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Evaluation and Damage Repair of Continuous GFRP Tensile Composite Laminate using FEA

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Abstract*: GFRP composites are replaced by metals in extreme domains due to high strength to weigth ratio. Presence of damage in a composite pannel reduces the structural integrity. The current research discusses about the criteria to improve the tensile strength of uni-directional glass fiber composite laminate using adhesively bonded patch repair over the damage area. The paper uses SIEMENS NX10 tool for modelling the samples and the structural analysis with and without patch work was done in ANSYS 19.1 work bench. The results are compared finally.

Keywords: GFRP, Composite, Damage, Patch Repair

I. INTRODUCTION

Invention of composite materials satisfying various design requirements has revolutionized the fields of research and development in material world. All most all the applications where high strength, high stiffness and light weight is required, the composites are preferred1-12. Glass fibers are first commercially produced in USA in 1937 and the first GFRP was produced in 1942. The percentage of FRP composites usage in aircrafts was about 10% in 1990's and now a days it was around 40%-50%. For experimentation work 430 GSM (Grams per Square Meter) fabric is imported from SIKA Corporation, USA. The main reason for selecting this fiber or in the other name the key noted advantages are optimised design, superior at production quality control, cost efficiency, extended range of weaving patterns, improved A-R property due to the addition of zirconia, adequate fiber resistance damage tolerances etc. The paper includes fabrication of tensile specimens using bagging and also design and analysis of damage specimens using FEA.

II. FABRICATION AND TESTING

Fiber composites can be fabricated through variuos technologies but an ideal composite should have maximum fiber and minimum epoxy13-17. Fig.1 shows the modelling of tensile specimen using SIEMENS NX10 tool. The characterization uses MTS servo hydraulic UTM at IIT Hyderabad. It has an ability to apply 100KN under dynamic loading. As per ASTM standards the tensile test coupons are tested at a rate of 2mm/min. At the time of testing the data regarding stresess, strains, extension is aquired in DAC (Data Aquasition Card) fitted to the test machine by means of a desktop. Tensile test is conducted on three samples of 430 GSM E-glass-epoxy composite laminates and average value is considered.

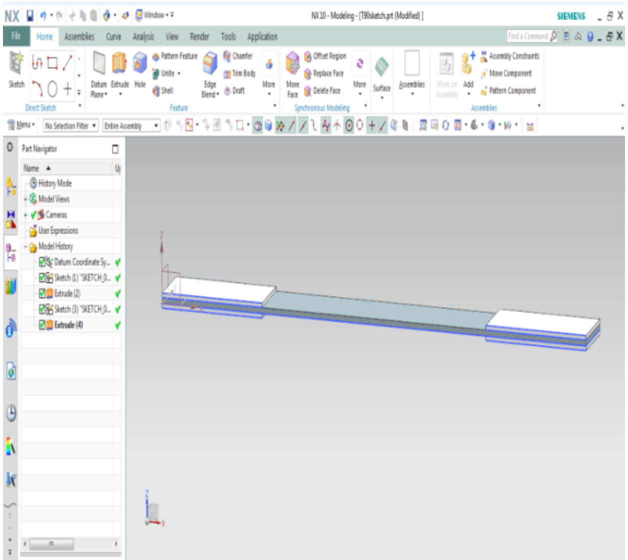

Fig. 1 Tensile 0^0 test cupon

III. MODELLING OF COMPOSITE REPAIR SPECIMENS

In spite of good design the composites fail during the servie. Aloha aircraft accident at Hawaii, April 28, 1998 is the best example of composite failure during the service time. Literature survey shows that always fiber composite initiates crack at high stress concentration area. The research work concentrates on reapiring of fiber composite at high stress concentration area. A circular hole is induced in the specimen treating it as stress concentration area.

Most effective method to repair damage parts is adhesive bonding of composites with circular patches over the damage area. Repairing is done in two ways: Single Side Patch Repair (SSPR) and Double Side Patch Repair (DSPR). Always patch work is done external to the damage.

Fig.2 shows stress concentrated sample. The samples are modelled in SIEMENS NX10 tool and are imported to Ansys 19.1 for finite element analysis later. Patches of E-glass-epoxy composite with circular cross section of 40mm diameter and 2mm thichness are adhesively bonded over the stress concentration areas on onside and two sides.

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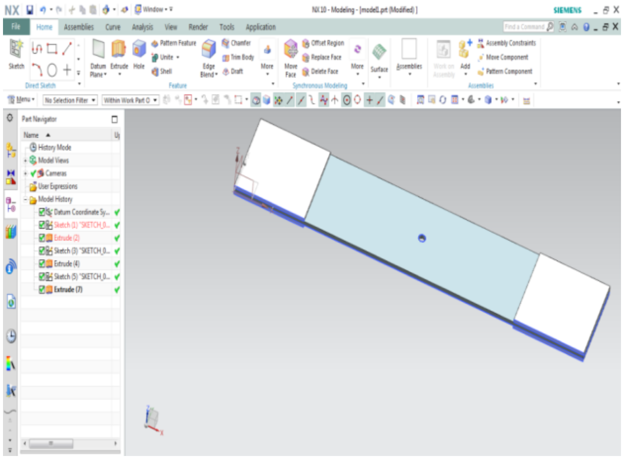


Fig. 2 Single hole damage part model

Fig.3&4 shows the model of patching over the high stress area with SSPR and DSPR.

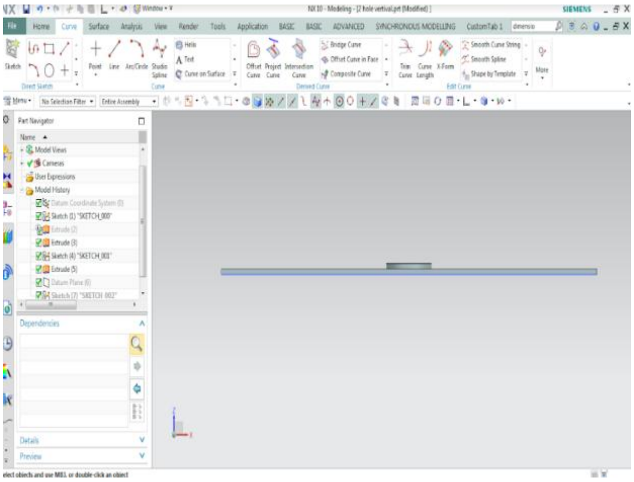


Fig. 3 Single Side Patch repair on damage pannel

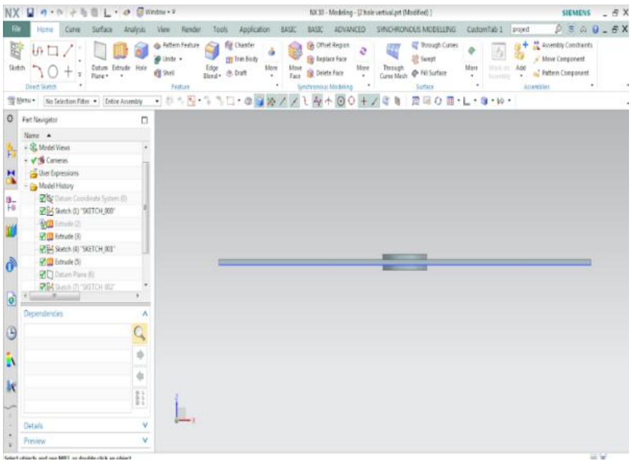


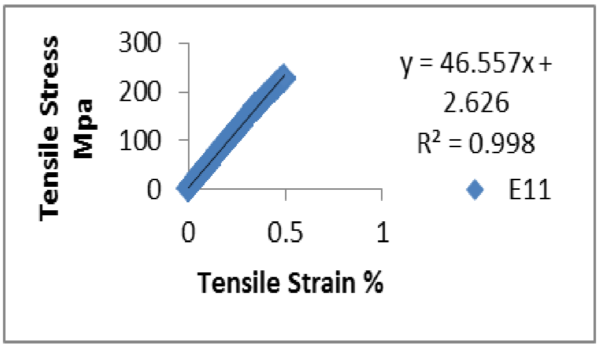
Fig. 4 Double Side Patch repair on damage pannel

IV. RESULTS AND DISCUSSIONS

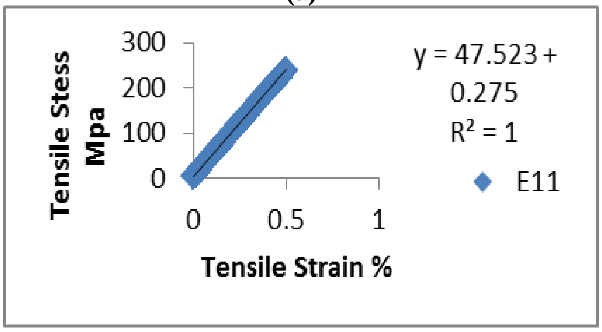
The paper discusses the results of characterization samples and damage repair pannels.

4.1 Characterization Results

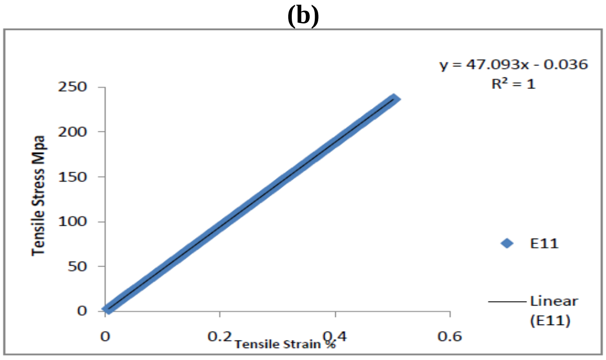
Initially the stress- strain curve is plotted until elastic limit to attain longitudinal elastic modulus E11. The values of stress and strains are adopted from MTS characterization data. Fig. 5 shows the plots of E11 for samples 1,2 and 3.



(a)



(b)



(c)

Fig. 5 MTS E11 data for Tensile 0^0 (a) sample1 (b) sample 2 (c) sample 3

From fig. 5 considering the slopes of the plots the longitudinal tensile modulus are 46.557 Mpa, 47.523 Mpa and 47.093 Mpa. The average value of E11 is about 47.05766 Mpa. Fig. 6 shows the variation of E11 data for samples 1,2 and 3. The tensile strength is calculated as the maximum stress adopted by the cross sectional area of the samples. The values of Xt are 919.32 Mpa, 983.956 Mpa and 942.513 Mpa. Fig.7 shows the variation of tensile strengths of three samples.

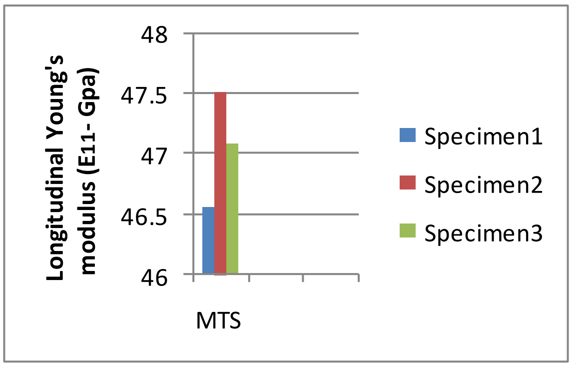


Fig.6 Scater of E11 data obtained from MTS

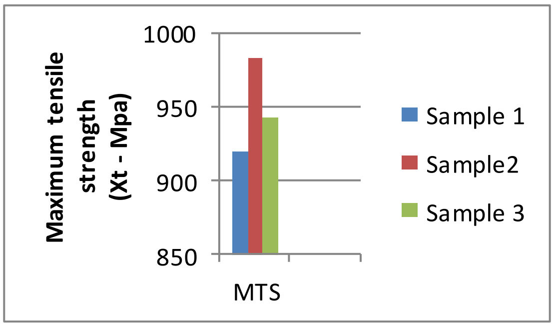


Fig.7 Calibrated Tensile strength (Xt) of tensile specimens

The FEA is applied under a load of 50KN to evaluates the values of minimum and maximum stresses, strains and deformations. Fig.8 shows the FEA models of tensile samples using ANSYS 19.1 work bench. The resultant values obtained from FEA is tabulated in table3.

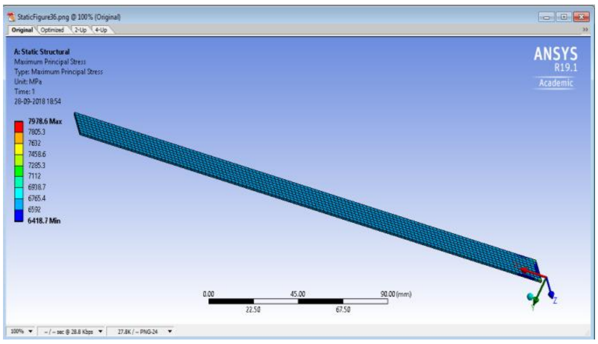


Fig. 8.a Maximum and minimum principle stresses for Tensile 0^0

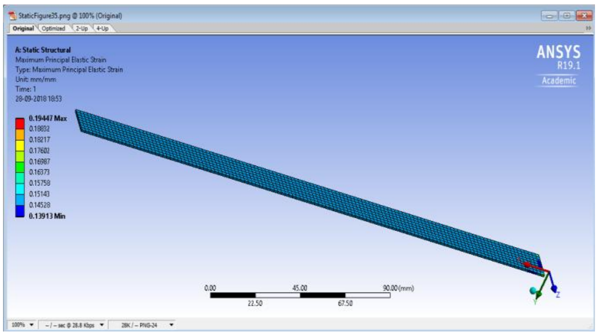


Fig. 8.b Maximum and minimum elastic strains for Tensile 0^0

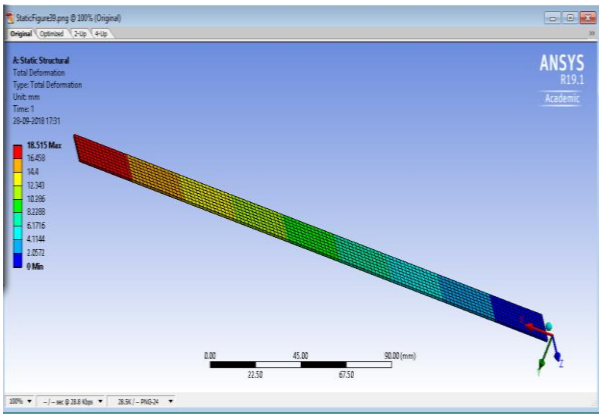


Fig. 8.c Maximum and minimum deformations for Tensile 0^0

4.2 Composite Damage Repair PANNEL Results

Initially FEA is done on stress concentrated pannel the minimum and maximum stresses around the hole 2.9782 Mpa to 1526.2 Mpa, strains 0.0035766 to 0.034411 mm/mm and deformation is extended from 0 to 2.237mm. Fig. 9 shows the stresses, strains and total deformations of the damge pannel.

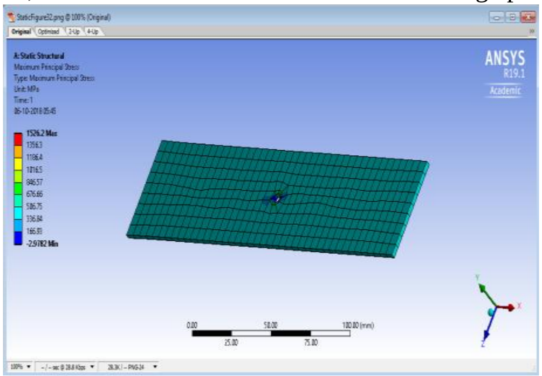


Fig. 9.a Maximum and minimum principle stresses for damge pannel

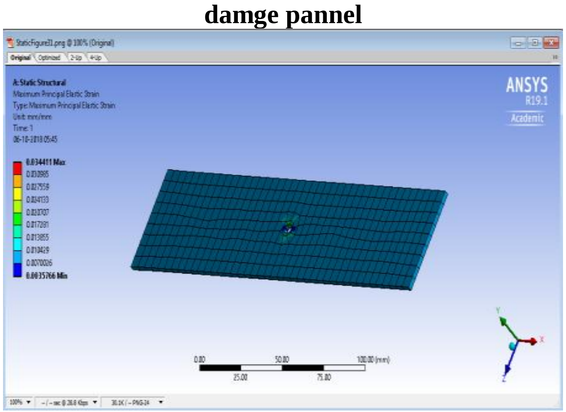


Fig. 9.b Maximum and minimum principle strains for damge panel

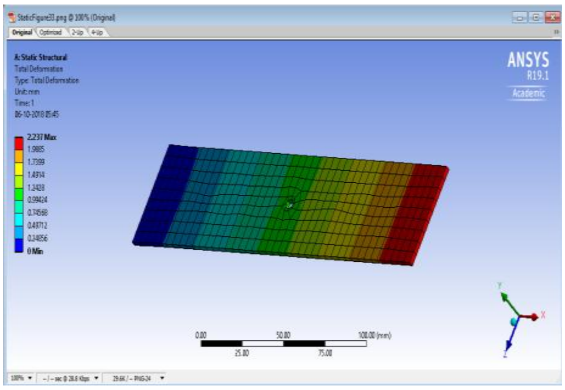


Fig. 9.c Total deformations for damge panel

Fig. 10 shows FEA of SSPR. Stress ranges from 1.508 Mpa to 972.18 Mpa, strain ranges from 0.00027531 to 0.091855 mm/mm and total deformation from 0 to 48.346 Mpa.

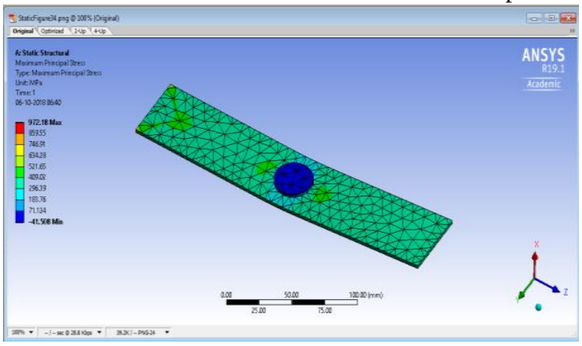


Fig. 10.a Maximum and minimum principle stresses of SSPR panel

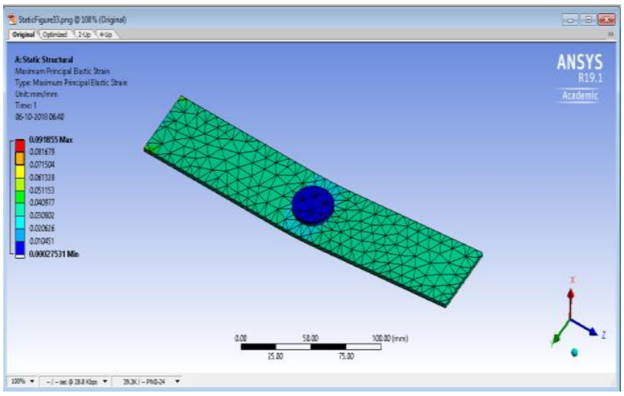


Fig. 10.b Maximum and minimum principle strains of SSPR panel

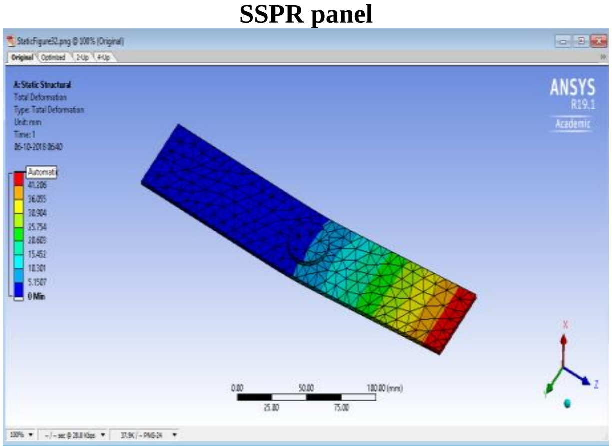


Fig. 10.c Total deformations of SSPR pannel

Fig. 11 shows FEA of DSPR. In DSPR the minimum and maximum stresses around the hole 1.9753 Mpa to 821.39 Mpa, strains 0.00059531 to 0.069843 mm/mm and deformation is extended from 0 to 9.554mm.

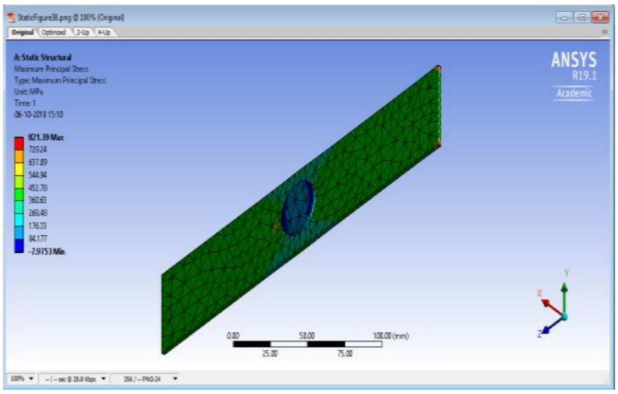


Fig. 11.a Maximum and minimum principle stresses of DSPR panel

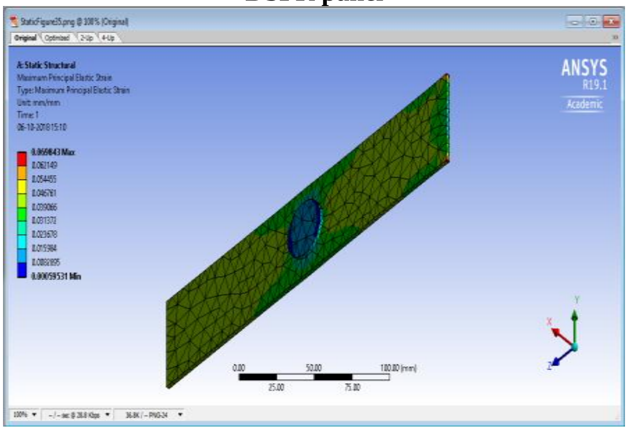


Fig. 11.b Maximum and minimum principle strains of DSPR panel

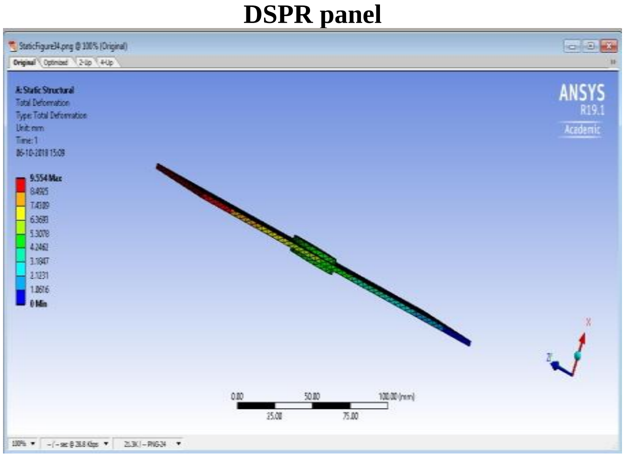


Fig. 11.c Total deformations of DSPR pannel

V.CONCLUSION

MTS characterization shows that the value of E11 attained for all the samples are close to each other. FEA of samples showed that there exists a maximum stress of 7978.6Mpa for tensile specimens. For unrepaired samples the maximum stress is 1526.2 Mpa. FEA of SSPR sample shows a maximum stress of 972.18 Mpa and for DSPR sample it was around 821.39 Mpa. Hence it was proved that stress reduces from 7978.6 Mpa to 972.18 Mpa due to one side adhesive patch repair and due to two sided patch repair the reduced from 1526.2 to 821.39Mpa.

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