Research Paper

STRESS CONCENTRATION AND FAILURE ANALYSIS OF DOUBLE NOTCHED COMPOSITE PANEL

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ABSTRACT

Many components fail during operation due to the phenomenon of stress concentration. In this paper the experimental and numerical studies were conducted to investigate the stress concentration around a cutout in composite panel. By the application of PhotoStress coating material, the stress measurements were performed in the vicinity of the notches. The stress at the edge of the notch is peak stress into the composite panel. These peak stresses were divided by the corresponding nominal far field stresses to obtain the stress concentration factors for specimen loaded in compression.

A mesh of quadrilateral elements was used to model specimen with double notches. The two dimensional finite element simulations were performed using ABAQUS general-purpose computer program. The experimental results of peak stress or maximum stress were compared with finite element solutions performed on the specimen geometries and loadings similar to the ones used in the experiments. The stresses were used to calculate the stress concentration factors.

KEYWORDS- ABAQUS, Composite panel, Finite element, PhotoStress coating, Simulation, Stress concentration.

1. INTRODUCTION

The constituents of a composite are generally arranged so that one or more discontinuous phases (generally fibers) are embedded in a continuous phase. The discontinuous phase is termed the reinforcement and the continuous phase is the matrix. In general the reinforcements are much stronger and stiffer than the matrix. Both constituents are required, and each must accomplish specific tasks if the composite is to perform as intended. Unlike conventional engineering materials, a composite material is generally non-homogeneous and does not behave as an isotropic material. Composite materials typically exhibit many local failures prior to rupture. The first failure does not necessary correspond to final failure. The local failures are called damage and development of additional local failures is called damage accumulation. The phenomenon of fiber micro buckling, which is responsible for the sudden degradation of the axial lamina properties under compression, is explicitly accounted by allowing the fiber rotation. This causes catastrophic failure of composites and material fails catastrophically. So work has been carried on stress concentration of composite materials.

2. OBJECTIVES:

- To develop vacuum bag molding setup and manufacture composite panel.
- To produce double notches into the panel.
- To prepare set-up for compressive loading.
- To find stresses induced for the composite plate with the help of reflection polariscope.
- Do the Abaqus software analysis.
- Find stress concentration factor.
- Compare the results of both experimental and software work.

3. COMPOSITE PANEL:

Manufacturing of composite materials is one of the most important aspects because it is going to affect the properties to the greater extent. The vacuum bag molding techniques is used for manufacturing of composite panel. This manufacturing technique reduces the void content and also volume fraction of the matrix material.

The mechanical properties determined for unidirectional glass-polyester composites with 0.31 volume fraction of matrix material are given in table 01.

Table: 01 Mechanical properties determined for unidirectional glass-polyester composite plate

E_{11}	15.713 (GPa)
E_{22}	3.067 (GPa)
E_{33}	3.067 (GPa)
v_{12}	0.253
v_{13}	0.253
G_{12}	6.27(GPa)
G_{13}	6.27(GPa)
G_{23}	6.27(GPa)

4. STRESS CONCENTRATION:

Any physical discontinuity in a structural member or a sudden change in the geometric form of a part leads to a region of stress concentration. The abrupt change in cross sections cause the stress "flow lines" to crowd causing high stress concentration. To mitigate this phenomenon, smoother changes such as fillet radii are introduced in structural members that make the "flow lines" less crowded causing lower stress concentrations. Theoretical stress concentration factor, *Kt is* defined in terms of maximum (or peak) stress, σ_{max} and nominal (or average or far-field) stress, σ_{nom} as:

$$Kt = \frac{\sigma max}{\sigma nom}$$

The value of σ_{nom} is determined by simple stress calculation formula considering minimum cross-sectional area of component as,

$$\sigma_{nom} = \frac{\text{load applied}}{\text{minimum cross-sectional area}}$$

And, σ_{max} can be determined at the edge of notch with the help photo elasticity or by FEM.

5. PHOTO ELASTICITY:

The Photo-elasticity is one of the particular methods, which can offers directly the stress-field of an analyzed model made from special, transparent materials. These materials, some polymers, present the accidental birefringence property, which consists of decomposition of the incident light (can resolves it) into two mutually perpendicular component waves, which present a delay in their oscillations (they will present different velocities). Consequently, these components will emerge from this special material at different time, or there will be a phase difference between them.

The photoelastic coating was casted according to the required dimensions and calibrated to find the strain optic coefficient. This coating material is then applied over the composite test specimen with the help of silver paint-cement. Finally coated panel is shown in fig. 01which is ready for experimentation.

Fig. 01PhotoStress coated double notched composite panel

6. EXPERIMENTAL ANALYSIS:

Test specimens with double notches were loaded in compression. The compression test specimen was loaded in Universal testing machine. The fringe pattern developed due to application of various loads is analyzed to obtain the peak stress value around the cutout. Fig.02 shows the experimental arrangement along with the reflection polariscope.

Fig.02 Experimental setup

The fringe pattern observed through reflection polariscope at the loads of 200 Kg, 400 Kg, 600 Kg and 800 Kg are as shown in fig.03. The digital compensator of reflection polariscope is adjusted in such a way that, the isochromatic(black) fringe passes throgh the point of interest (edge of the notch). The reading obtained from digital compensator is used for calculation of stress difference at the point of interest.

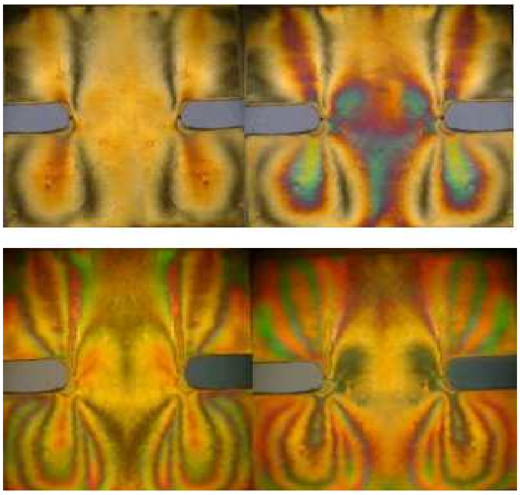


Fig.03: Fringe pattern observed at the loads of 200 Kg, 400 Kg,600 Kg and 800 Kg

The stress difference at a point is calculated by,

$$\sigma_1 - \sigma_2 = \frac{E11}{1+\nu 12} * (R1 - R0) * f\varepsilon$$

Where,

R_0= Initial reading of compensator =0

R_1 = Final reading of compensator

σ_2 = 0 (At the boundary)

$f\varepsilon$ = Strain optic coefficient

= 1272.12

In this case, the max stress occurs at the edge of notch, where σ_2 is zero and also R_0=0. The fringe order values and calculated max. Stress at the loads from 100Kg to 800Kg is given in table 02.

Table 02: Experimental stress concentration factor

Load (Kg)	Fringe order	Nominal stress (N/mm^2)	Max stress (N/mm^2)	S.C.F. K
100	0.45	03.114	7.179	2.305
200	0.88	06.229	14.038	2.254
300	1.30	09.343	20.739	2.220
400	1.72	12.457	27.439	2.203
500	2.13	15.571	33.980	2.163
600	2.55	18.686	40.680	2.177
700	2.99	21.801	47.699	2.188
800	3.46	24.914	55.197	2.215

7. FEM ANALYSIS:

Same model used for the experimental analysis is modeled in ABAQUS software and the max stress is observed at the edge of notch as shown in fig. 04. Table 03 shows the maximum stress obtained and corresponding SCF at various applied loads.

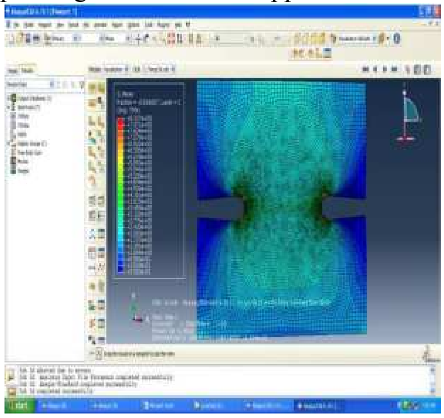
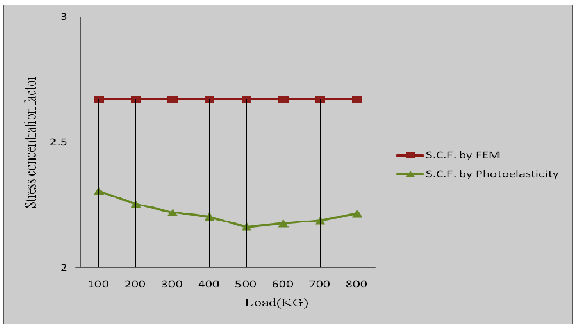


Fig. 04: Stress pattern at load of 100Kg

Table 04: Analytical stress concentration factor.

Load(Kg)	Nominal stress(N/mm^2)	Max stress (N/mm^2)	S.C.F. K
100	03.114	08.317	2.671
200	06.229	16.634	2.671
300	09.343	24.951	2.671
400	12.457	33.268	2.671
500	15.571	41.585	2.671
600	18.686	49.902	2.671
700	21.801	58.219	2.671
800	24.914	66.536	2.671



Graph: Comparison of results.

8. CONCLUSION:

In this paper the phenomenon of stress concentration factor is studied for the double notched glass – polyester composite panel subjected to the compressive loading; with the help of experimental stress analysis technique and the popular FEM technique.

The results obtained for the maximum stress and stress concentration factor using ESA technique are about 15 to 20 percent lower than obtained with the help of FEM technique but are within the acceptable limit.

The variation in results occurs may be because the PhotoStress coating applied over the surface of composite structure takes some of the applied load. The stress concentration in any structure can be easily determined with the use of any technique and can be reduced by suggesting some desired modifications at design stage only for reducing the damage or failure of structures or components.

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