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EXPERIMENTAL VALIDATION OF USE OF COMPOSITE MATERIAL TO RESTORE NATURAL FREQUENCIES OF EDGE CRACKED ALUMINUM CANTILEVER BEAM

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ABSTRACT

Faults in machines due to vibration are of major concern in the engineering filed. The repairing efficiencies cannot be identified directly from the point of view of frequency due to the nonlinear properties of damping and mass of composite patching under dynamic conditions. Crack arise may be because of defects due to manufacturing processes and mechanical defects. Mechanical accidents, fatigue, environmental attacks are responsible for a crack in a mechanical structure. Due to the mechanical loads and environmental conditions composite materials are damaged. For this reason bonded composite repair are generally preferred. They provide enhanced stress transfer mechanisms and also joint efficiencies and aerodynamic performance. Now a day's usage of advanced composites is increased in primary and secondary aerospace structural components. It is essential to have reliable, robust, and repeatable structural bonded repair procedures to restore damaged composite components. But this method has several scientific challenges with the current existing repair technologies. In order to optimize the patching geometry, the dimensions of composite patch were selectively extended along the platform dimensions (x and y), respectively.

Keywords: *Crack, Composite material, Repair, Cantilever beam, Optimize.*

I. INTRODUCTION

Resonance is a common for machines or structures under dynamic conditions. But sometimes it is very seriousproblem for machines or structures under dynamic conditions. The large amplitudes caused by resonance lead structural components to catastrophic failure, especially those components containing defects, e.g., the large amplitudes may cause the defect to grow continuously and in the case of airframes, endanger might safety. For cost and time, if the damage caused by the defects is not critical, the components are usually not replaced. Also due to patching the service life of many components can be extend.

When an aging airplane begins to show signs of wear, we have following options:

- The entire assembly can be replaced.
- The damaged part can be replaced.
- The damaged part can be repaired

There are two methods available for repair:

- Mechanically bolted or riveted joint
- Adhesively bonded composite

There are two approaches:

- Strength approach-original yield strength of the material is retain
- Stiffness approach- stiffness (Natural frequencies) of the material are retain

Adhesively bonded composite repairs provide a method of repair that controls stress concentrations better. The goal of a properly designed bonded repair is to restore the natural frequencies of damaged structures. Damage growth should either be arrested or significantly retarded. The repair must be carried out without causing further damage or creating a weak link in the structure. In short, the repair allows the structure to fulfill its original intended function.

The success of a bonding repair depends on the properties of both the adhesive and the patch. The quality of the repair depends upon bonding process and surface treatment. Carbon–epoxy composites have been mostly used in aeronautics due to their high stiffness and strength to weight ratios.

II. REVIEW OF LITRATURE

Okafor (2005):studied and analyzed the durability of adhesively bonded composite patch repairs of cracked aircraft aluminum panels repaired with octagonal single sided boron/epoxy composite patch. He used octagonal single sided boron/epoxy composite patch were used as test specimen

K.B.Katnam (2013) proposed a method of detection of crack locations and its size by relating the fractional changes in the natural frequency of the cracked beam to the healthy beam due to the presence of cracks. For that use the line spring model for formulating and applying the method of differential quadrature to solve it. For the strength of bonded patches, much research had been conducted, with different materials, to evaluate its effectiveness under various conditions. The strength of bonded joints using the traditional strength of materials approach. This does not agree with experimental results. Much experimental done investigation on the repairing effects of fiber composite patches on the fatigue life of a cracked aluminum specimen.

Wei-Chung Wang and Chien-hua chean (2000): was invented the vibration behavior of a clamped edge-cracked composite plate repaired by composite patching. Modal testing was first used to measure the natural frequencies and mode shapes of the composite plate before and after repair.

Vaziri.H. Nayeb-Hashemi (2005) suggested that the dynamic response of repaired composite beams under a harmonic peeling load was studied theoretically and experimentally. The repair method was based on removal of the damaged region and bonding a composite patch into the gap with adhesive.The patch section was either the fiberglass-reinforced epoxy composite or E-glass fiber reinforced composites with various stacking sequences. The repairing patches were bonded to the composite beam with an epoxy. The experimental results were compared to those of the theoretical model and finite element analyses. The experimental results were related to the adhesive material properties, its loss factor and to the patch material properties.

A. Baker and R. Jones (1998) analyzed thatdue to high specific strength and stiffness, composite material has been widely used in various flying vehicles. Occasionally, defects are found in the structural components. When defects are not critical enough to make the replacement of the components, patching is one of the best ways to extend the structural life and reduce maintenance expenses.

L. R. F. Rose (1982) formulated the theoretical derivations and discussed experimental aspects of various bonded repair methods. He determines the stress intensity factor of a side-cracked aluminum alloy sheet patched by the fiber-reinforced composite material.

Mahmoud Nadim Nahas (1982) In particular, cracks decrease the stiffness of the parts and lower the parts natural frequency, leading to failure under normal working conditions. This paper introduces a new application to carbon nanotube (CNT) composites in the repairing process of a cracked specimen to restore the natural frequency of the specimen. Commonly, patches are made of high strength and high stiffness materials. This paper shows that even low stiffness materials, such as epoxy reinforced with CNT, can contribute to the repair of a cracked specimen.

III. PROBLEM DEFINATION

Optimum design of composite patch to retain the natural frequencies of edge cracked aluminum cantilever using ANSYS and validation by using experimental modal analysis.

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IV. MATERIAL USED

3-aminopropyltriethoxysilane was used in 0.5 % amount of resin along with epoxy which improved bonding strength between aluminum alloy and CFRP patch.

V. FINITE ELEMENT ANALYSIS

Pre-processing:
A 3-D model of the Patched specimen is modeled and analyzed in ANSYS workbench 15.

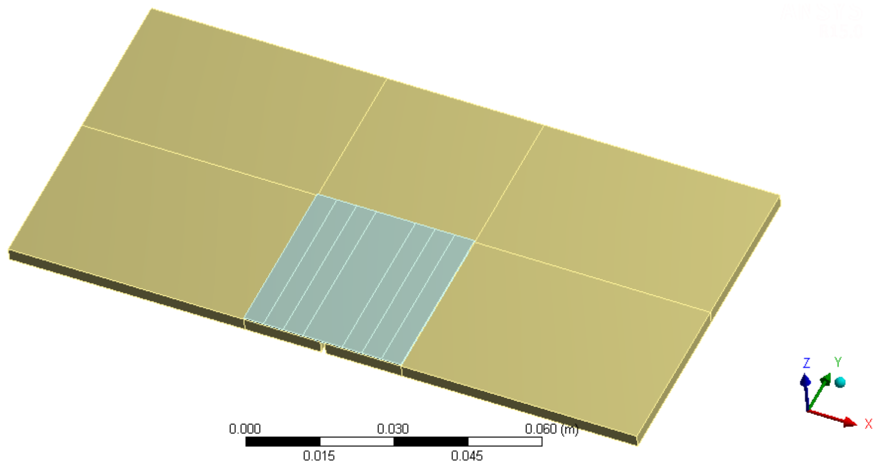

Figure 1: 3-D model of patched specimen

Solution:
Maximum mode to be found are given 5 and No damped control is given. Also solver type given is programmed control. Solution is obtained for cantilever support. The solution time for this analysis is approximately 45 min on a desktop computer.

Post processing:
The Mode shapes obtained for Un-cracked, cracked and repaired patched cantilever specimens are shown in following figures. The mode shapes obtained for un-cracked and repaired specimens are observed same.

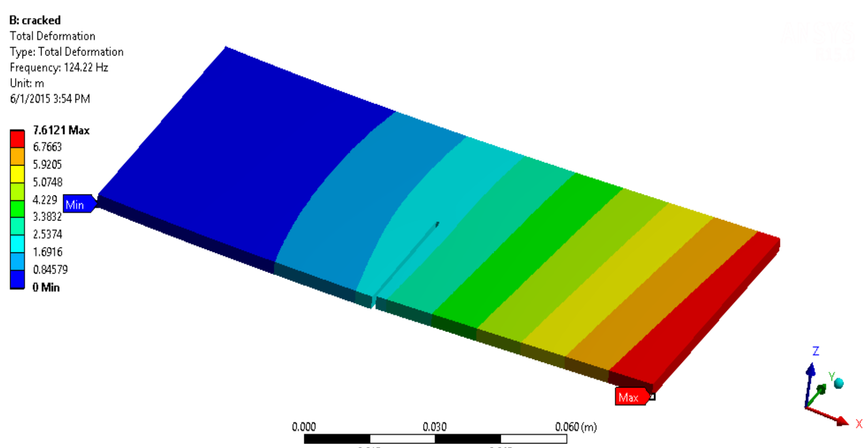

Figure 2: First Mode shapes of cracked cantilever plate

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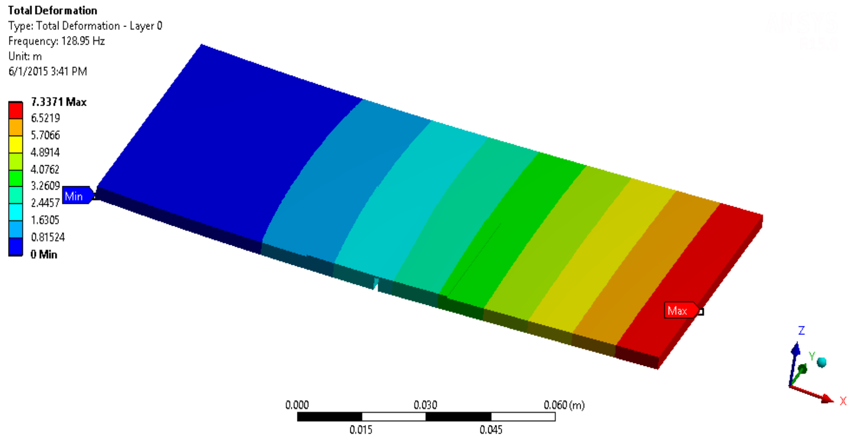

Figure 3:First Mode shapes of patched cantilever plate

VI. EXPERIMENTAL MODAL ANALYSIS

Experimental modal analysis is used to identify the modal response of an existing structure to solve a vibration problem. Impact test or bump test is used in the experimental modal analysis. Impact testing is a fast and low cost of finding the modes of machines and structures. Experimental modal analysis consists of exciting the structure with an impact hammer, measuring the FRF (frequency response function) between the excitation and many points on structure. Accelerometers measure the vibration levels at several points on the structure and a signal analyzer computes the FRF. Each FRF identifies the resonant frequencies of the structure and modal amplitudes of the measuring grid point associated with FRF.

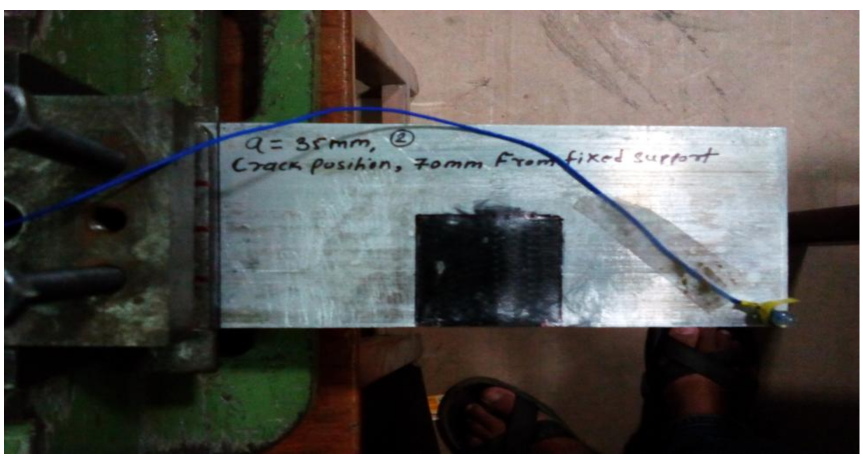

Figure 4: Test specimen set up for modal analysis

VII. RESULT AND DISCUSSION

The first five natural frequencies are obtained for un-cracked, cracked and sample patched specimen in ANSYS workbench 15. From the natural frequencies results, it is observed that natural frequencies of trial patched specimen increases and close to the natural frequencies of un-cracked specimen. Therefore the main objective is to develop an appropriate CFRP patch configuration in such a way that it enhanced the natural frequencies of the repaired plate up to the natural frequencies of original aluminum plate. The results obtained for first five modes are listed in table 1.

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Table1:Natural frequencies of un-cracked cracked and Trial patched specimen

Mode No	Natural frequencies		
	Un-cracked	Cracked	Trial patched
1	131.61	124.22	129.86
2	550.75	460.81	547.46
3	816.89	697.2	760.35
4	1794.3	1525.7	1745.9
5	2283.8	1875.5	2310.2

Selection of optimum cross section for first CFRP patch

To select the optimum cross section of first CFRP patch, it is need to compare the effect of patching in x y and z-direction on natural frequencies. From above results it is observed that, if patch dimensions are increased in x and y-direction, first four natural frequencies obtain are less than the natural frequencies obtained when adding material in z-direction. Therefore optimum cross selected for first CFRP patch is taken as 35mmx35mm.

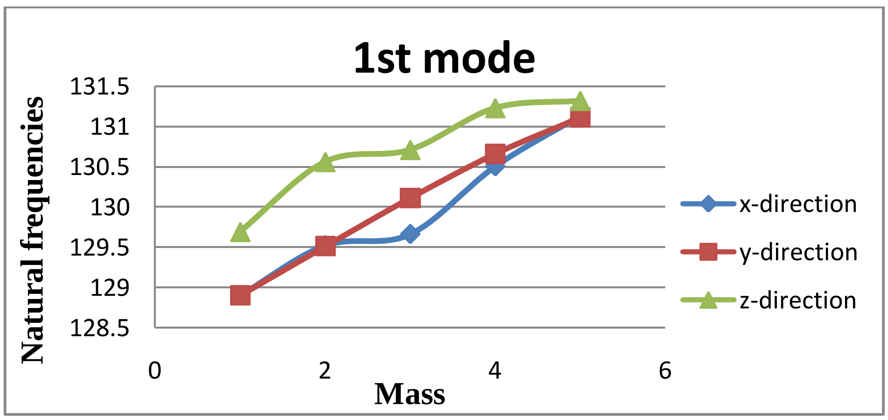

Figure 5:comparison of patching in x y and z direction for 1st mode

Optimization of CFRP patch configuration

From above results, it is observed that to increase the first four natural frequencies, z-direction is predominant and also to increase the fifth natural frequencies x-direction is predominant. Therefore cross section for first patch is taken as 35mmx35mm. after this the main objective of work is to decide the number of patches and sizes of patches in z-direction to be applied in such way that it enhanced the natural frequencies of the repaired plate up to the natural frequencies of original aluminum cantilever. Thickness of one patch is 0.225mm.to increase the natural frequencies of cracked cantilever up to the natural frequencies of un-cracked plate, first increase the 35mmx35mm patches in z-direction, from the results it is observed that the natural frequencies are retain after applying 6 (35mmx35mm) patches in z-direction. The objective of modal analysis is to understand the mode shapes by visualizing the deformed geometry and determination of natural frequencies of specimen.

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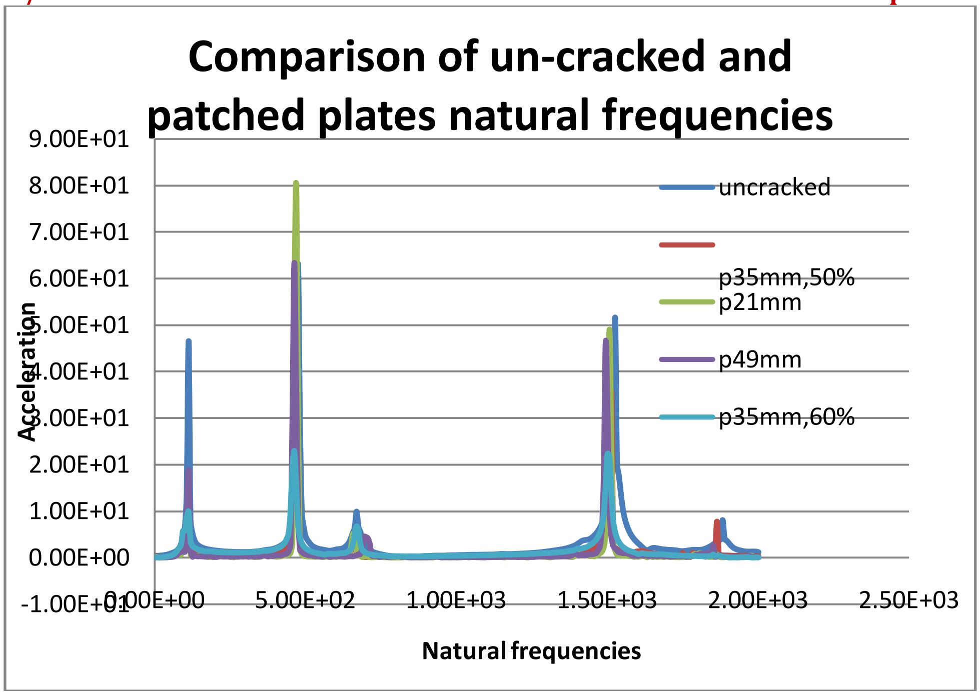

Figure 6: Comparison of un-cracked and patched plate's natural frequencies

From graph it is observed that the natural frequencies of cracked plates are different from the natural frequencies of un-cracked plate. But the natural frequencies of patched specimens are same as the natural frequencies of un-cracked plate.

VIII. RESULT AND DISCUSSION

- The ability of the patch to repair the cracked specimen and also restore the natural frequencies of cracked specimen has been studied in this project.
- No significant effect of patching in y-direction for first five modes of the edge cracked plate,but significant effect of patching in x and z-direction for first five modes of the edge cracked plate.
- While comparing experimental as well as ANSYS results, it has been observed that there is 10-15% error. This is because of some manual error during experimental modal analysis

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