Mechanical performance evaluation of woven and unidirectional GFRP composite through numerical simulation

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Abstract

In this research work, detail investigation on mechanical response of woven as well as unidirectional Glass fiber reinforced polymer (GFRP) composite has been performed using finite element analysis (FEA). Representative volume element (RVE) model of GFRP composite has been undergone different simulated mechanical tests such as tensile test by applying 160N load, three-point bending test by employing 160N against two fixed supports, cyclic loading from 0 to 160N, in-situ test at 120oC temperature, and free vibrational analysis to evaluate natural frequencies. Inter-laminar shear strength (ILSS) of woven GFRP composite has been observed by conducting Short beam shear (SBS) test. To investigate adhesive strength of unidirectional and woven GFRP composite, Peel-off test has been performed. Total deformation, equivalent stress and equivalent elastic strain are evaluated though numerical simulation using finite element method. It is observed that the total deformation obtained is more uniform in unidirectional structure composite compared to woven structure composite due to interlocking behavior of fibers in woven composite structure. It is also found that the equivalent stress value is higher in tension than three-point bending for both types of composites. The equivalent stress value is higher in case of woven GFRP composite as compared with unidirectional GFRP composite in three-point bending test. According to simulated in-situ test, maximum stress value decreases as temperature increases in unidirectional GFRP composite whereas, in woven GFRP composite variation in maximum stress value is negligible. Delamination failure of material after conducting SBS test is observed at time 45 sec for displacement 0.15mm. Material failure has been occurred at maximum load 160.512 N and the same value is assumed to calculate ILSS. By performing Peel-off test, it has been concluded that unidirectional GFRP composite structure has very low adhesive strength as compared to woven GFRP composite structure.

Key words: *Glass fiber reinforced polymer; Finite element analysis; Representative volume element; Inter laminar shear strength.*

Introduction

The properties of composite material depend on fiber laminated in the matrix, orientation of fiber and composition of fiber and matrix. GFRP composite have stiffness greater than aluminum, and specific gravity is of one quarter to that of steel [1, 2]. There are different types of fiber orientation like unidirectional structure; woven structure and chopped fiber are used to intensify various properties such as mechanical and tribological properties of composite [3]. In case of unidirectional fiber reinforced composite, practically fibers are aligned in the longitudinal orientation but their arrangement in the matrix over transverse cross section is at random orientation [4]. Woven fiber structure composites give a number of attractive properties as compared to without woven counterparts such as greater flexibility in processing options, a better resistance to fracture as well as transverse rupture because of weaving resistance, and also good impact strength [5, 6]. A true understanding of deformation behavior of composite materials and its dependence on structural variation are highly necessary. In this study, we analyze the deformation, strain and stress distribution of FRP structure composite having glass fiber distributed in two different fashions such as unidirectional and woven, under tensile loading and 3-point bending.

Simulation Methodology

Static structural analysis has been selected for tensile test and three-point bending test. Fig. (1) shows geometry of unidirectional and woven GFRP composite.

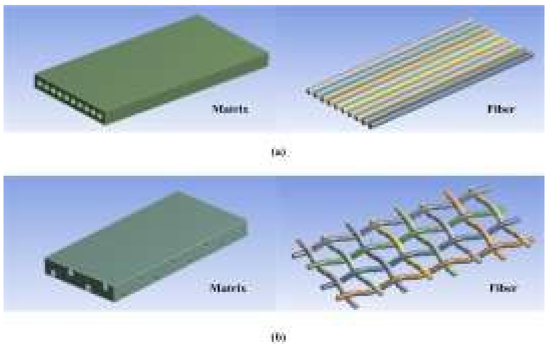

Fig. 1. 3D FE model of (a) unidirectional and (b) woven GFRP composite

Subsequently meshing is done and succeeding steps of FEA are carried out by using ANSYS Workbench solver R15.0. In tensile test, 160N uniaxial force is applied in X direction of RVE model. In three-point bending test, 160N force is applied in Z direction (downward) against the two fixed supports.

Results and discussion

Total deformation, equivalent stress and equivalent elastic strain for both unidirectional and woven composite have been shown in Fig. 2(a), Fig. 2(b) and Fig. 2(c) respectively. It is observed that unidirectional composite structure has more uniform deformation as compared to woven composite structure. Uniformity in strain distribution is observed to be higher in case of unidirectional composite structure, as the interlocking fabric structure of woven GFRP composite perturbs the homogeneity of stress as well as strain distribution.

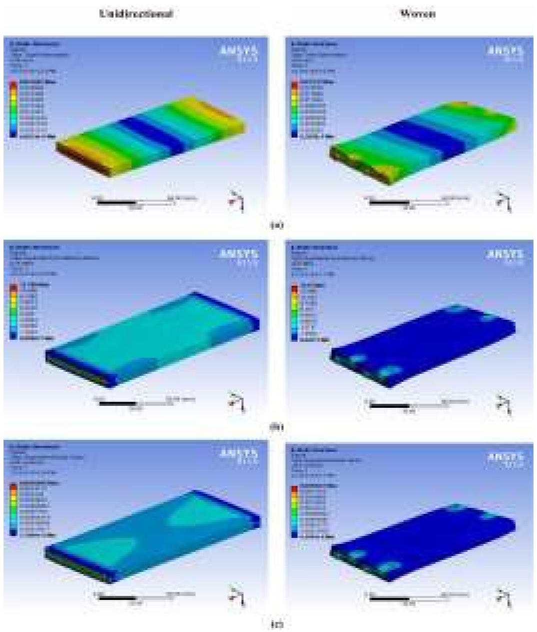

Fig. 2. Contour plots of (a) total deformation, (b) equivalent stress and (c) elastic strain of unidirectional and woven GFRP composite of tensile test

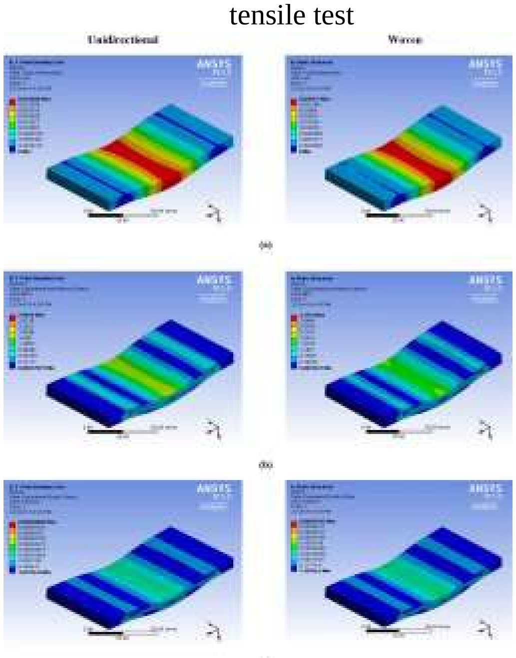

Fig. 3. Contour plots of (a) total deformation, (b) Equivalent stress and (c) Elastic strain of unidirectional and woven GFRP composite of three-point bending Test

In the current FEA simulation study, equivalent stress value in the case of flexural test is higher in woven structure composite than unidirectional structure composite. Total Deformation is slightly higher in the case of unidirectional structure as compared to woven composite structure (refer Fig. 3).

Conclusions

The total deformation obtained is found to be more uniform in unidirectional GFRP composite as compared to woven structure composite because of the interlocking behavior of fiber in woven GFRP composite. The maximum equivalent stress value obtained in tensile test is higher than the maximum equivalent stress value obtained in three-point bending test.

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