Finite element analysis and simulation of Flax/Epoxy composites under tensile loading

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ABSTRACT

Flax fiber composite has been proved to have the ability to replace the synthetic fiber in many engineering applications. Unprecedented growth in the field of computational techniques has opened the doors of analysis and simulation of the composite materials under various environment. In the present work, an attempt has been made to develop a finite element model for the analysis of mechanical strength of flax fiber composites using the software Siemens NX 10.0 student version. A 3-dimensional modelof the test specimen was developed using ply-stacking method and then the strain-stress values were verified by the available literature. The model showed a good agreement between the literature and software values.

Keywords: Tensile Test, Simulation, Flax fiber, Finite element modelling, composites.

I INTRODUCTION

It is estimated that the growth of market size of natural fiber composites is compounding year by year due to its use in various industrial applications [1]. Specific properties of the natural fiber reinforced polymer composites are greater than some of the conventional materials, which makes them favorable materials for various applications [2]. Flax woven mat is widely being used as a reinforcement in the polymer based composites to replace the synthetic fibers such as glass and carbon in some of the applications. The production of the flax fiber woven mat has increased drastically in the past decade in order to cope up with the ever increasing demand. It is a vital step to evaluate the mechanical strength of a material before using that material in an application [3]. Tensile loading, compression loading, flexural loading and bending loading or a combination of two or more than two type of loading are the common type of loading that a material can undergo in an application. With the advent of computational techniques, various simulation software platforms like Simulia Abaqus, NX Nastran and Autodesk Inventor provides the solution of the real world problems. These softwares can be used to model the natural fiber reinforced polymer composites along with simulating the behavior in various structural or thermal environments. Nirbhay et al. [4] used the finite element method to simulate the tensile test of the carbon/glass fiber reinforced epoxy composite specimens by using the Abaqus software. Author developed the shell and solid model of the test specimen. With the help of both the finite element models, authors concluded that carbon /epoxy laminates were stiffer than the glass/epoxy laminates. Some authors developed the numerical models to understand the deformation behavior of the woven and unidirectional composites. Laroche and vu-khanh [5] introduced the five types of deformation mechanism in the forming of woven fabric composites. Authors concluded that woven fabric may be considered as a two dimensional rectangular array connected by pin joint net system.Avdic and saha [6] also used the Abaqus software for the simulation of carbon fiber composite specimen under tensile loading. Authors developed shell model, solid continuum shell model and solid-solid model of the test specimens. Authors concluded that all the three developed finite element model showed the similar behavior under tensile loading environment.Thermal environment simulation is also possible using finite elements methods. Bajpai et al. [7] performed the finite element simulationof the microwave curing process of the thermoplastic based bio-composites.

II FEA- FINITE ELEMENT ANALYSIS

Siemens NX 10.0 student version was used for the finite element analysis of the fiber reinforced polymer composites in the following manner.

2.1 Part modelling and Geometry

In the present work, an available literature was used as a reference of the experimental investigation. Camellia cerbu [8] used two different flax fiber as a reinforcement each in warp and weft direction and epoxy as matrix material for the fabrication of composite material.Author investigated the behavior of the developed composites. The experimental values of the result was used to compare the accuracy of the developed model. Properties of the fiber and matrix material was used as per the referenced literature [8]. Figure 1 and 2 shows the initial condition of the specimen. Each ply is depicted by a different color for better visualization.

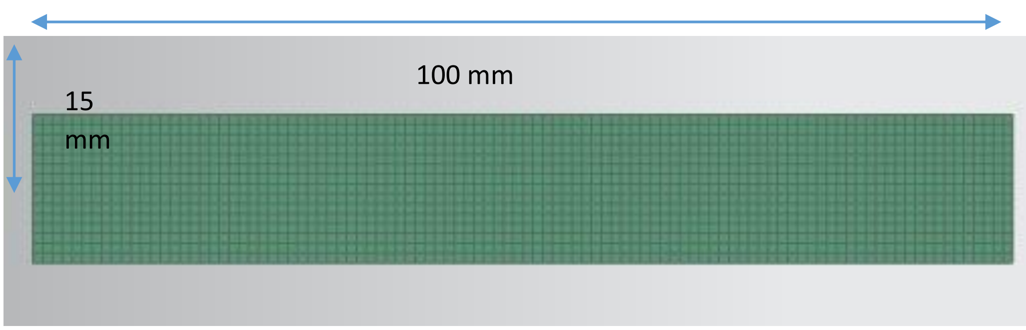

Figure 1. 2-D Meshed rectangular bar used for extrusion of laminate.

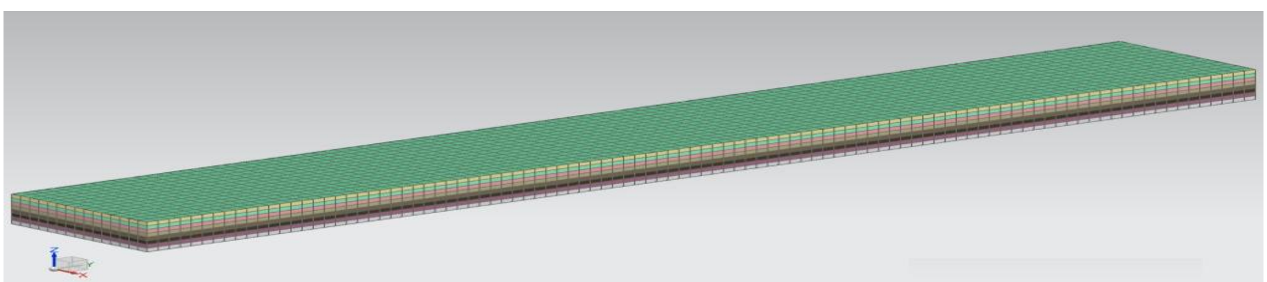

Figure 2. 3-Dimensional extruded model of 8-ply test specimen.

2.2 Boundary conditions

In this tensile test simulation, one end of the test specimen is fully fixed constrained and the load is applied on the other end of the specimen. In order to apply the constraints, first of all a face is needed on which the constraint could be applied. In this shell model, the laminate is extruded from the two dimensional meshed surface so there was no pre-existing face available. Siemens NX 10.0 student version provides an option to create a face from the mesh. 3-dimensional elements of each side was selected to make a "face from mesh".

2.3Ply-Stacking sequence

Three orientations of the plies were used to create a three types of laminates. In the first laminate L1, all the plies were stacked at 0º angle with respect to the longitudinal direction of the specimen. This sequenced laminate L1 (0, 0, 0, 0, 0, 0, 0, 0) is similar to the literature used [8] for comparing the values of tensile test simulation. Second laminate L2 was prepared by stacking the eight plies in another fashion. The effect of the orientation of plies of second laminate L2 (0, +45, 90, -45, 90, +45, 90, 0) was investigated. The third laminate L3 (0, 90, 0 90, 0, 90, 0, 90) was prepared to check the accuracy of the software used to develop the model.

III RESULT AND DISCUSSION

Laminate L1 was used to compare the elongation (change in length Δl) of the model test specimen and the specimen used by the literature [8]. Laminate L1 was modelled by using similar properties and boundary conditions as used by the referenced literature [8]. Laminate L3 and Laminate L1 are same as the stacking sequence of laminate L3 has no contribution to the material properties. This can be easily explained as the properties of the woven flax fiber mat in the longitudinal (0º) and transverse (90º) direction are same. In the second laminate L2, the directions of the some laminas are at the 45º with respect to the longitudinal direction.These laminas at 45º will definitely offer lower resistance than the laminas at 0º when the load is applied in the longitudinal direction of the specimen. The result of tensile test simulation of laminate L2 clearly shows that elongation of the L2 laminate is higher than the other two laminates. Higher elongation is a mathematical representation of the lower resistance offered by the body when the same load is applied on all three laminates. The orientations of plies of the second laminate L2 is non-symmetric, due to which the resistance offered by the above +45º layer is different than lower -45º layer. From the behavior of second laminate, it can be concluded that non-symmetric lay-up orientation results in bending of the specimen even when the load is purely tensile. Table 2 compares the change in length of the specimen during the experiments conducted by the referenced literature [8] and the elongation of the modelled specimen. Figure 3, 4, 5 shows the elongation values of the laminates under tensile test simulation when the applied load is 1.5 kN.

Table 2. Change in length of model under tensile loading.

Laminate	L1		L2	L3
	Experimental[8]	Model	Model	Model
Load	1.5 kN	1.5 kN	1.5 kN	1.5 kN
Elongation	0.25 mm	0.21 mm	0.44 mm	0.21 mm

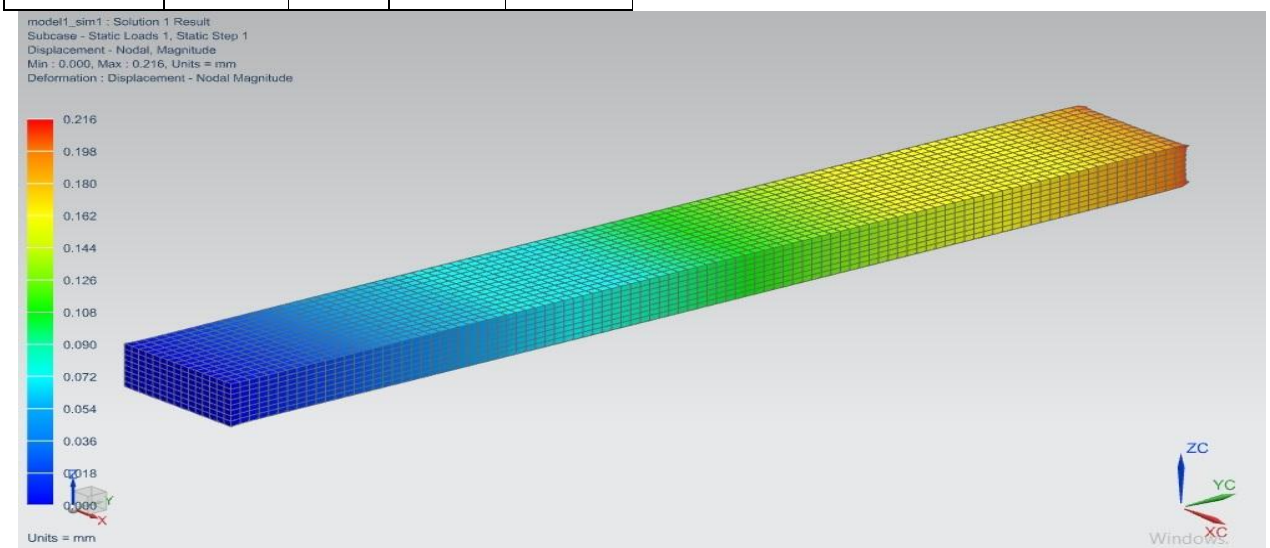

Figure 3. Elongation of Laminate L1 under uniaxial tensile loading.

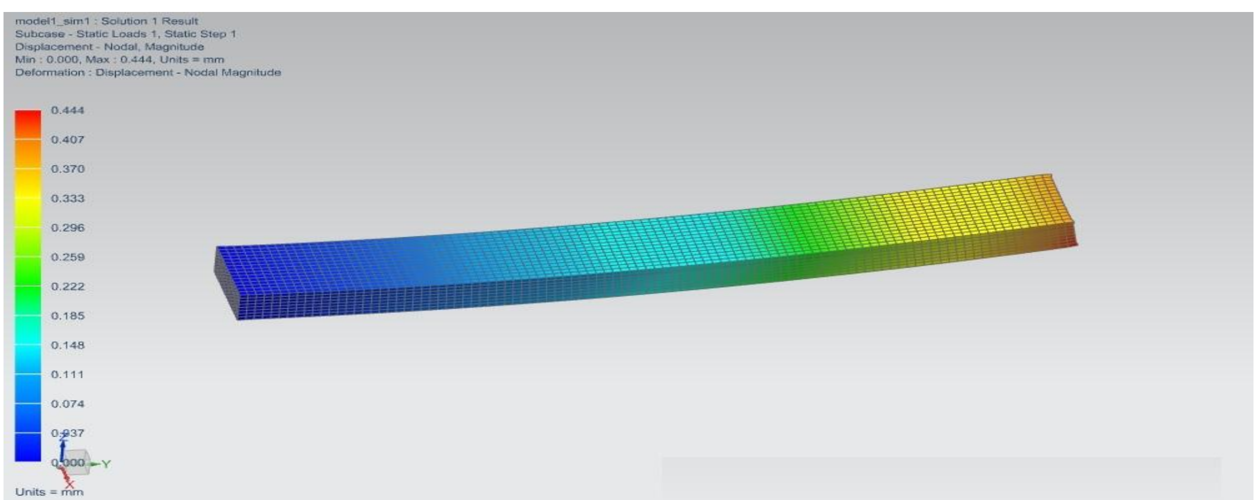

Figure 4. Elongation of Laminate L2 under uniaxial tensile loading.

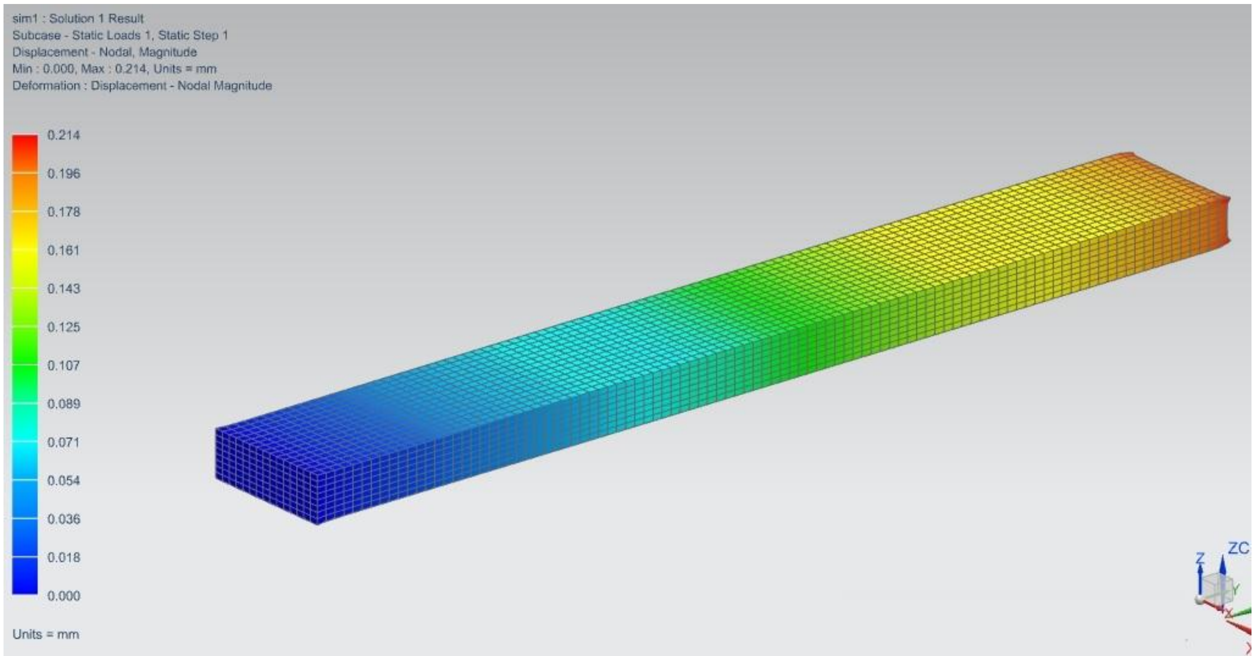

Figure 5. Elongation of Laminate L3 under uniaxial tensile loading.

IV CONCLUSION

In the present study, simulation of the tensile test of the flax fiber reinforced epoxy polymer composite was done using the software Siemens NX 10.0 student version. Shell model was extruded by applying 8 plies of flax fiber and epoxy polymer, each ply having equal thickness. Three laminates L1, L2 and L3 were developed by using the software. The displacement of the free end showed the total change in length of the specimen keeping one fixed. The study reveals the effect of ply orientation on the tensile strength of the laminate and the following significant conclusions were drawn:-

(1) The ply orientation effects the tensile strength of the natural fiber reinforced polymer composites.

(2) If a bi-directional woven mat is used in ply, the orientation 0º and 90º produces similar effect on the laminate tensile strength.

(3) The un-symmetric orientation of the plies results in the bending of the specimen even when the applied load is purely tension.

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