composite Structures 92.2 (2010).*

Author's Profile

James Paul K is presently a PG Schooler in Machine designing from PVP Siddhartha institute of technology Vijayawada. Author also published a paper in Elsevier journal and participates in several international conferences.