Mechanical Properties of Unidirectional and Woven Lamina FR glass composite by using Finite Element Analysis

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In this paper equivalent stress, equivalent strain, total deformation, directional deformation, and temperature distribution are calculated during performed simulated tensile test, bending test and cyclic loading of unidirectional and woven glass fabric surrounded by epoxy resin matrix using Finite Element Method. The simulation for static structural has been carried out at 22^{o} C (Room temperature) under a stress 100N in Y-direction for evaluating tensile strength and 100N in Z-direction for bending strength. Structural cyclic tests (8 cycles) have been undertaken for GFRP, at a stress ranging from 50N – 100N, time duration of each cycle consisted of 60 seconds, comprising the total analysis time 481 seconds. A temperature of 300^{o} C is employed for thermal analysis. The simulation based study for tensile strength, bending strength and temperature distribution across the GFRP unidirectional composite and GFRP woven composite inferred that, woven GFRP composite possesses better mechanical properties over unidirectional GFRP composite. All the simulations are performed by using Sparse Matrix Direct solver method ANSYS Workbench R15.0, using Augmented Lagrange method formulation in the contact region.

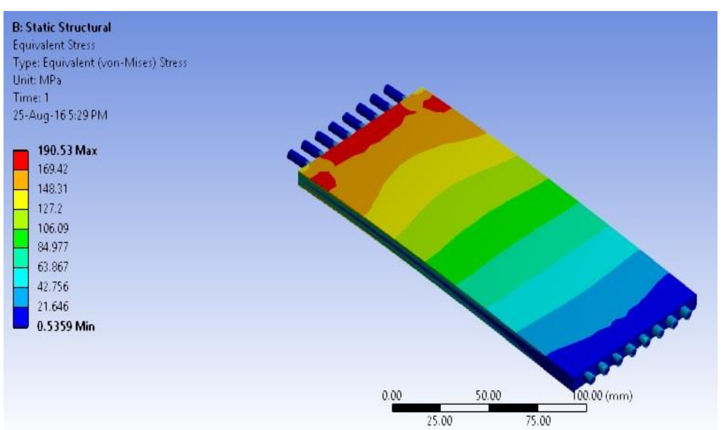

Fig: *Equivalent stress after Bending test*

Key words: *[Unidirectional Glass fabric/Epoxy composite, Woven Glass fabric/Epoxy composite, Mechanical Properties, Solver ANSYS Workbench R15.0]*

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Abstract

In this work, total deformation, equivalent stress, equivalent strain and directional deformation are calculated during performed simulated tensile test, three-point bending test and cyclic loading test of unidirectional and woven glass fabric surrounded by epoxy resin matrix (GFRP) using Finite Element Method. The simulation for static structural has been carried out at 22^{o} C (room temperature) under a stress 100N for evaluating tensile stress and 100N in Z-direction against two fixed supports for three-point bending stress. Structural cyclic tests (8 cycles) have been undertaken for GFRP, at a stress ranging from 50N – 100N. The simulation based study for tensile stress distribution and bending stress distribution across the GFRP unidirectional composite and GFRP woven composite inferred that, woven GFRP composite possesses better mechanical properties over unidirectional GFRP composite. All the simulations are performed by using Sparse Matrix direct solver method ANSYS Workbench R15.0, using Augmented Lagrange method formulation in the contact region.

Introduction

- Glass fiber reinforced polymer (GFRP) composite is widely used because of their high strength, light weight, chemical resistant property and low cost.
- The mechanical behavior and properties of composite material is depend on fiber strength and modulus, matrix strength, effectiveness of bonding between fiber and matrix, fiber laminated in the matrix, fiber orientation and composition of fiber and matrix.
- Finite element analysis (FEA) have variety of application because of their huge advantages such as no geometric restrictions, application of various boundary conditions and types of loadings are not restricted. Hence, it can be apply for any field of problems like stress analysis, heat transfer, magnetic field and so on.
- In the current FEA study, Representative volume element (RVE) model has been considered.

Objective

- To study the behavior of unidirectional and woven GFRP composite under the different mechanical performances by using finite element analysis.

Simulation Details

- Simulation details include selection of analysis type, geometry preparation, meshing and mechanical tests set-up.
- Here, static structural analysis has been selected as analysis type for all tests.
- Geometry has been prepared for both unidirectional and woven GFRP composite as shown in fig. 1.

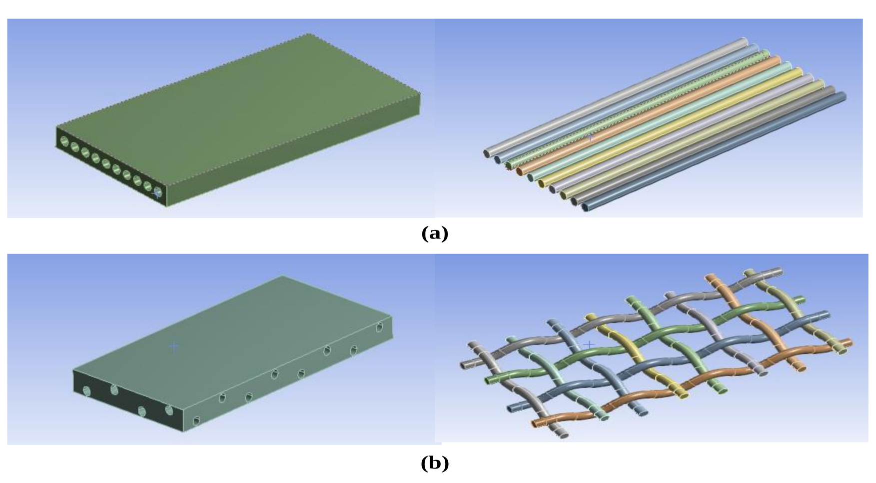

Fig. 1: Geometry of (a) unidirectional and (b) woven GFRP composite

- Subsequently meshing is done, fig. 2 shows meshing of unidirectional and woven GFRP composite.

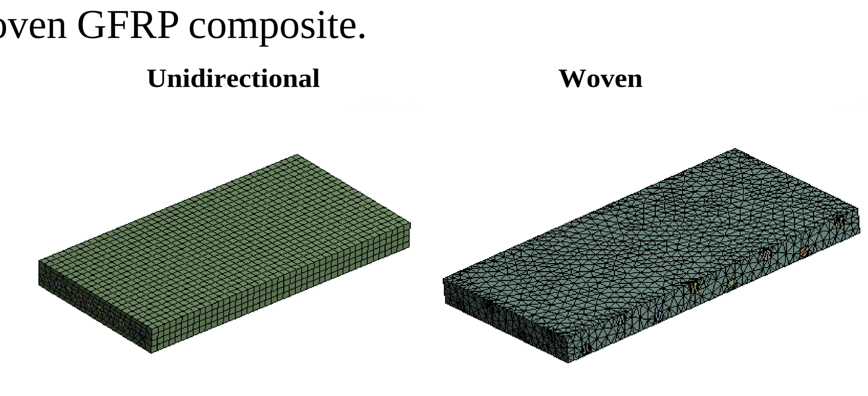

Fig. 2: Meshing of (a) unidirectional and (b) woven GFRP composite

- In the tensile test, 100 N tensile force is applied to RVE model as shown in Fig. 3.

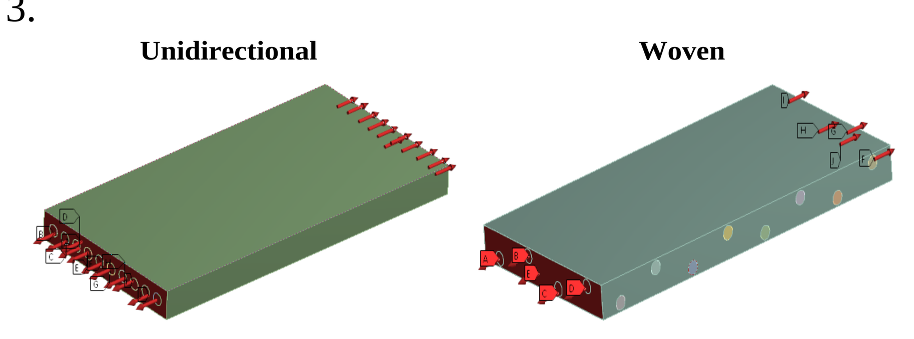

Fig. 3: tensile test set-up of (a) unidirectional and (b) woven GFRP

- 100N force in Z direction is applied against two fixed support in 3-point bending test as shown in fig. 4.

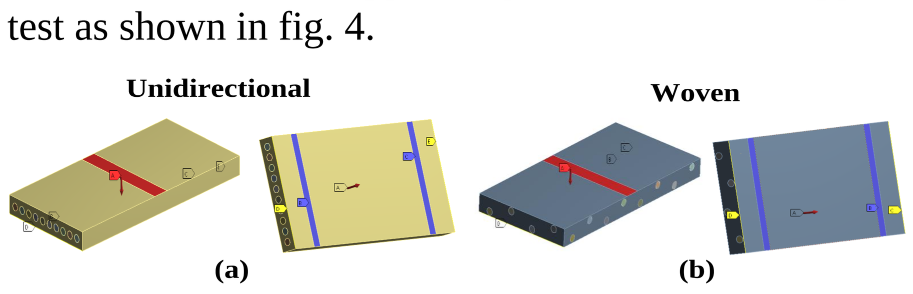

Fig. 4: Three-point bending test set-up of (a) unidirectional and (b) woven GFRP

- In cyclic loading test, repetitive tensile force 50-100N is applied in number of cycle 8.

Result and Discussion

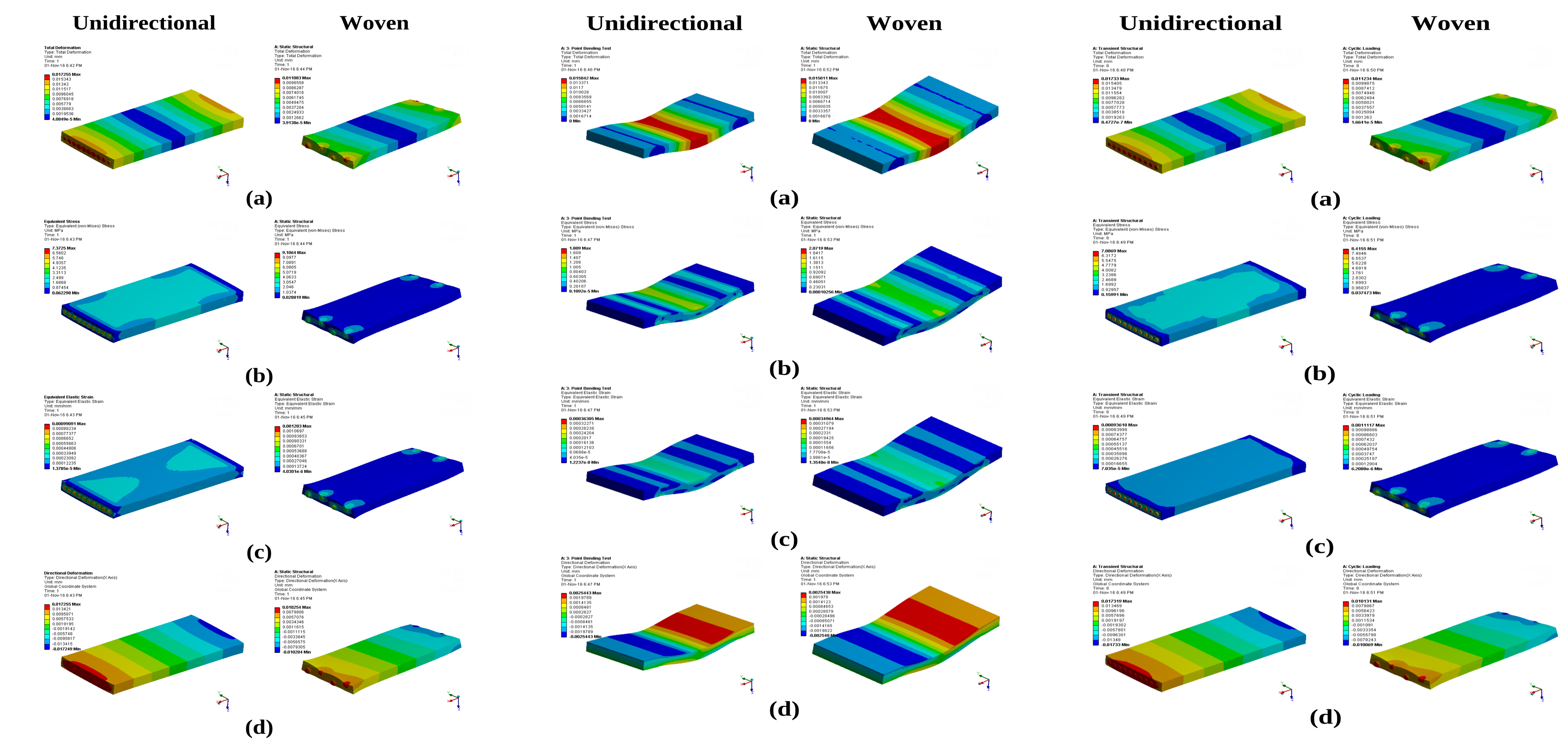

Fig.5: Tensile test **Fig.6:** Three-point bending test **Fig.7:** Cyclic loading test
(a) Total deformation, (b) Equivalent stress, (c) Equivalent elastic strain, (d) Directional deformation

Graphs and Plots

Results	Total deformation (mm)		Equivalent stress (MPa)		Equivalent elastic strain		Directional deformation (mm)	
GFRP structure	Unidirectional	Woven	Unidirectional	Woven	Unidirectional	Woven	Unidirectional	Woven
Tensile test	0.0172	0.011	7.37	9.11	0.0009	0.0012	0.0173	0.0102
3-point bending test	0.0150	0.015	1.80	2.07	0.0003	0.0003	0.0025	0.0025
Cyclic loading test	0.0173	0.011	7.08	8.41	0.0009	0.0011	0.0173	0.0101

Table 1: Results obtained by performing tensile test, Three-point bending test and Cyclic loading test.

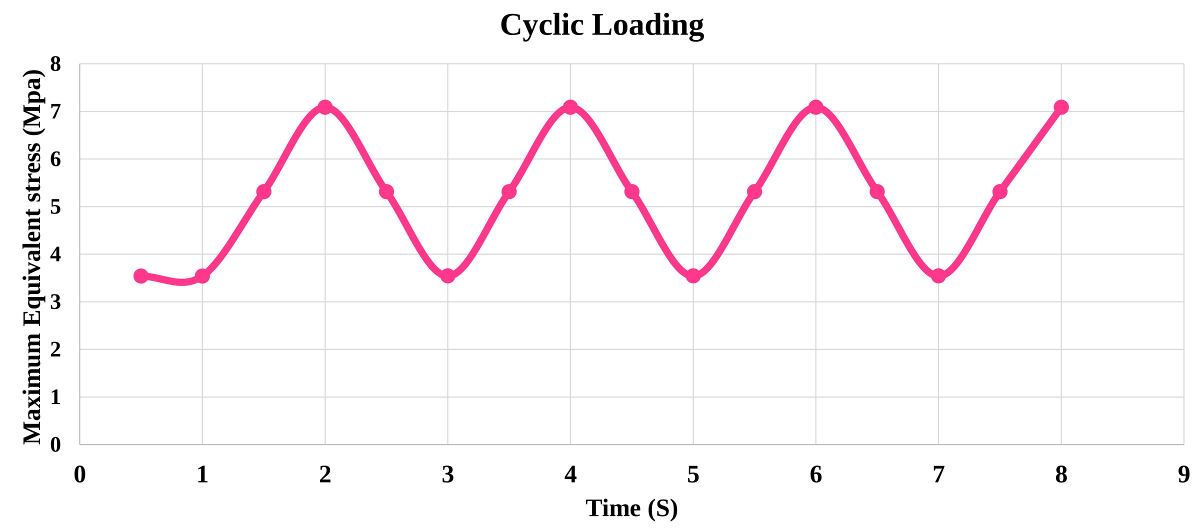

Fig. 8: Maximum equivalent stress (MPa) versus Time (s)

Conclusions

It is observed that the total deformation obtained is more uniform in unidirectional GFRP composite as compared to woven GFRP composite because of the interlocking behavior of fiber in woven GFRP composite. The maximum equivalent stress value obtained in tensile test is higher as compared to three-point bending test. In flexural test, the maximum equivalent stress value obtained is higher in woven GFRP composite than unidirectional GFRP composite. The maximum equivalent stress value and elastic strain value in both unidirectional and woven GFRP composite are slightly changes in cyclic loading test with respect to static tensile test.

Acknowledgements

We thank the Naval Research Board, DRDO, Ministry of Defense, Govt. of India (Project No. CCTM/TM/NRB/GIA/15-16/0364) for financial support.

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