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Role of Rectangle Inbuilt Patch Material on Reduction of Stress Concentration Effect in Polymer Composites

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Abstract – *Composite materials are finding wide applications in the field of structures. Geometric discontinuities are an inherent part in the structures created for assembly. These discontinued regions posses concentrated stress across its boundaries, hence initiating failure to occur. In this study efforts have been made to reduce stress concentration effect in GFRP composites by altering rectangle inbuilt patch material in the stacking sequence. The study reveals that, using a more strong and compatible fibre material as patch exhibits least stress concentration factor.*

Key Words: Polymer Composites, Stress Concentration effect, GFRP composites, inbuilt patches.

1.INTRODUCTION

Isotropic materials are substituted from composite materials because of their advantage of tailor-made properties. Discontinuities are created for assemblies of parts in structures, the surrounding of these discontinuities have concentrated stress across its periphery which leads to initiation of failure in structures. [1-11]. Therefore, the effect of stress concentration has to be minimized by alternating the design or the properties. In composite materials, we have the advantage of altering the material properties by altering the reinforcement orientation, matrix curing and by inbuilt patches without altering the design of the structure [12-14]. Hence stress concentration can be altered without changing the design.

Fibres oriented at 45° exhibit least stress concentration effect but lowers the load carrying capacity. [2-4, 10-14]. Hence inbuilt rectangle patch of aspect ratio 5 with respect to hole size(indicating patch width 5 times the hole size) had fibres oriented 45° but the main reinforcement is oriented along the loading direction in order to maintain the load carrying capacity of the composite.

In this study, effect of patch material on stress concentration factor is carried out. A glass fibre of 300GSM is used as the main reinforcing material with epoxy resin as the matrix. Carbon fibre is more compatible and stronger compared to glass fibre. Hence, inbuilt patches used for the study was made of glass fibre and carbon fibre.

2. Materials and Fabrication

2.1 Materials

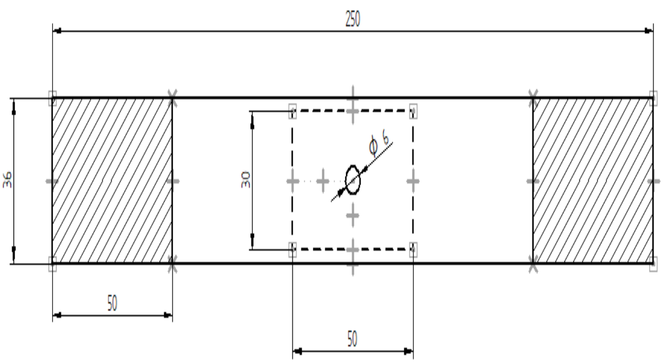
E-Glass fibre bidirectional mat was used as the main reinforcement and epoxy resin LY556 and with HY951 as hardener in the ratio 10:1 was used as the matrix material. Table- 1 gives the description of materials used.

Table -1: Materials Utilized

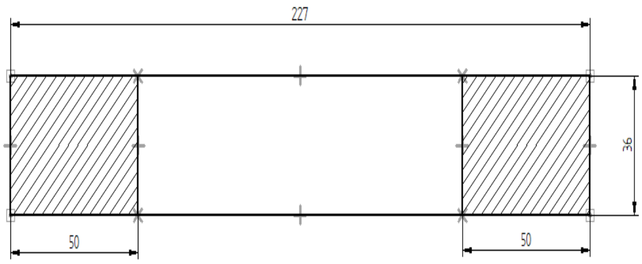
Main Fibre reinforcement	Matrix
E-Glass Woven Roving cloth of 300gsm is used with density, 1.3334 x 10-3 g/mm3 and with thickness 0.2 mm	Epoxy, LY556 and Hardener, HY951 are used in the ratio 10:1 for better strength

2.2 Fabrication

Open hole tensile and plain tensile tests specimens were fabricated according to ASTM D5766 and ASTM D3039 respectively by hand lay-up process. 6 layers of main reinforcement with rectangular patches provided just below the outermost layers at the discontinuity maintaining fibre volume fraction around 60:40. Fig-1 shows the ASTM standards and the stacking sequence of the laminate.



(a)



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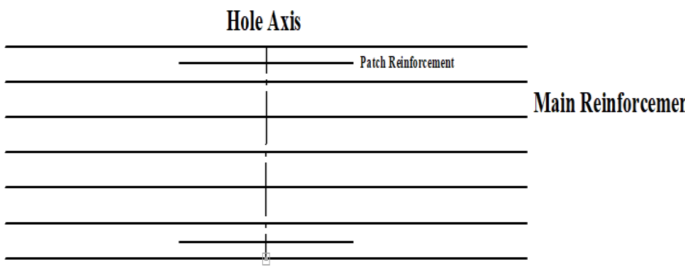
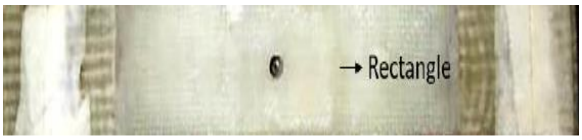


(c)

Fig-1: (a) Open hole tensile test specimen with rectangular patch, (b) plain tensile testing specimen and (c) stacking sequence

The rectangle patch has length of 50mm and width of 30 mm based on the aspect ratio 5 with its center aligned with the hole center.

Fig-2 shows the fabricated specimens of both glass fibre rectangle and carbon fibre rectangle patch



(a)

(b)

Fig-2: (a) Glass fibre patch specimen, (b) Carbon fibre patch specimen

3. Testing and Analysis

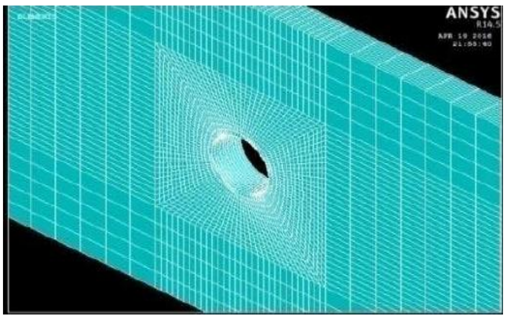
3.1 Testing

All the specimens were subjected to tension test in a Computerized Universal Testing Machine with a maximum applied load of 100KN at the strain rate varied from 1mm/min to 2.5 mm/min as shown in Fig-3. In each category 3 specimens were tested for its Ultimate Tensile Strengths (UTS) and averaged. The stress concentration factor is given by ratio of UTS of the specimen without hole to with hole [15].

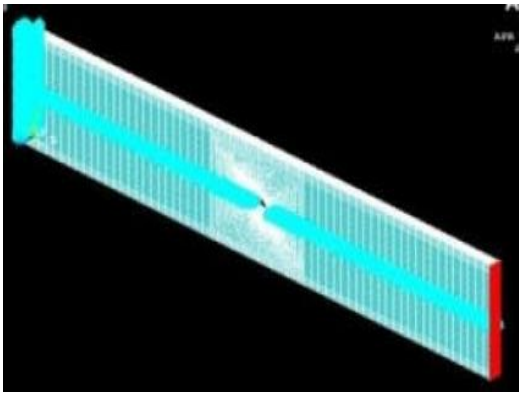
Fig- 3: Computerized Universal Testing Machine

3.2 Finite Element Analysis

Finite element modeling and analysis was carried out for glass fibre patch to compare with the experimental results. ANSYS 14.5 APDL was used to conduct FEA, laminates were built using PLANE and SOLID -SHELL elements layer by layer as shown in fig-4.



(a)



(b)

Fig-4: (a) laminate sequence built, (b) Boundary conditions applied

The SCF is calculated by ratio of maximum stress at the hole periphery to the applied remote tensile stress at minimum cross-sectional area [15].

4. Results and Discussion

4.1 Results of Glass Fibre Patch

The experimental and FEA results are compared for the glass fibre rectangular patch. Table-2 shows the calculated stress concentration factor of the two results. Fig-5 shows the comparison chart of the two results from the results it is found that experimental results and FEA results match each other with % difference less than 2%.

Table -2: % difference of Experimental and FEA results

Experimental SCF	FEA SCF	% difference
2.10	2.078	1%

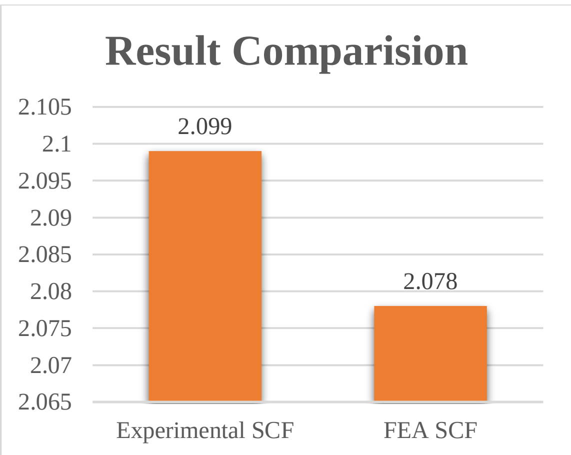


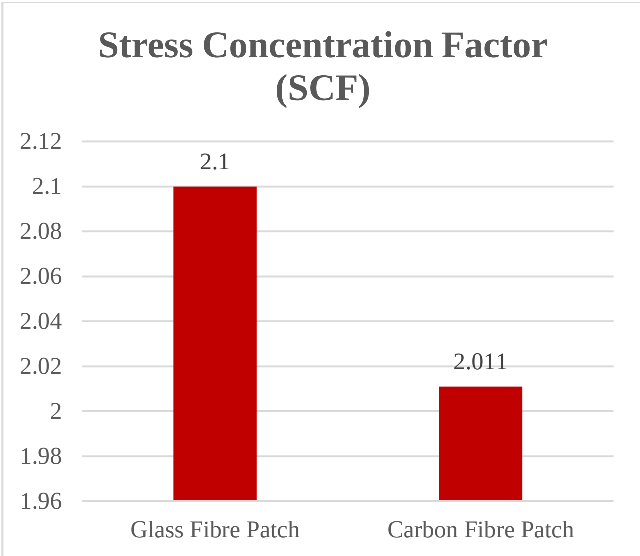
Fig-5: Experimental and FEA result comparison

4.2 Comparision of Glass fibre patch and carbon fibre patch

Experimental results of carbon fibre patch and glass fibre patch were noted and compared in Table-3. Fig- 6 shows the comparison chart of the SCF values of glass fibre patch and carbon fibre patch. From the results it can be found that incorporating a stronger fibre as patch material i.e carbon fibre compared to the parent reinforcement i.e glass fibre reduces the stress concentration effect at the circular hole discontinuity with rectangular shape patch by 4%.

Table -3: Experimental SCF

Glass Fibre Patch	Carbon Fibre Patch	% Reduction of SCF
2.10	2.011	4.23%



5. Conclusions

A study was carried out to find the effect of selecting inbuilt rectangular patch material on SCF of GFRP laminates have a circular hole at the center.

- Epoxy, LY556 and Hardener, HY951 are used in the ratio 10:1 as matrix with E-Glass Woven Roving cloth of 300gsm as reinforcement.
- Regular reinforcement at 0º and inbuilt patches at 45º with respect to loading are considered.
- Glass fibre and Carbon fibres were considered as patch materials for the study.
- Experimental and FEA study was done for Glass fibre patch where it was found that % difference between the results was less than 2%.

- Experimental results of glass and carbon fibre patch reveals that incorporating carbon fibre patch reduces SCF by 4%.

Hence, we can conclude that selection of inbuilt patch material plays a crucial role in reducing the stress concentration effect at discontinuity.

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