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Structural Response of Composite Panels with a Bonded Patch Repair Using Full-Field Measurement

Sameer Hamoush[1], Kunigal Shivakumar[2] and Ibraheem Kateeb[3]

Abstract: This paper presents an experimental/analytical evaluation of patch repair of solid laminated composites. The experimental program was focused on destructive evaluation of full-scale repaired panels under static tension loading conditions using speckle test full-field image recording technology. The speckle test results were used to validate a finite element analytical model. Based on the evaluation performed in this study, the finite element model and the speckle imaging technology provide major enhancements in understanding the performance of the scarf repairs.

Keywords: solid laminates, speckle tests, image recording.

1 Introduction

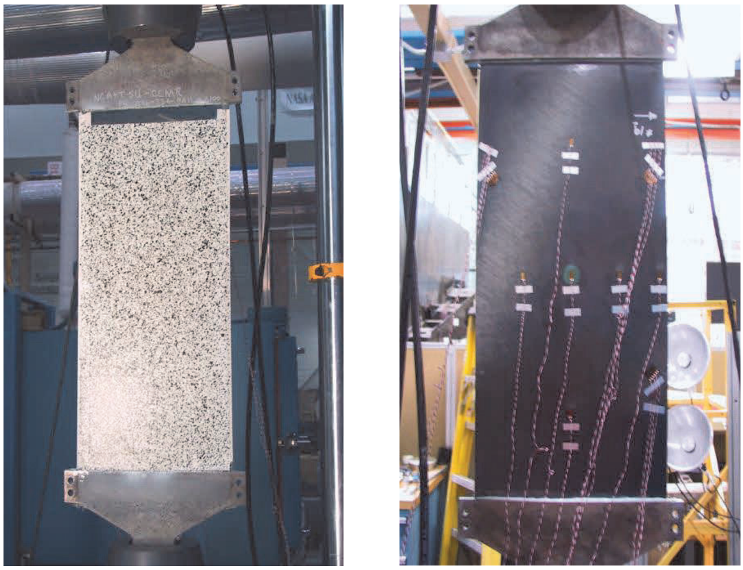
Patch-repair of composite structures is relatively a new technology. Reliability and survivability of repaired components issues remain uncertain. The composite patching technology is attractive, in part, because the lay up of the reinforcing fibers can be matched/optimized to handle the service conditions of aircrafts. However, the design must also anticipate the severe loading conditions that can occur in rough weather or during emergency evasive maneuvers. Proactively appraising the performance of composite patching systems under long-term normal service and short-term abnormal conditions is essential to ensure safety of repaired aircraft sections [Wang, Chen, Guo, and Ren (2001); Bair, Hudson and Ghanimati (1991); Armstrong, Keith B. (1997); Donaldson, Song and Roy (1997); John Tyson II (1996)].

[1] Civil and Arch Engineering, NCA&T State University, Greensboro, NC 27411- USA.
[2] Center for Composite Material Research, NCA&T State University, Greensboro, NC 27411- USA.
[3] Computer Systems Technology, NCA&T State University, Greensboro, NC 27411- USA.

2 Experimental evaluation

The structural response of the repaired panels was monitored by the speckle full field measurements on the front of the panel and strain gauges on the backside.

Fig. 1a shows the speckle pattern while Fig. 1b shows the backside strain gauges.



(a) The speckle pattern (b) Strain gages on the back.

Figure 1: The speckle pattern and strain gages.

All panels were tested in a load stroke controlled MTS test machine. The loads were applied at a rate of 1.25 mm stroke displacement/min. Loads and the strains were recorded continuously using Vishay's system 5000 data acquisition system. Recoding channels and the associated strain gage locations are shown in Fig. 2.

The arrangement of the VIC-3D set-up used to obtain full-field displacement measurements of the composite test panel is shown in Fig. 3. As the load is applied, the 3-D measurements of speckle were recorded at regular intervals (once in 5 seconds). From the measured displacements, the complete full field mapping was completed using the software VIC-3D. Fig. 4 shows the front and back views of the panel after the ultimate load was reached. The failure initiated at the top edges of the patch near gage #33. Then, the failure progressed toward the mid-section to reach the ultimate failure between the patch and the parent panel.

To establish the ultimate strength and the mechanical properties of the parent materials, the first set of tested specimens was the pristine panels. A uniform strain

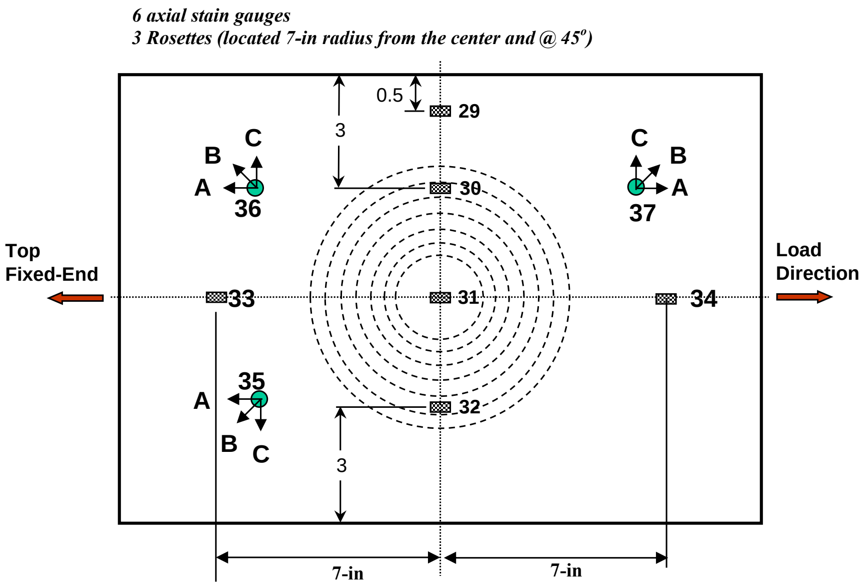
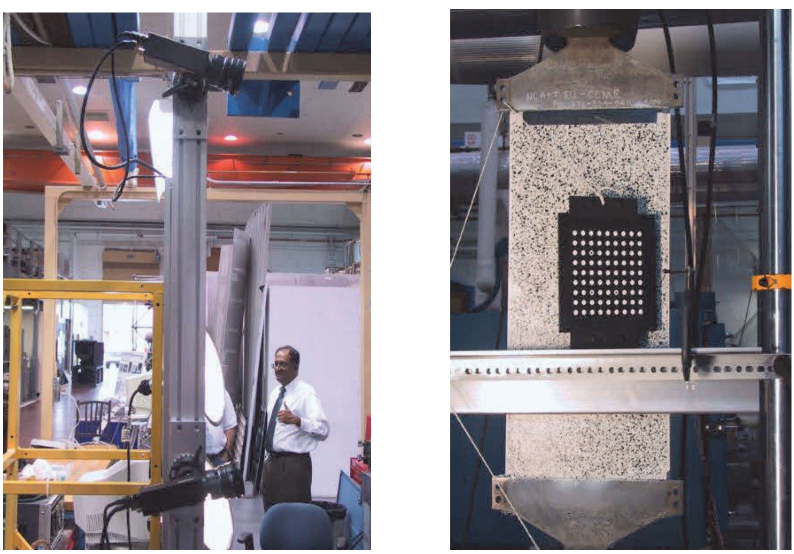


Figure 2: A schematic diagram for strain gauges locations and types.



(a) The digital stereo camera setup (b) The camera calibration target

Figure 3: The speckle test and the recording set-up.

(a) The patched side w/speckle pattern (b) The back side w/strain gages

Figure 4: The speckle (static) test at failure.

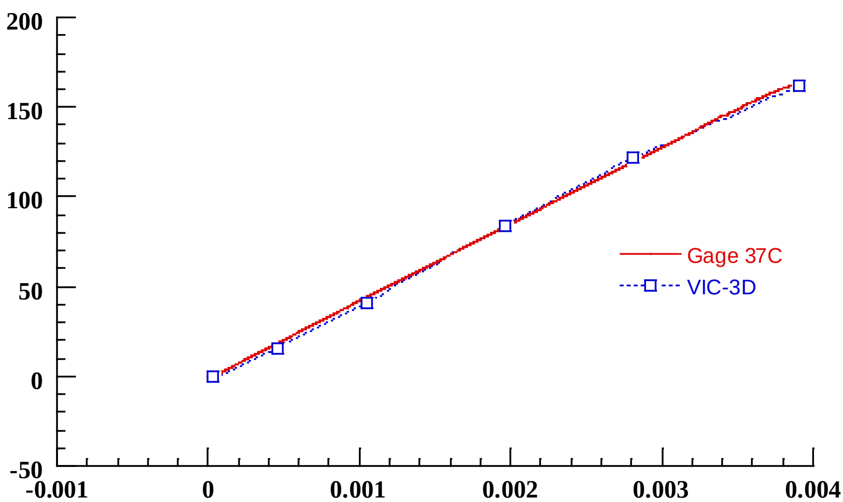


Figure 5: Comparison between the VIC and Strain gauge (Gauge 37C).

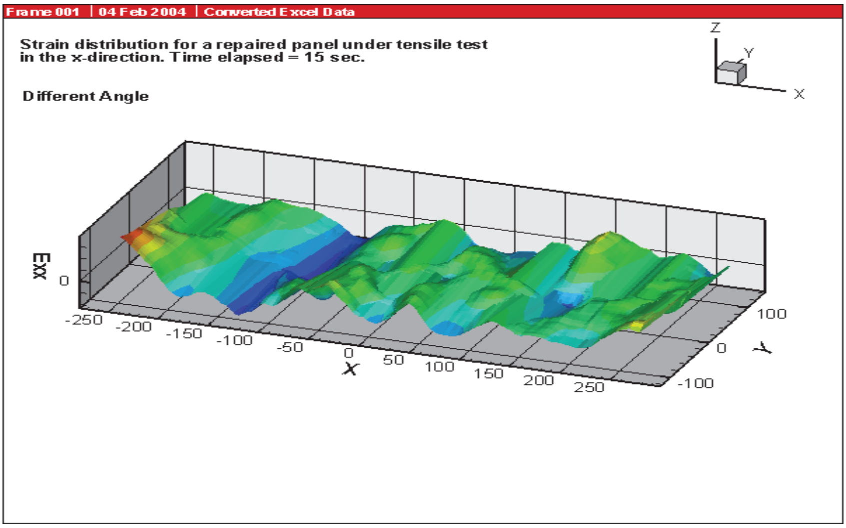


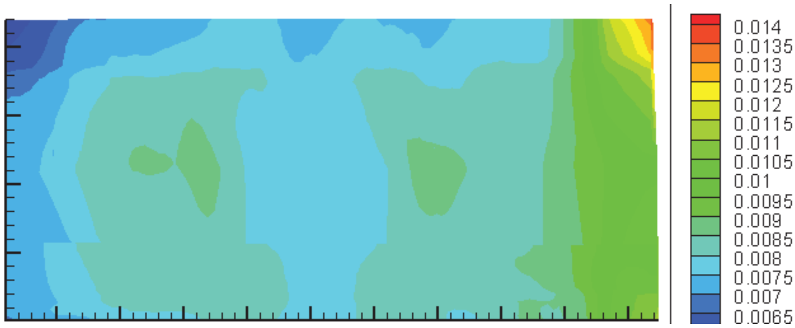
Figure 6: A typical 3-D plot of axial strain at the 15 seconds stress level.

distribution along the mid-section of the pristine panels was noted during the testing. The uniform strain distribution indicated the designed grips achieved the intended purpose of eliminating the stress concentration at the grip ends. The second set of tested specimens was the damaged panels with 25 mm hole in the center of the panel. The center hole presents the removed damaged zone. As expected, the strains at the middle section were not uniform due to the drilled hole and damaged panels failed at mid-section.

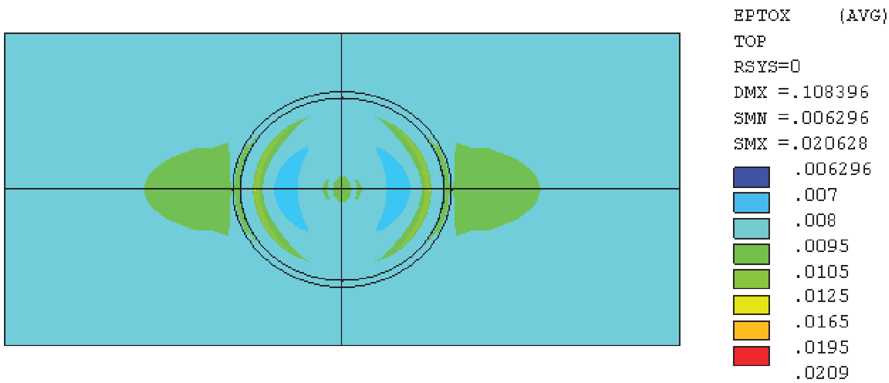
The third set of specimens was repaired panels. The test showed a uniform strain distribution of the patched panels at middle section. A typical plot of the transverse strains vs. applied load for repaired panel at gage 37B is shown in Fig. 5. This plot shows the consistency between the strain gauge reading and the speckle image results. Fig. 6 shows a three dimensional plot of the axial strain at the maximum stress level.

General comparison was made between the stains at various strain gage locations and the VIC-3D measurements at a various load levels. The matched reading enhanced the confidence in the results.

Fig. 7 presents mapped comparison between the full field measurements and the out put of the numerical model. It appears that the two results shown relatively matching data which indicates the accuracy of techniques, the numerical model and the full field measurements.



(a) Mapping of the full felid measurements of the normal strains



(b) Mapping of the finite element model of the normal strains

Figure 7: Full field comparisons of normal strains between the VIC 3-D and FE model.

3 Conclusions and recommendations

The objectives of the present paper are to evaluate the use of full field measurements as a means to monitor the response of the patch repair to tension static loading conditions and to investigate the performance of defectively repaired panels under unidirectional tensile load. Based on the test performed in this study, the following can be concluded:

1. The full field measurements provide accurate recordings of the full strain fields around the patch.

2. It appears that stress concentration is experienced at the connection of the patch and the parent materials.

3. Scarf repairs are an effective retrofitting technique of defected solid composites where the repair restores 85 to 95 percent of the undamaged Solid composites.

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