International Journal of Mechanical and Industrial Technology ISSN 2348-7593 (Online)
Vol. 3, Issue 1, pp: (296-302), Month: April 2015 - September 2015, Available at: www.researchpublish.com

Progressive Damage Analysis on Tensile and Flexural Strength of E-Glass Epoxy Laminates by Using Abaqus

[1]Hosamani Vijayavardhan Reddy

[1]Department of Mechanical Engineering
[1]Ballari Institute of Technology and Management, Bellary, India

Abstract: **The use of Composite material in aircraft industries is booming now-a day to grab the advantage of high strength to weight ratio. These materials are used to build main components of aircraft like fuselage, panels, rudder, and skins. It is unavoidable to provide different size, shaped cu touts in such components for different purpose i.e., inspection, maintenance. The deformed behaviour on composite plate with different loading conditions has been explored by many researchers in last 2 decades. The presented project is an attempt to summarize the issue of critically examines the current status, problems and opportunities to use of composite in aircraft industries. The loading on the fiber and the behaviour of the fiber orientation due to that loading condition is studied and upon that best orientation is decided i.e.., stacking orientation $[0,90]_S$.**

Keywords: **Fiber orientation, Epoxy resin composites, Glass fiber, laminated polymer composites.**

I. INTRODUCTION

A composite is a combination of two or more materials in which one of the materials is called the reinforcing phase which is in the form of fibres, sheets, or particles, and is embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic or polymer. Composites typically have a fibre or particle phase that is stiffer and stronger than the continuous matrix phase and serve as the principal load carrying members. The matrix acts as a load transfer medium between fibres and in less ideal cases where the loads are complex, the matrix may even have to bear loads transverse to the fibre axis. The matrix is more ductile than the fibres and thus acts as a source of composite toughness. The matrix also serves to protect the fibres from environmental damage before, during and after composite processing. When designed properly, the new combined material exhibits better strength than would each individual material. Composites are used not only for their structural properties, but also for electrical, thermal, tribological and environmental applications.

II. EXPERIENTAL DETAILS

A. Materials:

The matrix material used was medium Epoxy resin widely used in industries due to their strong adhesive properties, chemical resistance and toughness. The reinforcement material employed was E-glass which is a popular fiber. The matrix materials are epoxy resin LY556 and hardener HY951 mixed in appropriate ratio1:10 with room temperature curing cycle of 48 hours duration.

Instrumental:

The composite laminates were subjected to various loads and computer controlled UTM as shown in fig1. The specimens were clamped and tests were performed. The tests were closely monitored and conducted at room temperature. The load at which the completed fracture of the specimen occurred has been accepted as breakage load.

Fabrication:

The glass/Epoxy composite is fabricated using simple hand layup technique. The procedure consists of placing the glass fibers, layer by layer and applying liquid epoxy mixed with hardener on the glass fibers in order to form a solid network cross-linked polymer. The layup assembly is pressed with the help of roller so that excess air between the layers is expelled out. The laminate is cured at ambient conditions for a period of about 24hrs. The laminate is prepared for three different compositions of E-glass/Epoxy with a size of 300mm×300mm×4mm.

Experimentation:

The fabrication involves three different compositions of composites where the composite plates are cut down according to the ASTM standards in order to carry out tensile, flexural on each specimen.

Plan of Experiments for conducting tests:

Tensile test &3-point bending test ASTM D3039, ASTM D790 standards. ASTM standards for the above stated tests are given in Fig 2 and Fig 3 respectively.

Material properties for different volume fraction:

Bending test and tensile test is carried out for different volume percentage of E-glass/Epoxy composites. For three different series of E-glass/epoxy: Series 1- 50:50% by volume of E-glass/Epoxy, Series2- 40:60% by volume of E-glass/Epoxy, Series3- 35:65% by volume of E-glass/Epoxy. As shown in table :1

B. Figures, Graphs and Tables:

Fig 1: Computer controlled UTM.

Tensile test and3-point bending tests are carried out in accordance with ASTM D3039 and ASTM D790 standards respectively under displacement control using an UTM/E-40 with resolution of the piston movement of 0.01mm.

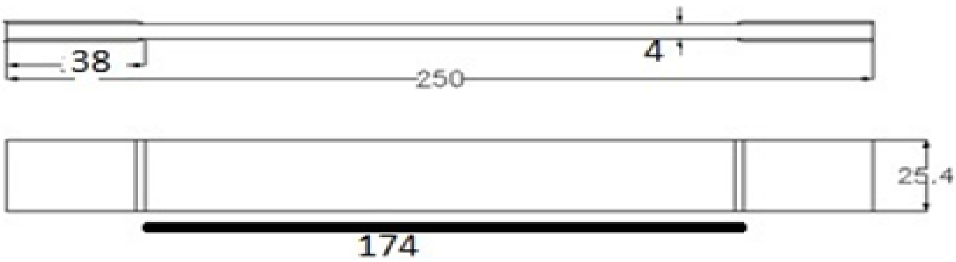

Fig 2: Tensile test specimen as per ASTM D3039 standards. All Dimensions are in mm

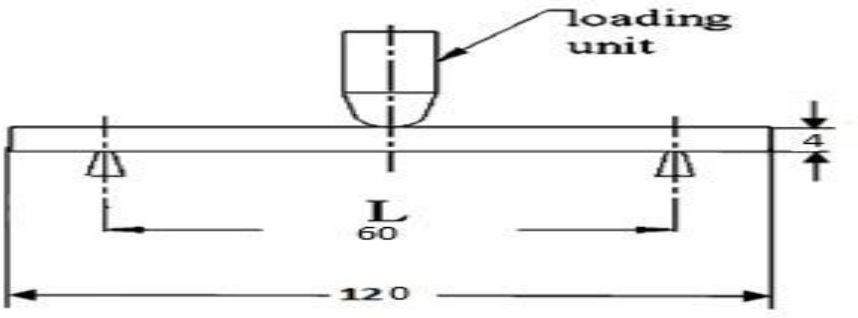

Fig 3: Flexural test specimen as per ASTM D790 standards. All Dimensions are in mm

Experimental result in tensile &flexural specimens

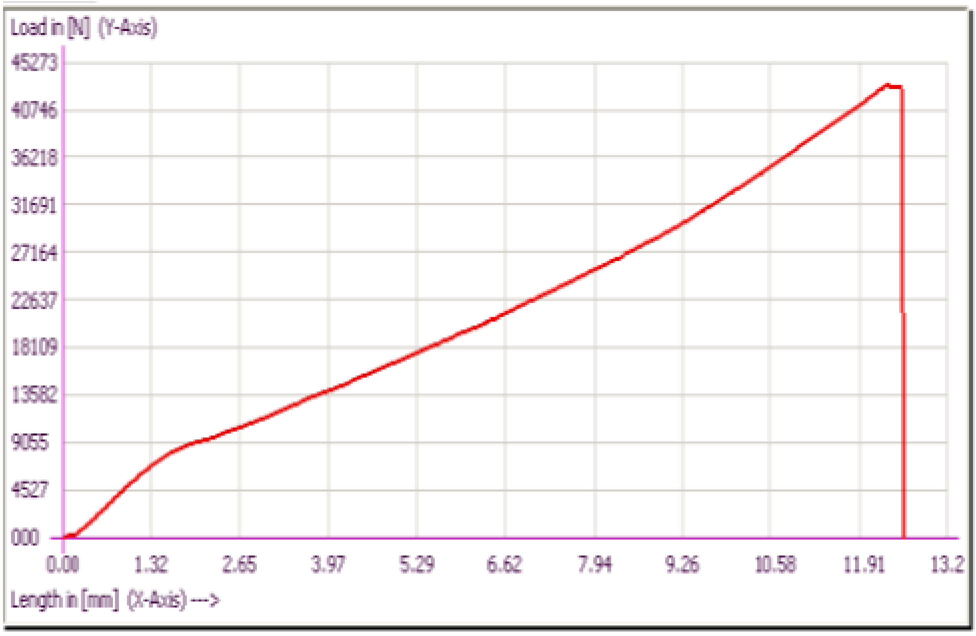

Figure 4: tensile load v/s deflection graph for E-glass epoxy specimen

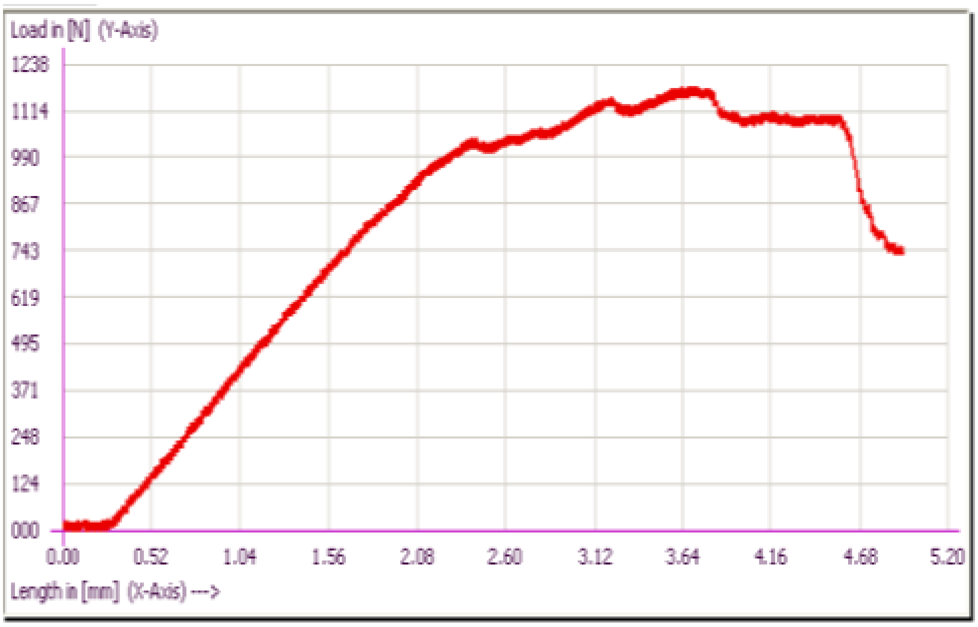

Figure 5: Flexural load v/s deflection graph for E-glass epoxy specimens

FIINITE ELEMENT ANALYSIS RESULT FOR BOTH TENSILE &FLEXURAL SPECIMENS

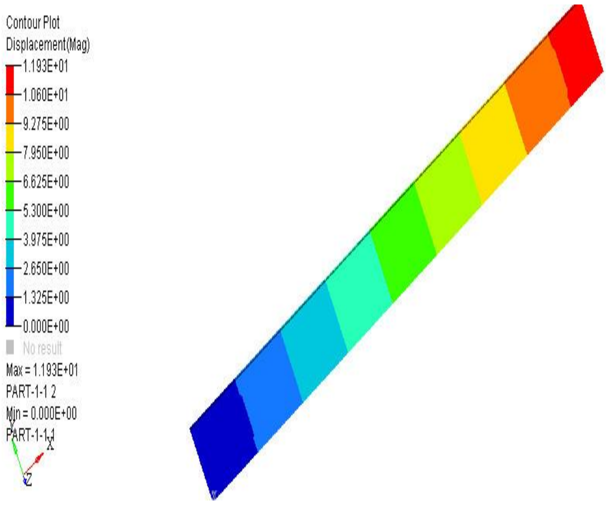

Fig 6: Displacement contour plot of the tensile specimen

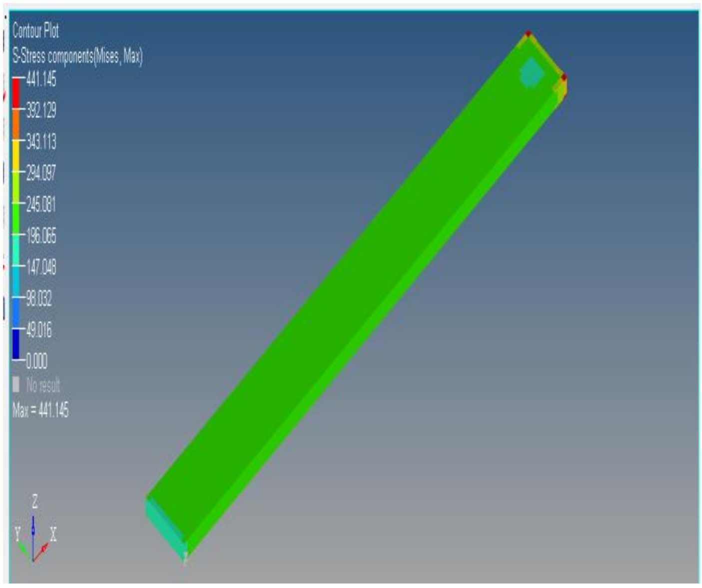

Fig 7: Stress contour plot of the tensile specimen

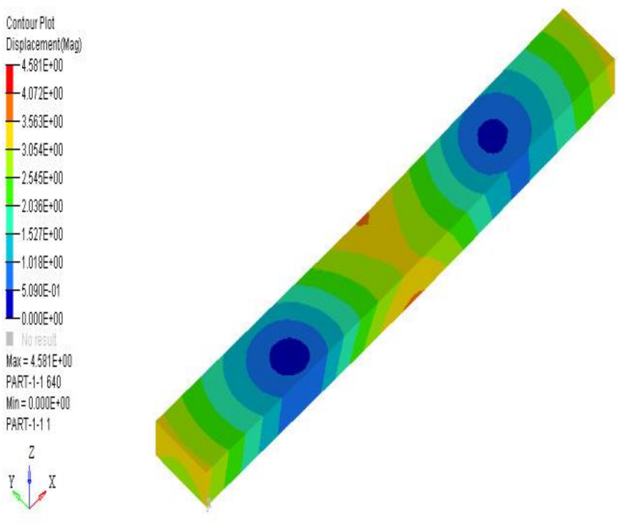

Fig 8: Displacement contour plot of the flexural specimen

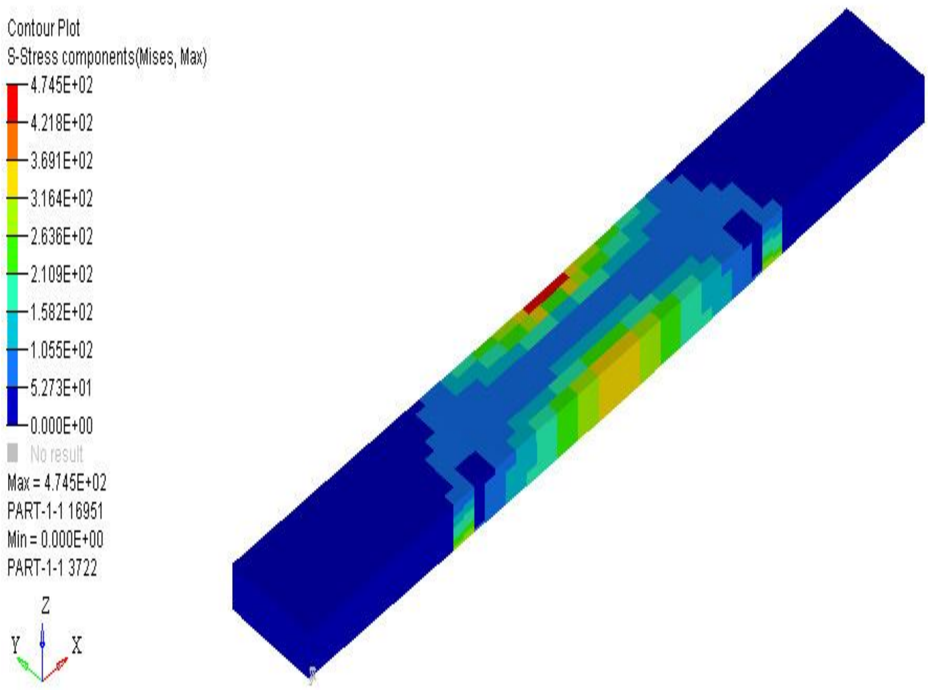

Fig 9: Stress contour plot of the Flexural specimen sample 1

Table 1: Material Property

VOLUME FRACTION	E1 IN GPA	E2 IN GPA	ν_{12}	ν_{21}	G_{12} IN GPA
50:50	38.06	7.076	0.25	0.046	3.57
40:60	31.192	5.99	0.26	0.049	2.92
35:65	27.758	5.56	0.265	0.053	2.568

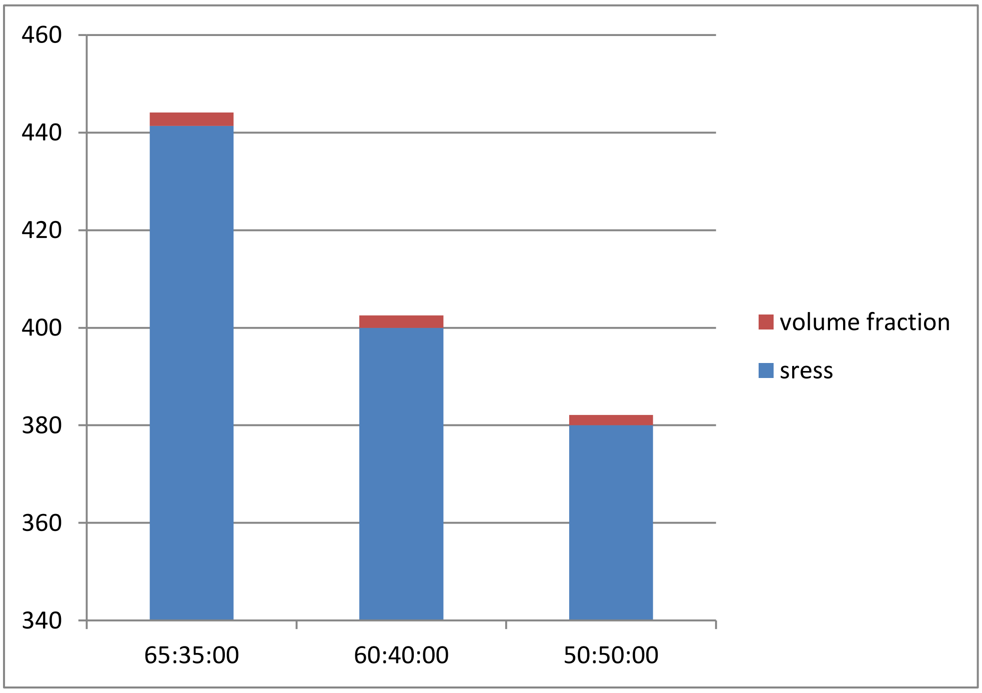

Fig 10: stress v/s volume fraction

Table: shows the values for different stacking sequence for different laminates

Laminates		Stacking sequence	Pull	Push	Bending		Pull	Push	Bending		Pull	Push	Bendi
Angle ply laminate	Displacement	[-15/+15]$_s$	147.66	51.88	210.15	Compressive	0	11.03	1.81	Tensile	94.13	11.94	67.3
		[-30/+30]$_s$	0.5	40.07	203.32		0	8.77	2.5		167.46	4.71	100.
		[-45/+45]$_s$	12.43	27.72	195.92		0	4.18	6.35		158.55	2.36	225.
		[-90/+90]$_s$	3.85	0.38	2.67		0	0.51	8.81		31.05	0	5.3
Anti-symmetric laminate	Displacement	[15/60/-60/-15]	17.81	26.39	190.14	Compressive	6.36	2.08	1.12	Tensile	6.38	2.81	5.1
		[30/60/-60/-15]	16	29.03	186.41		2.62	2.45	0.13		60.46	2.34	10.4
		[45/60/-60/-15]	13.03	20.96	175.44		0	4.31	0.72		148.65	1.75	26.2
		[90/60/-60/-15]	7	13.32	43.29		0	2.29	11.37		145.82	1.37	27.0
Cross ply laminate	Displacement	[0/15/0/15/0]	145.34	65.38	155.68	Compressive	0.56	6.03	49.89	Tensile	1.28	0.21	0.3
		[0/30/0/30/0]	64.94	78.4	111.78		0.068	22.44	46.36		0.11	3.94	1.5
		[0/45/0/45/0]	33.32	60.15	68.99		0.5	12.84	33.19		0.04	4.43	1.7
		[0/90/0/90/0]	7.07	10.9	26.92		0.01	0.04	4.16		0.01	0.01	0.3
Symmetric laminate	Displacement	[0/-15/0/-15/60]	127.72	65.35	50.62	Compressive	126.57	10.4	19.37	Tensile	0.04	35.09	5.8
		[0/-30/0/-30/60]	61.52	27.09	38.72		78.99	0.08	45.31		0.01	23.11	15.2
		[0/-45/0/-45/60]	40.71	30.44	28.78		62.96	0.73	41.03		0	36.87	14.0
		[0/-90/0/-90/60]	18.6	24.87	22.39		1.06	1.95	3.11		0.02	1.43	1.4

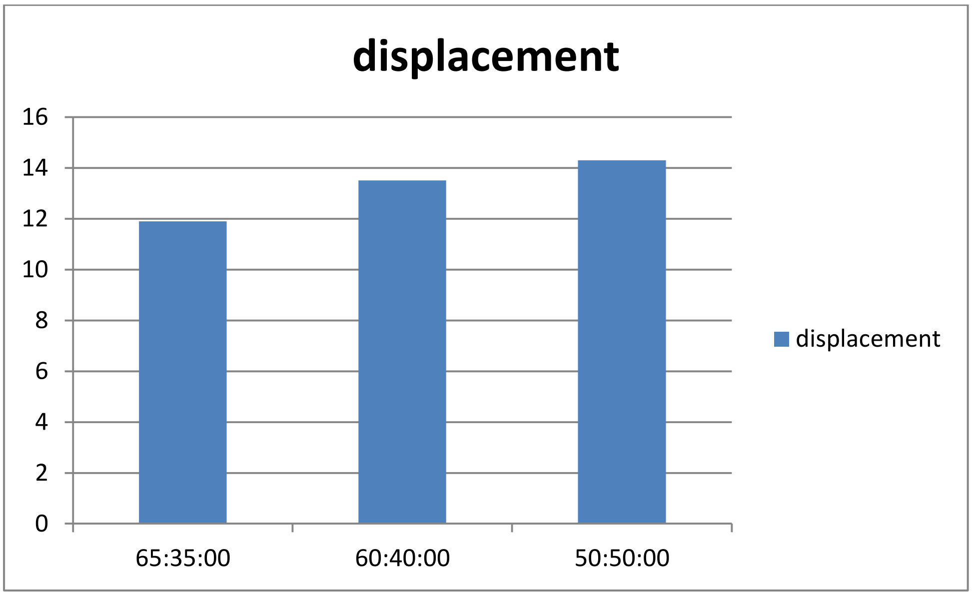

Fig 11: Comparison 0f Different Laminates

C. Conclusion Acknowledgement and Appendix

Conclusion section is mandatory and contains advantages, disadvantages, review the main part of research paper and use of research work. If author want to acknowledge someone, then acknowledgement section should include in research paper after conclusion. Appendix section (if required) appears before acknowledgement section.

III. CONCLUSION

- The deformed behavior of Glass fiber reinforced polymer subjected to bending, pull and push loading has been studied by the finite element method. Effects of various parameters on the rectangular plates with aspect ratios of 1 have been investigated.
- There are various parameters which affects the results of this study. Cutout size, Angle of cutout, Specimen geometry (plate), Thickness, Fiber types, Stacking sequences (no. of ply), Ply angles, Loading condition.
- Based on the findings, the following conclusions and recommendations have been made:

- The deformed load increases with small ratio with the increase the angle of orientation i.e., 0^0 to 90^0.
- The optimal fiber angle ɵ for the [+ 0/90] composite plates with the analysis using the in-plane shear formulation and the hashin's failure theory is quite different from that obtained using the deformed analysis.
- E-glass/epoxy having cross ply laminate has less stress and displacement when compared with the other stacking orientation.

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