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PREPARATION OF PATCHED SPECIMEN USING COMPOSITE MATERIAL TO RESTORE NATURAL FREQUENCIES OF EDGE CRACKED ALUMINUM CANTILEVER BEAM

Manish Awari[*1] & Hredeya Mishra[2]
[*1]PG Scholar, Mechanical Engineering, Jaihind College of Engineering, Kuran, India
[2]Assistant Professor, Mechanical Engineering, Jaihind College of Engineering, Kuran, India

ABSTRACT

Crack arise may be because of defects due to manufacturing processes and mechanical defects. Cracks may cause serious damage of the structure with due course of time. 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. A new composite material carbon nanotube (CNT) composite in the repairing process of a cracked specimen is used to restore the natural frequency of the specimen. Generally patches are made of high strength and high stiffness materials. In this paper low stiffness materials, such as epoxy reinforced with CNT is prepared. It can contribute to the repair of a cracked specimen. A 2D finite element simulation is used to study the effects of bonding CNT composite patches. The effects of the patch thickness, length, and CNTs weight concentration ratio are considered while preparing specimen.

Keywords: *Crack, Defect, Composite, Repair, Carbon nanotube, Restore, Patches.*

I. INTRODUCTION

Cracks in vibrating element of a structure can make serious consequences on the workability of the structure. In some extent it may convert to a ruinous failure of a structure. Hence, there is a need to determine and identify the dynamics behavior of cracked structures .After detecting crack location and its extent, it is very important to replace or repaired the damage parts. In most cases, replacing the entire structure is not an option due to the high price of system. It is also very difficult to replace some complex parts. This means new parts have to be custom made which is expensive and time consuming. The best and feasible option is to repair them. Repairing a damaged part using composite repair patches will be at less cost and quick method. Two approaches for part repair are usually adopted such as mechanically bolted or riveted repairs and adhesively bonded composites. By mechanically fastened repair, crack maygrow under the patch. They introduce further stress concentration at the additional fastener holes. This result in increased in cracks tendency.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 repair of metal structures with composite materials is a technology that was first introduced in Australia in the early 1970s and later in USA in early 1980s. 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. The performance of the adhesive plays a key role in the successful utilization of bonded composite patch repairs. The role of a bonded composite patch is to restore the original strength and natural frequencies of cracked structure. The stress intensity factor is then reduced by the presence of the patch.

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II. REVIEW OF LITRATURE

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.

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.

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

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.

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.

III. CFRP COMPOSITE PATCH&ALUMINUM CONFIGURATION

The cracks present in the metal sheets can be arrested by bonding the CFRP composite patch on the cracked areas. This type of crack repair by bonding the CFRP patch on the cracked thin metallic sheets.

Table 1: Material Properties of Aluminum

Material Property	Value
Young's Modulus	70 GPa
Density	2612 N/mm^3
Poisson's ratio	0.33
Yield Stress	197 MPa

The life of a component is enhanced.Fig.1 shows the schematic diagram of repaired patched specimen

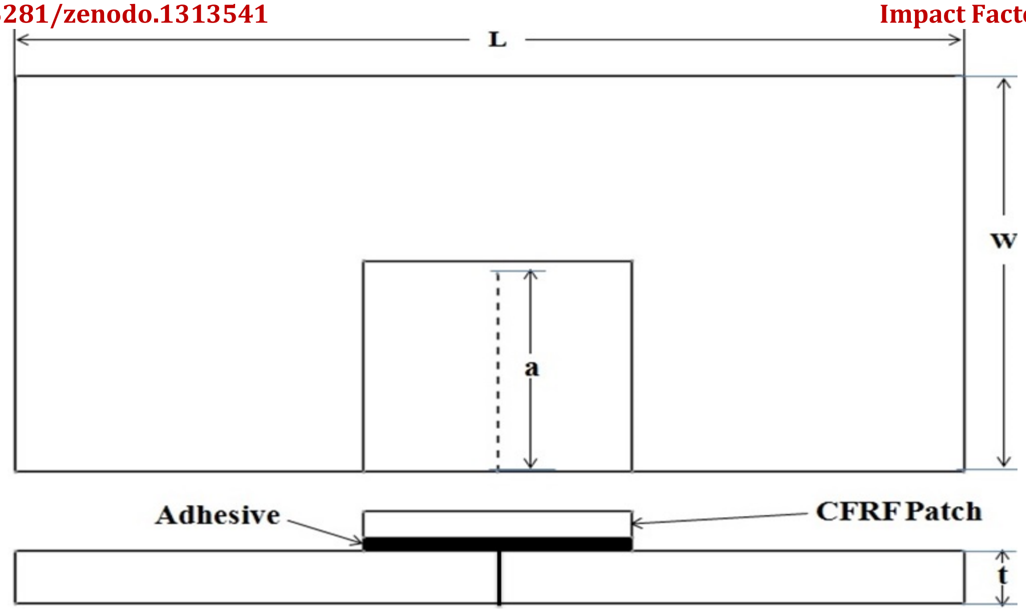

Figure 1: Schematic Diagram of Repaired patched specimen

The dimensions of Un-cracked and Cracked plateare summarized in Table 2.

Table 2: Dimensions of Un-cracked and Cracked plate

Description	Symbol	Value
Plate Thickness	t	3.0 mm
Plate width	W	70 mm
Plate length	L	140 mm
Crack length	a	35 mm

IV. COMPOSITE MATERIAL CONFIGURATION

EPOXY:

In fibre-reinforced composites the role of a matrix is to keep fibres in place and to transfer stresses between the fibres also to provide a barrier against an adverse environment, such as chemicals and moisture. However, the matrix plays a minor role as long as its load carrying capacity was small due to its much smaller modulus compared to that of carbon fiber, Selection of a matrix has major influence on the compressive, inter laminar shear as well as in-plane shear properties of the composite material.In this study, epoxy (Debeckot520F) and hardener (Hardener 758) was used as a matrix material to bond the composite patch. The composite patch was wetted in epoxy and bonded over cracked aluminum plate using the vacuum bagging technique. The mechanical properties of epoxy are $E=3.8$ GPa, $\nu=0.4$, and $\rho=1200$ kg/m^3

AMINO SILANE:

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

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Table 3: Properties of 3-aminopropyltriethoxysilane.

Sr. no	Test	Observation
01	Color	Pale Yellow
02	Viscosity at 25^0C, (cPs)	1.6
03	Flash Point, ^{0}C	96
04	Purity, %	98.66
05	Specific Gravity	0.946

The orthotropic material properties for CFRP are summarized in Table 4.

Table 4: Material Properties of CFR

Material Property	CFRP160GSM	CFRP100GSM
Density(kg/cubic m)	1440	1452
Vf	0.4	0.42
E_1 (GPa)	94.04	98.57
E_2 (GPa)	9.33	9.82
E_3 (GPa)	9.33	9.82
v_{12}	0.298	0.295
v_{23}	0.41	0.4
v_{13}	0.298	0.295
G_{12} (GPa)	2.834	2.968
G_{23} (GPa)	3.30	3.5
G_{13} (GPa)	2.834	2.968

V. SPECIMEN FABRICATION

Preparation of the cracked specimen:

To prepare the edge crack, initially a cut of length of about 33 mm was made through a EDM as shown in figure 7. The width of the crack was about 1.25 mm. Then the crack was extended using a surgeon blade by about 1.5 mm length as shown in figure 8. To make the crack tip very sharp, a fresh razor blade was used to have the final crack extension by about 0.5 mm again by using a suitable designed blade holder. It is worth noting that the crack was made of thin width, only 2 mm because this kind of crack geometry is closer to cracks in most of the real life structures.

Figure 2: Un-cracked specimen

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Preparation of patched specimen:

A specimen was prepared by wetting the UD reinforcement sheet in epoxy and stacking them on the specimen plate. The stack was prepared during the curing of epoxy through a vacuum bag. The surface of the aluminum specimen plate was first made rough by rubbing an emery paper of number 50 in transverse direction of the specimen. Then the specimen was cleaned thoroughly with the help of acetone to remove dust, debris and any other foreign particles that were present on the specimen. The UD-FRP pieces of the required sizes and with the required number of plies and ply configurations were cut properly. The cut pieces of UD reinforcement were gently dipped in acetone to remove wax, if any, before they were wetted with epoxy. In addition the area of the specimen, to which the patch would bond, was wetted with the epoxy. The wetted UD-FRP patches appropriately stacked on the specimen surface and the excess resign was rolled out by using a highly finished stainless steel roller. The specimen, thus prepared, was placed inside the vacuum bagging setup.

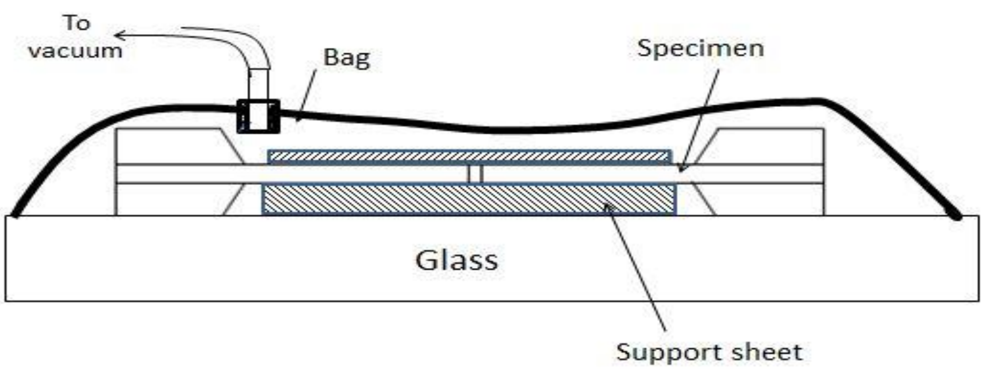

Figure 3: Schematic set up of vacuum bagging technique

A glass plate of 500 mm length, 300 mm width and 18 mm thick with very smooth top surface was employed as base plate. A double sticking tape of 3mm thickness and 20mm width was pasted all around all edges of glass plate. Then a glass fiber reinforced Teflon (PTFE) sheet was placed on the glass plate inside the double sticking tape area. A 5 mm nozzle port was inserted on the bagging sheet. The nozzle port was connected to the vacuum pump with the help of a 5 mm inside diameter flexible hose.The vacuum pump was operated for the duration of about 4 hours at constant pressure of 550 mm Hg vacuum.After curing the specimen within the vacuum bag, it was post cured for about 5 hours at 80^0C,The Vacuum bagging technique ensured uniform pressure on the composite patches, during the curing of the epoxy. Because of uniform pressure, thickness of a FRP/epoxy ply was found to be constant on the entire patch area. Also, it takes most of the entrapped air bubbles and excess resin out under vacuum pressure, thus enhancing the quality of adhesion between the FRP patches and aluminum plate. Figure 4 show the photograph of specimens bonded with FRP patches.

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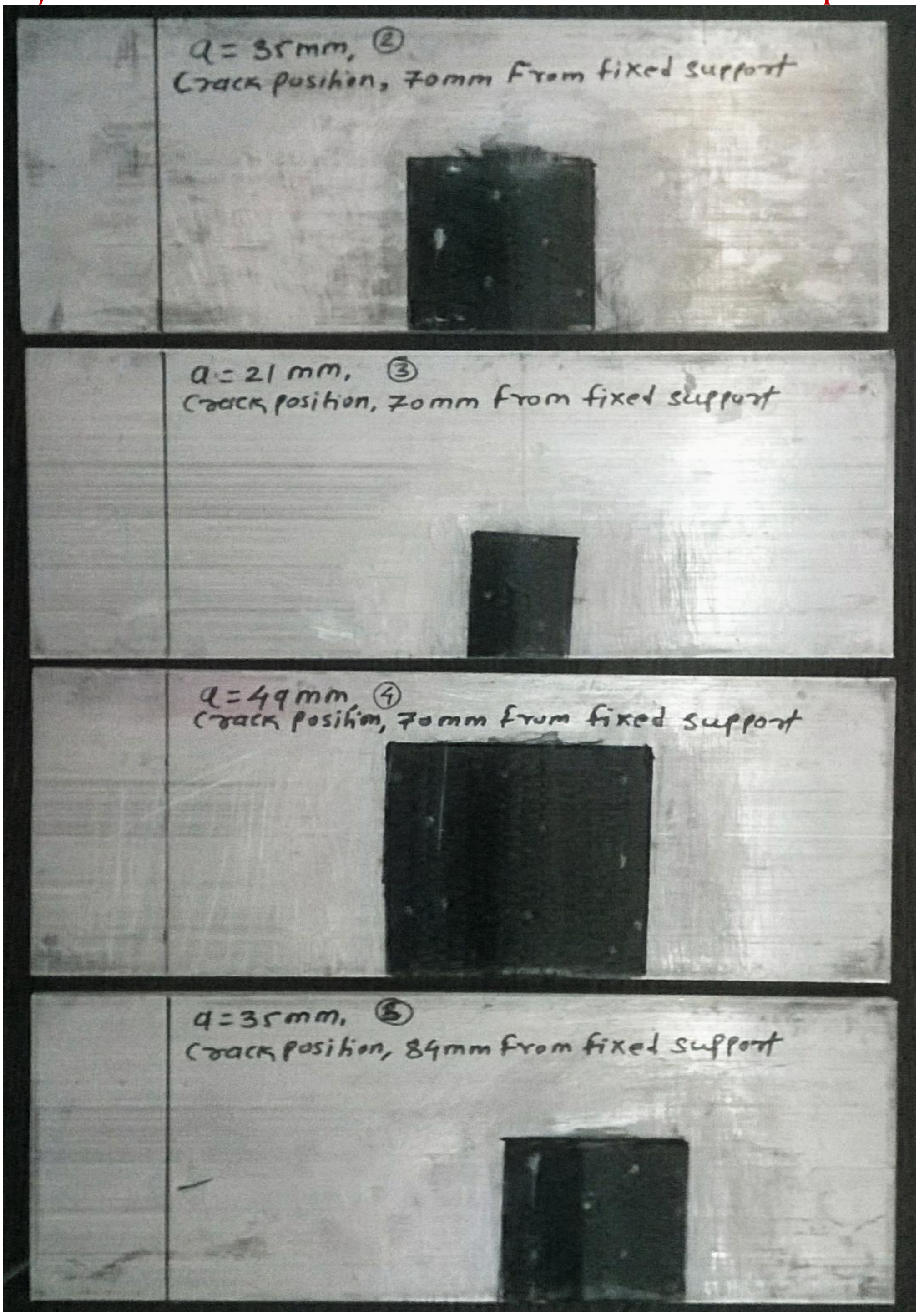

Figure 4: Photograph of specimens bonded with FRP patches.

VI. CONCLUSION

Using Vacuum bagging technique we prepared the specimens bonded with FRP patches of composite material to restore natural frequencies of edge cracked Aluminum cantilever beam.

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