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Effect of Heating Source on Stress Concentration and Strength of GFRP laminates

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Abstract: ***Composite materials are becoming the most preferred structural material because of its advantage of tailor-made properties. Minimising Stress Concentration Effect (SCF) at geometric discontinuities is very important as these regions are failure initiators. Hence in this study an attempt has been made minimize SCF in Polymer matrix composite by improving polymerization. Three heat sources were compared for this study, which includes conventional hot air, microwave and infrared heating at 140ºC for 2 hours. It was found that, selection of heating source for post curing has a considerable effect on strength of the laminates***

Keywords: Post curing, Stress Concentration effect, Glass Fibre Reinforcement Composites, Heating Source, Infrared, Microwave, Hot air heating

I. INTRODUCTION

Isotropic materials are substituted from composite materials because of their advantage of tailor-made properties. Geometric 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. Therefore, alternating the design or the properties minimises effect of stress concentration. In composite materials, altering the material properties can be achieved by altering the stacking sequence, matrix curing and by fibre material without altering the design of the structure. Hence stress concentration can be altered without changing the design.

Fibres oriented at 45º exhibit least stress concentration effect but lowers the load carrying capacity. Hence inbuilt square patch of aspect ratio 5 with respect to hole size (indicating patch width 5 times the hole size) had fibres oriented 45º but the main reinforcement is oriented along the loading direction in order to maintain the load carrying capacity of the composite[1-5].

In this study, effect of post curing heating source on minimizing stress concentration effect is studied. Three different heat sources were considered which are, conventional heating, microwave and infrared. Specimens both with and without hole was fabricated and tested for SCF. The specimen with hole was incorporated with square shape inbuilt patch made of parent reinforcement material (Glass fibre) with these fibres oriented at 45º with respect to loading direction. All the specimens were post cured at 140ºC for 2 hours as categorised by heating source[6-13].

II. MATERIALS AND FABRICATION

A. Materials

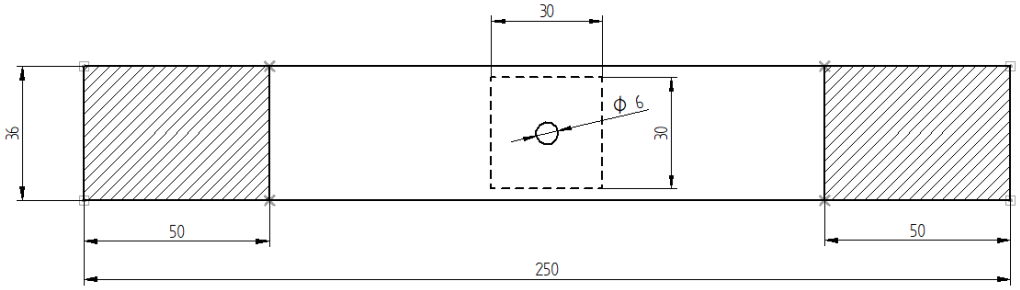
E-Glass fibre bidirectional mat was used as the main reinforcement and epoxy resin LY556 and with HY951 as hardener in the ratio 10:1 was used as the matrix material. Table- 1 gives the description of materials used.

TABLE I
MATERIALS UTILISED

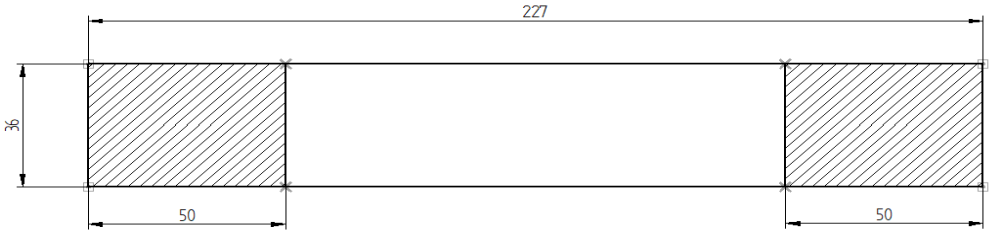
Fibre reinforcement	Matrix
E-Glass Woven Roving cloth of 300gsm is used with density, 1.3334 x 10-3 g/mm3 and with thickness 0.2 mm	Epoxy, LY556 and Hardener, HY951 are used in the ratio 10:1 for better strength

B. Fabrication

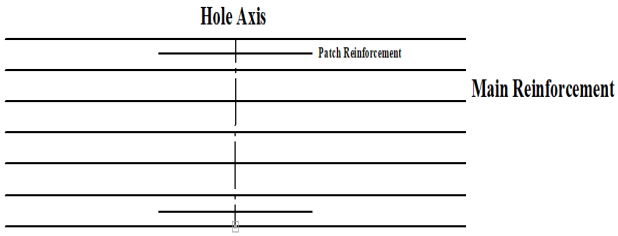
Open hole tensile and plain tensile tests specimens were fabricated according to ASTM D5766 and ASTM D3039 respectively by hand lay-up process. 6 layers of main reinforcement with square patches provided just below the outermost layers at the discontinuity maintaining fibre volume fraction around 60:40.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



(a)



(b)



(c)

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

Specimens after room temperature curing for 24 hours, they were categorized and post cured based on the three heat sources considered for the study. In each categories 3 specimens were tested. Fig-2 shows the three heating sources for post curing at 140ºC for 2 hours.

(a) (b) (c)

Fig-2: (a) Conventional hot air heating, (b)Microwave heating and (c) Infrared heating

III. 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

IV. RESULTS AND DISCUSSION

Table- 2 tabulates the UTS and SCF of all the specimens with and without holes subjected to different post curing heat sources. Fig-4 shows the Comparision chart of the different post cured heating sources. From the result it can be found that, using infrared heating source for post curing of polymer matrix composites gives better strength to the matrix because of better polymerization. It reduces stress concentration effect by 34% compared to laminate with hole post cured by conventional means without square shape inbuilt patch (SCF 2.601). Whereas microwave post curing also gives a satisfactory reduction in SCF by reducing it by 30.03%.

TABLE-II
EXPERIMENTAL Results

Heating Source	SCF of Specimens with Hole have square shape inbuilt patches	Percentage reduction in SCF with reference to without patch conventional curing specimen
Conventional	2.74	Increased by 6.9%
Microwave	1.82	Reduced by 30.03%
Infrared	1.70	Reduced by 34.64%

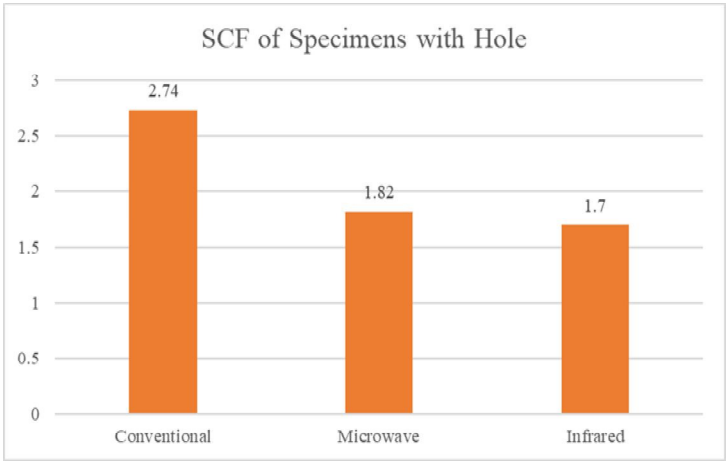


Fig- 4: SCF Comparision

V. CONCLUSIONS

Composite materials have unique advantage of high stiffness to weight ratio, hence being implement for design and fabrication of light weight structures Drilling holes in parts is unavoidable due to assembly purpose. Periphery of these holes are prone to stress concentration which further leads to initiation of failure of the structure. In this study an effort has been made to minimize SCF in polymer matrix composites by selecting a suitable heating source for post curing at 140ºC for 2 hours. Three different heating sources was considered for the study. From the results it can be found that,

1) Heating source used has a considerable effect on the strength of the laminate
2) Infrared curing is found to be most effective heating source for post curing as it reduces SCF by 35% compared conventional heating source.
3) Followed by microwave heat source also gives a decent result of reducing SCF

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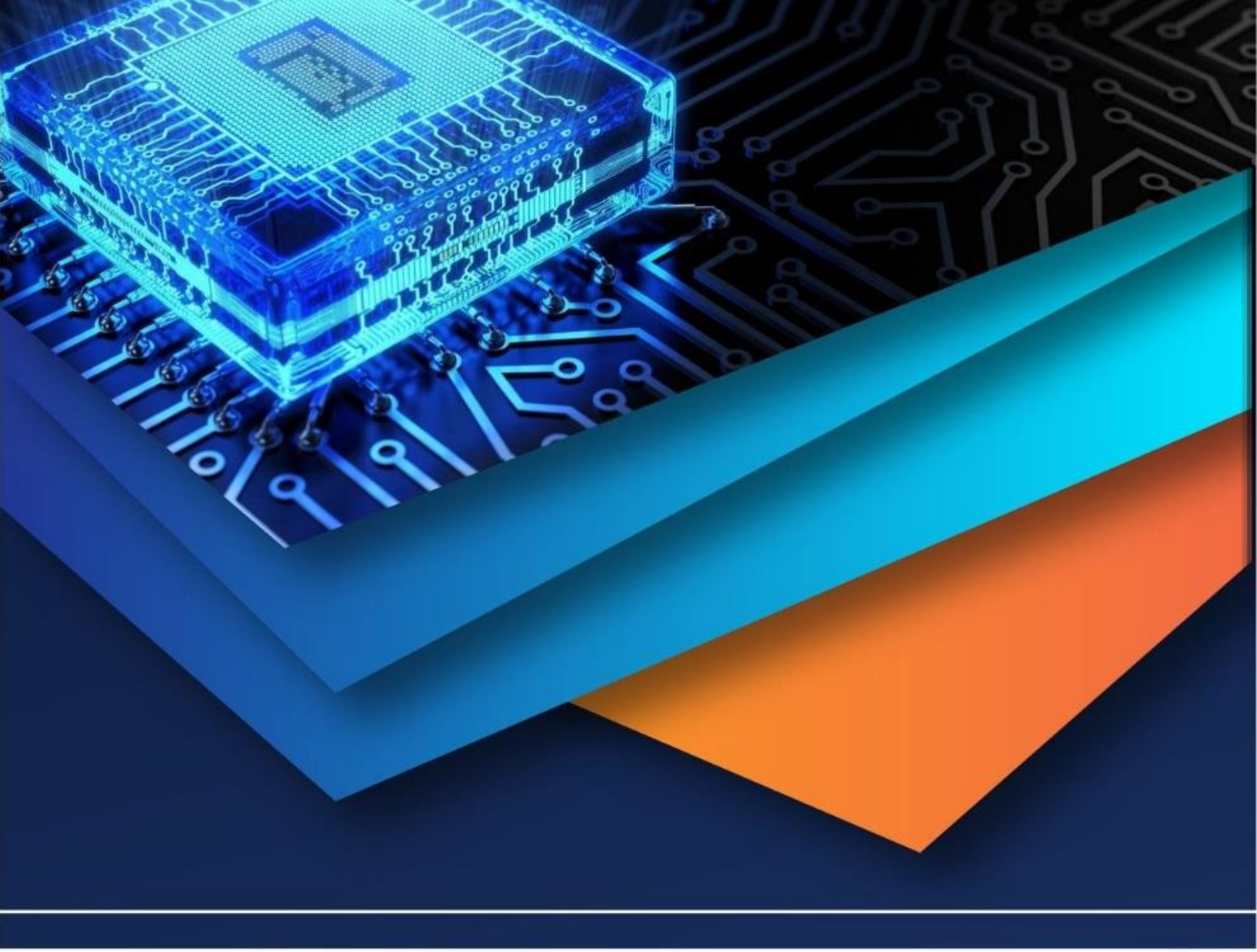

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