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Experiment to Restore Natural Frequency of Edge Cracked Aluminum Cantilever Beam Modern Mechanical Systems and Machining

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Abstract

Faults in machinery due to vibration are of great concern in the engineering sector. Due to the nonlinear features of damping and mass of composite patching under dynamic settings, the repairing efficiencies cannot be determined directly from a frequency standpoint. Cracks can form as a result of manufacturing process flaws or mechanical flaws. A mechanical structural crack is caused by mechanical accidents, fatigue, and environmental impacts. Composite materials are harmed as a result of mechanical loads and environmental conditions. For this reason bonded composite repair are often preferred. They offer improved stress transfer mechanisms, as well as increased joint efficiency and aerodynamic performance. The use of advanced composites in primary and secondary aerospace structural components is on the rise these days. To recover damaged composite components, it is critical to have dependable, strong, and reproducible structural bonded repair techniques. But this procedure has significant scientific hurdles with the present existent repair methods. The dimensions of the composite patch were selectively stretched along the platform dimensions (x and y) in order to optimise the patching shape.

Keywords: *Composite material, Repair, Machinery, Crack, Cantilever beam*

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INTRODUCTION

Under dynamic situations, resonance is a typical phenomenon for machines or structures. However, under dynamic situations, it can be a very serious problem for machines or structures. The huge amplitudes induced by resonance force structural components to fail catastrophically, especially those with faults.

For example, the large amplitudes may cause the defect to expand constantly, endangering safety in the case of airframes. If the harm caused by the flaws is not critical, the components are usually not replaced for cost and time reasons. Many components' service lives can also be extended via patching.

When an old plane starts to exhibit indications of wear, we have a few choices:

- You can replace the entire assembly.
- The faulty component can be replaced.
- It is possible to fix the damaged section.

There are two options for repairing your car:

- Joint that is mechanically fastened or riveted
- Composite that is adherently bound

There are two methods:

- Strength approach: the material's initial yield strength is preserved.
- Rigidity approach: the material's stiffness (natural frequencies) is preserved.

Adhesively bonded composite repairs are a type of repair that allows for better control of stress concentrations. The purpose of a well-designed bonded repair is to return damaged structures to their normal frequency. Damage growth should be stopped or considerably slowed down. The repair must be completed without causing additional damage or introducing a weak link in the structure. In other words, the repair permits the building to return to its original purpose. The qualities of both the adhesive and the patch are critical to the success of a bonding repair. The bonding procedure and surface treatment have an impact on the repair's quality. Because of their excellent stiffness and strength-to-weight ratios, carbon–epoxy composites have mostly been used in aeronautics.

LITERATURE REVIEW

Okafor (2005) investigated and examined the long-term endurance of adhesively bonded composite patch repairs of fractured aircraft aluminium panels using an octagonal single-sided boron/epoxy

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composite patch. As a test specimen, he used an octagonal single-sided boron/epoxy composite patch.

By connecting fractional variations in the natural frequency of the fractured beam to the healthy beam due to the existence of cracks, K.B.Katnam (2013) suggested a method for detecting crack sites and size. To do so, utilise the line spring model to formulate the problem and the differential quadrature method to solve it. Much study had been done on the strength of bonded patches, using various materials to test their usefulness under various settings. The standard strength of materials approach was used to assess the strength of bonded joints. This contradicts the findings of the experiments. The effects of fibre composite patches on the fatigue life of a broken aluminium specimen have been studied extensively in the lab.

The vibration behaviour of a clamped edge-cracked composite plate repaired by composite patching was invented by Wei-Chung Wang and Chien-hua Chean (2000). Before and after the repair, modal testing was done to determine the natural frequencies and mode shapes of the composite plate.

The dynamic response of repaired composite beams under a harmonic peeling stress was examined theoretically and practically, according to Vaziri.H. Nayeb-Hashemi (2005). The restoration process involved removing the damaged area and using glue to adhere a composite patch to the gap. The patch part was made out of fiberglass-reinforced epoxy composites or E-glass fibre reinforced composites stacked in various ways. Epoxy was used to adhere the patching patches to the composite beam. The results of the experiment were compared to those of the theoretical model and finite element analysis. The adhesive material properties, its loss factor, and the patch material qualities were all investigated in the experiments.

Composite materials have been widely used in numerous flying vehicles, according to A. Baker and R. Jones (1998), due to their high specific strength and stiffness. The structural components are occasionally found to have flaws. Patching is one of the finest solutions to extend the structural life and decrease maintenance costs when flaws aren't severe enough to warrant component replacement.

L. R. F. Rose (1982) presented theoretical derivations and experimental characteristics of several bonded repair procedures. He

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calculates the stress intensity factor of a fiber-reinforced composite material patched side-cracked aluminium alloy sheet.

Mahmoud Nadim Nahas (1982) (1982) in instance, cracks diminish the stiffness of the components and lower the parts natural frequency, leading to failure under normal working conditions. This research describes a new application of carbon nanotube (CNT) composites in the repair of a damaged specimen in order to restore the specimen's natural frequency. Patches are typically made of high-strength, high-stiffness materials. Even low-strength materials, such as epoxy reinforced with CNT, can help mend a fractured specimen, as demonstrated in this work.

DEFINITION OF THE PROBLEM III.

ANSYS was used to develop the best composite patch to keep the natural frequencies of an edge fractured aluminium cantilever, and experimental modal analysis was used to validate the design.

MATERIALS APPLIED

The use of 3-aminopropyltriethoxysilane in a 0.5 percent resin with epoxy increased the bonding strength between the aluminium alloy and the CFRP patch.

FINITE ELEMENT ANALYSIS

Pre-processing:

In ANSYS workbench 15, a 3-D model of the Patched specimen is modelled and examined.

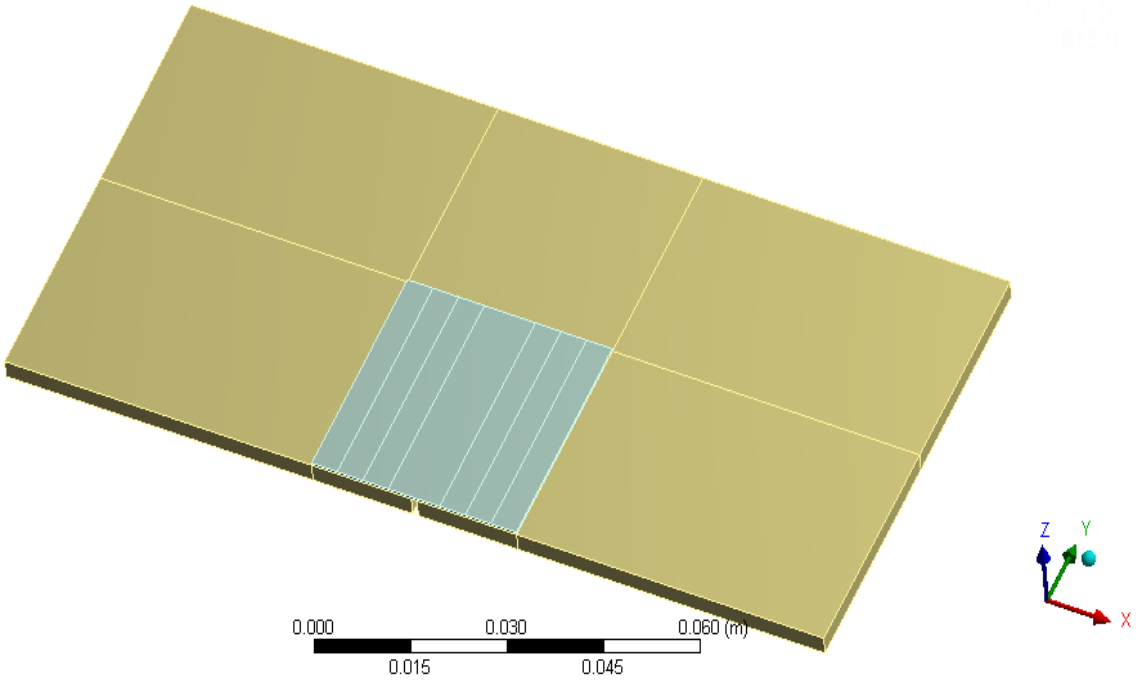


Figure 1: 3-D model of patched specimen

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Solution:

The maximum mode that can be identified is 5, and there is no damped control. Also solver type offered is programmed control. A solution for cantilever support has been found. On a desktop computer, this analysis takes about 45 minutes to complete.

Post processing:

The following figures illustrate the Mode shapes produced for un-cracked, cracked, and patched cantilever specimens. Uncracked and repaired specimens have the same mode shapes.

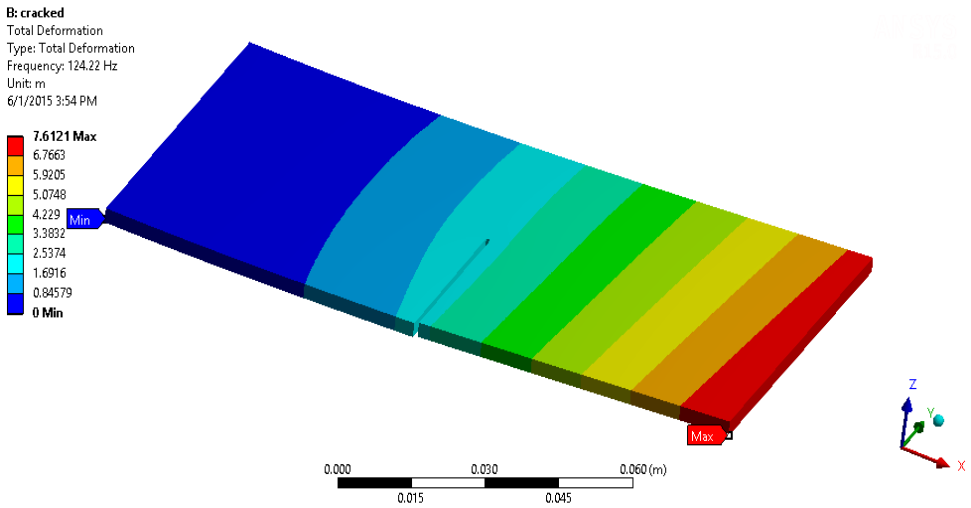


Figure 2: First Mode shapes of cracked cantilever plate

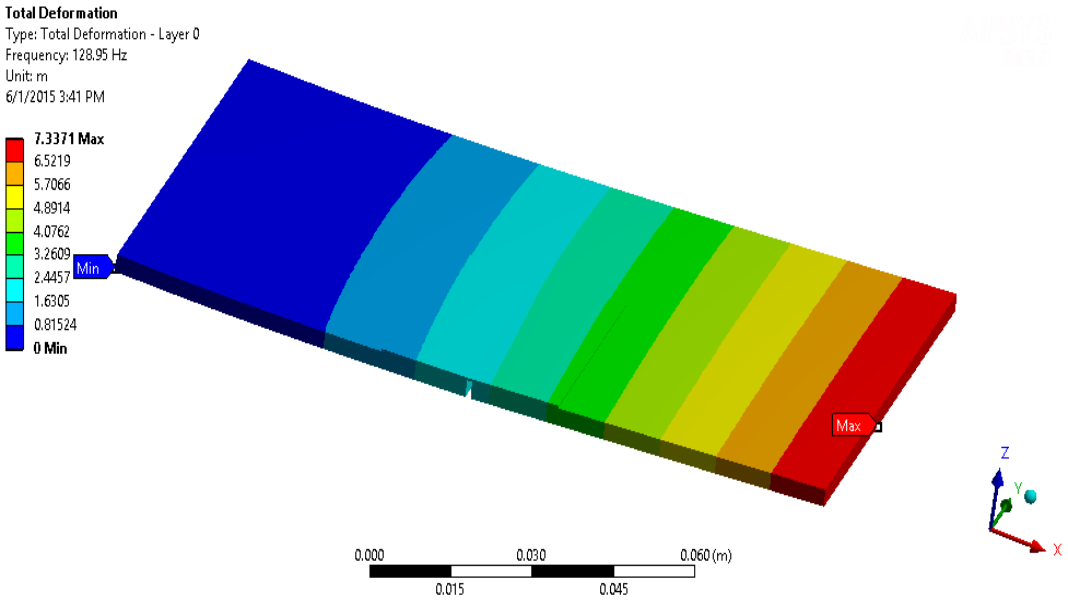


Figure 3: First Mode shapes of patched cantilever plate

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EXPERIMENTAL MODAL ANALYSIS

To tackle a vibration problem, experimental modal analysis is utilised to determine the modal response of an existing structure. In experimental modal analysis, the impact test or bump test is utilised. Impact testing is a low-cost and quick method of determining machine and structure modes. An impact hammer is used to excite the structure, and the FRF (frequency response function) between the stimulation and several places on the structure is measured. A signal analyzer computes the FRF after accelerometers record the vibration levels at different spots on the structure. The resonant frequencies of the structure and the modal amplitudes of the measurement grid point associated with each FRF are identified. (See Figure 4)

RESULT AND DISCUSSION

In ANSYS workbench 15, the first five natural frequencies are determined for un-cracked, cracked, and sample patched specimens. The natural frequencies data show that the natural frequencies of the trial patched specimen grow and approach those of the un-cracked specimen. As a result, the primary goal is to create a CFRP patch configuration that improves the natural frequencies of the repaired plate to match the natural frequencies of the original aluminium plate. Table 1 shows the findings obtained for the first five modes.

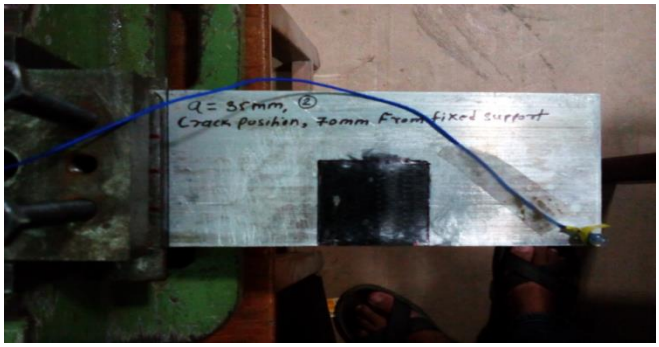


Figure 4: Test specimen set up for modal analysis

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

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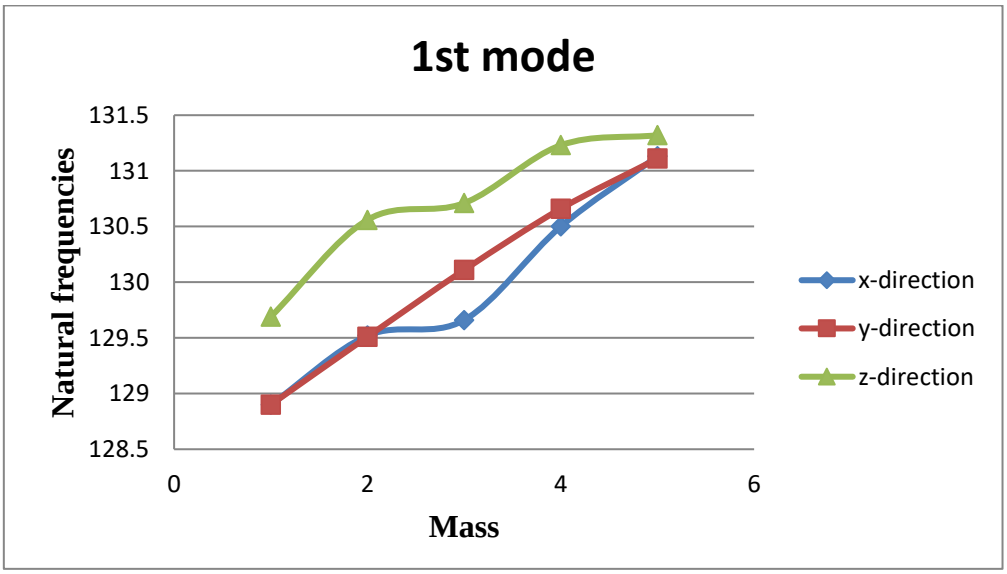
4	1794.3	1525.7	1745.9
5	2283.8	1875.5	2310.2

Selection of optimum cross section for first CFRP patch

To determine the best cross section for the initial CFRP patch, the effect of patching in the x, y, and z directions on natural frequencies must be compared. The first four natural frequencies obtained when patch dimensions are raised in the x and y directions are fewer than the natural frequencies obtained when material is added in the z-direction, as seen in the above data. As a result, the best cross for the initial CFRP patch is 35mmx35mm.

Optimization of CFRP patch configuration

From above data, it is noted that to increase the first four natural frequencies, z-direction is prevalent and also to increase the fifth natural frequencies x-direction is predominant. As a result, the initial patch's cross section measures 35mmx35mm. after this the major purpose of work is to decide the number of patches and sizes of patches in z-direction to be applied in such way that it boosted the natural frequencies of the repaired plate up to the natural frequencies of original aluminium cantilever. One patch has a thickness of 0.225mm. to enhance 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 seen that the natural frequencies are retain after applying 6 (35mmx35mm) patches in z-direction. The goal of modal analysis is to see the distorted geometry and determine the natural frequencies of the specimen in order to understand the mode forms.



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

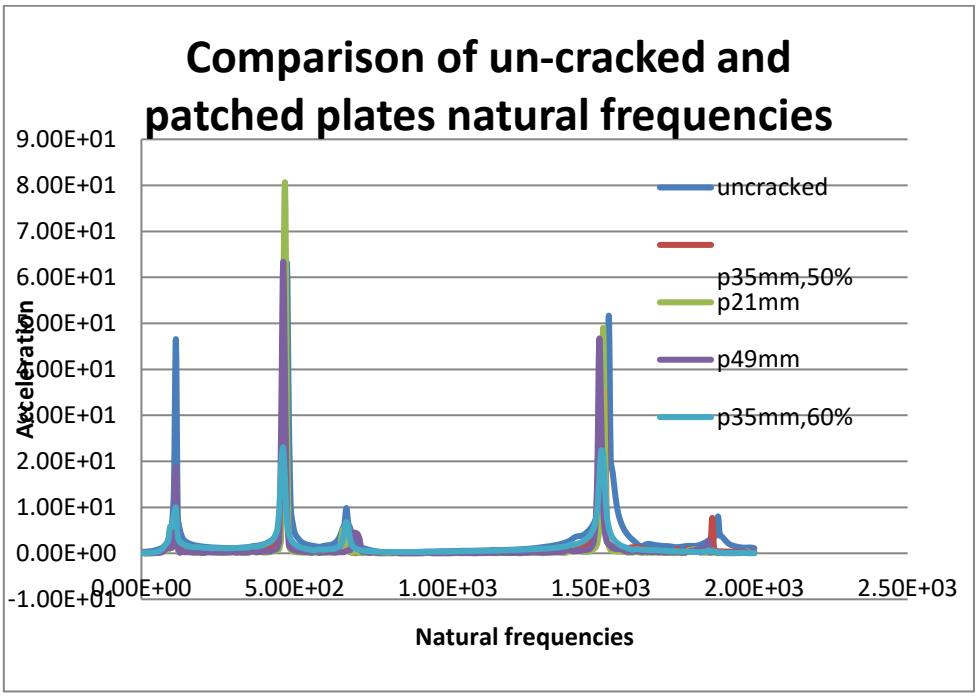


Figure 6: Comparison of un-cracked and patched plate's natural frequencies

The natural frequencies of cracked plates differ from the natural frequencies of uncracked plates, as shown in the graph. However, the natural frequencies of patched specimens are identical to those of uncracked plates.

RESULT AND DISCUSSION

- In this project, the ability of the patch to repair the cracked specimen as well as restore the natural frequencies of the cracked specimen was investigated.
- 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.

\s• while comparing experimental as well as ANSYS results, it has been observed that there is 10-15 percent error. This is due to a clerical error made during the experimental modal analysis.

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