Progressive Damage Analysis of E-Glass Epoxy Composite Laminates

Adil Ahmed. S[1], Dr. N. S. PrasannaRao[2], Dr. P. L. Srinivas Murthy[3], Manu. N[4]

[1]Assistant prof, Mechanical department, M S Engineering College, Bangalore, Karnataka, India
[2] Professor, Mechanical department, MSRIT, Bangalore, Karnataka, India
[3] Professor, Mechanical department, MSRIT, Bangalore, Karnataka, India
[4]PG Scholar, Mechanical department, M S Engineering College, Bangalore, Karnataka, India.

Abstract: Prediction of damage behavior of composite laminates finds more importance and this is the challenging task for researchers in present days. Progressive damage analysis of e-glass epoxy fibers is outlined in this paper. Finite element analysis of e-glass fiber reinforced composite is performed. Tsai-hill failure theory has been considered in the methodology for progressive failure analysis. Here e-glass fibers are woven and hand layup technique is used for the preparation of plates. Experimental and finite element analysis is performed. It has been found that the results obtained via the progressive failure analysis correlate reasonably well with the experimental results.

Keywords: *Progressive damage analysis, finite element analysis, e-glass epoxy, failure theory.*

1. INTRODUCTION

Composite materials are one of the leading fields where research is going on frequently and continuously. As a result of research many advanced materials with increased strength have been evolved. Usually these composite materials find their existence in the followingfield aerospace, automobile, marine and civil engineering applications due to their superior properties over conventional engineering materials such as metals.

High strength and stiffness to weight ratio has attracted the aerospace industries [1]. With the use of composite materials advantages such as less cost, increased strength, less weight, high stiffness can be seen.

Carbon fiber fuselage structures are expected to be realized with future generations of aircraft. Such applications of composite materials are expected to reduce the weight of aircraft structures by about 30-40% and to reduce the cost about 10-30% as compared to the conventional metallic structures [2-4].

Prediction of damage behavior of composite laminates finds more importance and this is the challenging task for researchers in present days.

Finite element method, a numerical approach used to replace the structural testing to predict the progressive damage of laminates and failure modes. The ability to predict the initiation and growth of crack (damage) in the composite structures is required to evaluate performance and to create safe designs as per the requirement. Quasi-brittle failure is most common failure seen in composite materials [5]. Under normal operating condition many materials fails due to the propagation of crack.

In this paper, a progressive failure analysis of composite laminates using finite element analysis is developed for predicting the failure of brittle fibre reinforced composites under static condition. A stress-based failure criterion has been employed in the progressive failure algorithm for modelling material nonlinearity in composite laminates [6]. Woven glass/epoxy panels are fabricated and tested experimentally for comparison and validation with the numerical results [7].

2. COMPRESSION TESTS

Experiments were conducted to evaluate the performance of the woven panels made of C-glass/epoxy subjected to compression load.

Glass epoxy flat panels with and without centrally located circular cut-out which consists of eight layers with different fibre orientations were fabricated using the hand lay-up technique and were cured at room temperature [8].

Four types of flat rectangular symmetric composite panels with and without cut-outs were fabricated. The stacking sequence and fibre orientations studied are as listed in following table.

Table 1: Stacking sequence and fibre orientations of panel A, B, C and D

Sl no	Panel	Type of glass-epoxy
1	A	Glass/Epoxy composite panel without cut-out- [0/90]2s
2	B	Glass/Epoxy composite panel with cut-out- [0/90]2s
3	C	Glass/Epoxy composite panel without cut-out- [45/-45]2s
4	D	Glass/Epoxy composite panel with cut-out- [45/-45]2s

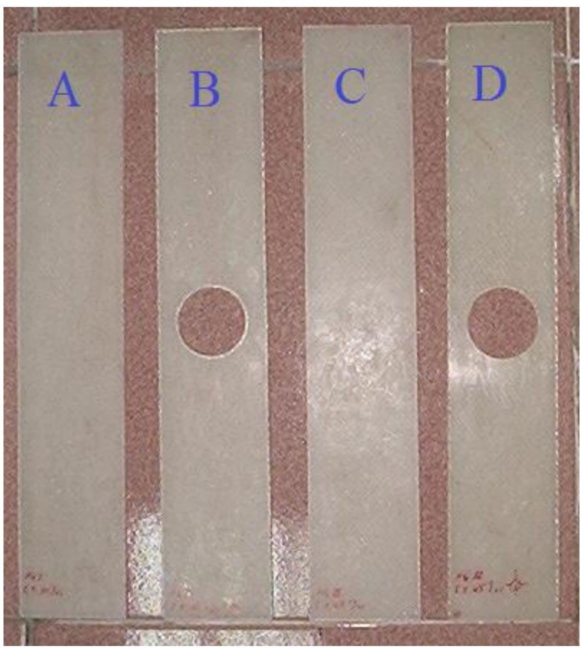

Fig 1:Specimens for experimental test

Figure 1 shows the specimens fabricated. Figure 2 shows the schematic view of geometry of fibre glass laminated panels containing a central circular hole with length *l*, of 320 mm, width *w*, of 60 mm, average thickness *t*, of 2.5 mm, and the cut-out diameter of 38 mm. Effective length of specimen is 210 mm. the specimens with cuts have the same dimension as specimens without cuts.

The fiber glass laminates are subjected to uniaxial compressive loads as shown in fig 3. Load (P) is applied in Y-direction. Bottom and top ends of the component are clamped.

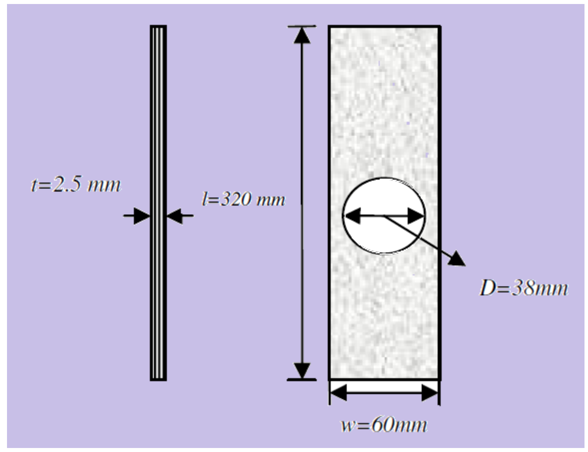

Fig 2 Specimen dimensions

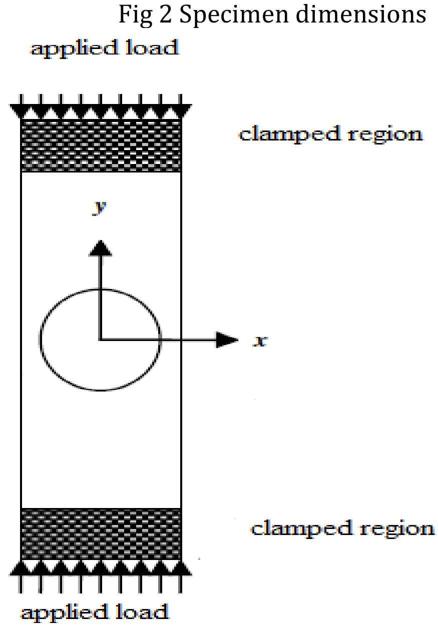

Fig 3Boundary conditions and loading conditions

Fig 4 Compression of specimen

Fig 4 shows the experimental setup for uniaxial compression. Where the damage properties are simultaneously seen and plotted.

3. FEA FOR PROGRESSIVE FAILURE ANALYSIS OF SPECIMEN

In general FEA involves following steps

- Preparation of model
- Meshing of model
- Deck preparation
- Processing
- Visualization

Preparation of CAD model in CATIA V5R19, CATIA is one of the modeling software which is used in most of the design industries. Meshing deck preparation are carried in ANSA. ANSA stands for Automatic Net-generation structural analysis software. The important step is processing here ABAQUS CAE6.10 is used for solving purpose and visualization is carried in ABAQUS Visualization tool only.

Deck preparation involves creation of material properties, providing thickness, loading and boundary conditions. Elements at both the ends are allowed for load application so that deformation can be seen clearly at the midsection.

Finite element model prepared for progressive damage analysis of e-glass epoxy laminates with cuts (panel A and paned C) and without cuts (panel B and panel D) are shown in fig 5 and fig 6. The component is divided into finite number of quadratic elements [9].

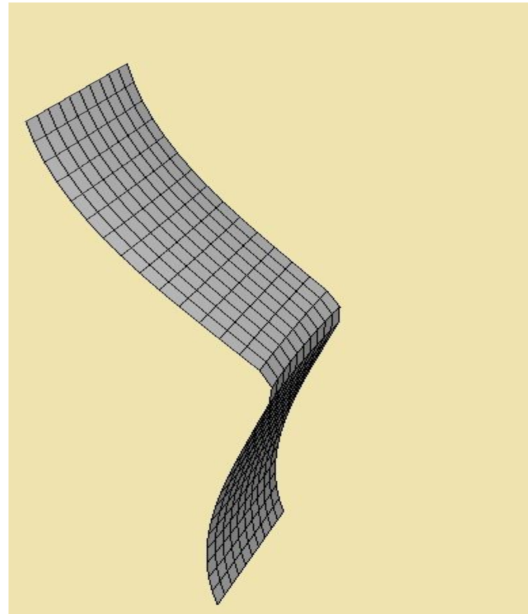

Fig 5 Deformed view of glass epoxy specimen without cuts

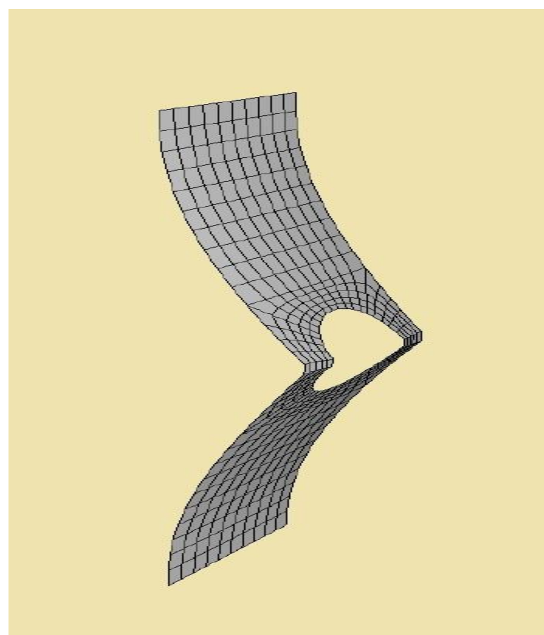

Fig 6 deformed view of glass epoxy specimen with cuts

4. RESULTS AND DISCUSSION

Results are called while deck is prepared in output block as displacement which provides the complete pictorial view of component. When load is applied at both ends of the component in uniaxial compression mode the deformation will be seen as shown in fig 5 for specimens without cuts and in fig 6 for specimen with cuts.

For specimen (panel A, panel B, panel C, panel D) the results of both experimental and FEA are plotted which is shown below.

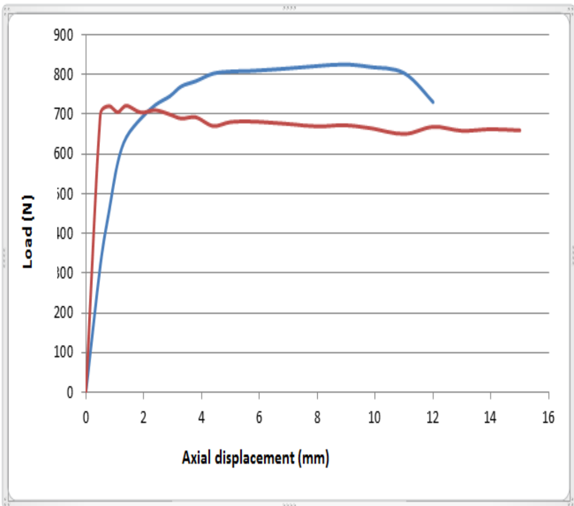

Fig 7 load v/s axial displacement

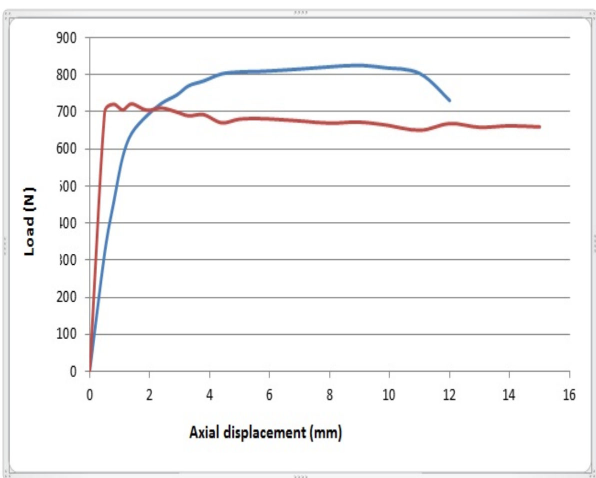

Fig 8 load v/s axial displacement for panel B

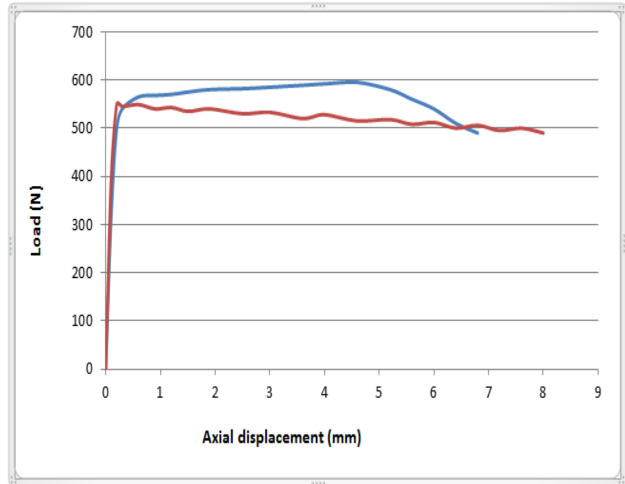

Fig 9 load v/s axial displacement for panel C

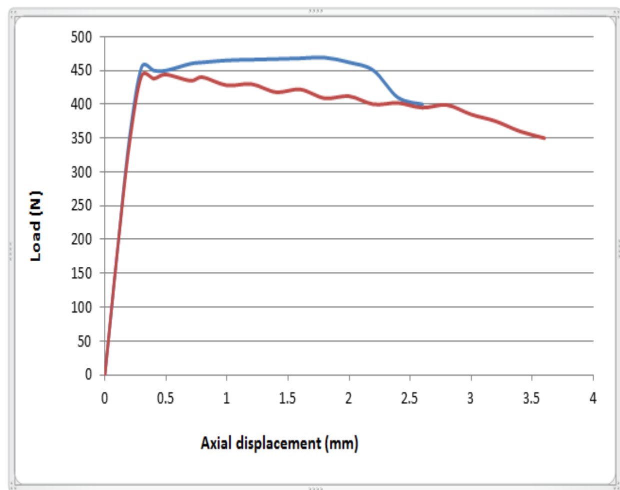

Fig 10 load v/s axial displacement for panel D

5. CONCLUSION

Specimens for progressive damage analysis of e-glass epoxy laminates are developed for non-linear static Finite element analysis. By observing the results it is found that the strength/load bearing capacity of components mainly depend on the orientation of woven specimen. Tsai-hill failure theory is employed for predicting the damage of component.

Results obtained from both FEA and Experiments are almost similar. With this it is concluded that accuracy of progressive damage analysis.

REFERENCE

1. Ambur, D.R., Jaunky, N., Hilburger, M.W., 2004. Progressive failure studies of stiffened panels subjected to shear loading, Composite Structures, 65, 129-142.
2. Rizal ZahariJurnalMekanikal June 2008, No. 25, 80 – 91.
3. Goyal, V.K., Jaunky, N.R., Johnson, E.R., Ambur, D.R., 2004. Intralaminar and interlaminar progressive failure analyses of composite panels with circular cutouts, *Composite Structures*, 64, 91-105.
4. Reddy, YSN, Moorthy, CMD, Reddy JN, 1995. Non-linear progressive failure analysis of laminated composite plates, *Int. J. Non-Linear Mechanics*, 30,629-649.
5. Yidris, N., 2007. Crash simulation of a composite unmanned aerial vehicle fuselage, *MSc Thesis*, University Putra Malaysia.
6. ShiladityaBasu, Anthony, M., Waas, Damodar, R., Ambur, 2007. Prediction of progressive failure in multidirectional composite laminated panels, *International Journal of Solids and Structures,* 44, 2648-2676.
7. ShiladityaBasu, Anthony, M., Waas, Damodar, R., Ambur, 2006. Compressive failure of fiber composites under multi-axial loading, *Journal of the Mechanics and Physics of Solids*, 54, 611-634.
8. Lee, JD., 1982. Three dimensional finite element analysis of damage accumulation in composite laminate, *Computers & Structures*, 15, 335-350.
9. ABAQUS6.10 user manual 2012
10. Padhi, GS, Shenoi, RA, Moy, SSJ, Hawkins, GL., 1998. Progressive failure and ultimate collapse of laminated composite plates in bending, *Composite Structures*, 40, 277-291.
11. Tsai, S.W., 1968. *Strength theories of filamentary structures in Fundamental aspects of fibre reinforced plastic composites*, Schwartz, R.T. and Schwartz H.S., Eds., Wiley Interscience, New York, 3.

BIOGRAPHIES

Adil Ahmed S is Assistant Professor of Mechanical Department at M S Engineering College, Bangalore. He has completed M-Tech at Gousia College of Engineering and presented journal papers in international research journals. He has teaching experience of 16 years and 1 year industrial experience. His area of interest is composite and smart materials.

Dr. N S PrasannaRao is Professor in Mechanical Department at MSRIT. He has 21 years of teaching experience. There are many international research journals with his name. His area of interest is CFD.

Dr.P L Srinivas Murthy is Professor in Mechanical Department at MSRIT. He has 29 years of teaching experience in same college. Materials are special interested field and there are many international journal papers on these.

Manu N is PG scholar (Machine Design) Mechanical Department, M S Engineering College, Bangalore. He is interested in under water acoustics and automotive engineering.

