Analysis of Fatigue Life Improvement Using Composite Patch for Crack Arresting

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***Abstract*— In this paper fatigue life of cantilever beam with generated notch and bonded patch has been investigated numerically and experimentally for fatigue life improvement. In this work natural frequency of cantilever beam is calculated numerically and experimentally. Modal analysis of cantilever beam is carried by doing impact hammer test. From that natural frequency of cantilever beam and maximum acceleration at that natural frequency is obtained. These results are correlated with the FEA. This test result is to be used for calculating fatigue life of cantilever beam. Also the fatigue life of cantilever beam with different dimensions of notch and different position is obtained by both numerical and experimental procedure. From this experimentation it is expected that cracked cantilever beam with patch gives more fatigue life than cracked cantilever beam.**

Keywords: -Accelerated fatigue testing, Fatigue Life, Composite Patch.

I. INTRODUCTION

The project deals with the accelerated fatigue failure testing and effect of composite patch on notch cantilever beam. Cantilever beam under consideration contains micro or macro cracks under the effect of various alternating loading conditions [1]. These cracks propagate and cause sudden failure of the material. This type of fatigue failure can be arrested with new composite patch attached at the critical location. This also adds the advantage of increased service life of the component. The replacement of cantilever beam is expensive; therefore the beam is repaired with the composite material patch to use the same beam in future [3]. This is cost effective alternative for the part. Analysis of accelerated fatigue life of notch over cantilever beam is performed with two major variables, the first one with different depth and second one is at different locations from the fixed end [4]. The cantilever beam is analyzed under dynamic condition of variable accelerated loading. The specifications of the cantilever beam to be analyzed are specified as, length of 1000 mm, width 40mm and the thickness of 10mm with different notch depth and position from fixed end. Using the beam with above specified dimensions and with the two analysis constraints, modeling of beam is done to test it for the fatigue failure through crack propagation. The first analysis is done without attaching composite material and in the second analysis the composite material is considered. The effect of addition of composite material is studied by comparing both the results. Whenever the vibration fatigue occurs it is mostly generated with the changes in the natural frequency and damping loss factor [1]. The vibrating frequency associated with the different modal parameters that are varying during experimentation. The addition of layers of composite material can reduce the crack propagation and hence increased the fatigue life but it is observed after certain point, the further addition of composite it will not make any significant change in results [3]. This limit of acceptance of composite is also brought out during this experiment.

II. OBJECTIVE

- To find out the effect of notch on natural frequency and fatigue life of cantilever beam with various depth and various position.
- To check effectiveness of composite patch bonded on notch cantilever beam.
- To extends fatigue life of product.
- To maintain product accuracy and reliability.
- To do numerical analysis of cantilever beam on ANSYS software.

III. CONCEPT MODELING

Analysis of Fatigue Life Improvement Using Composite patches for crack arresting. It is the study of fatigue failure of structure under dynamic condition. For that study take a beam with above mentioned specification is consider. The experimental procedure of accelerated fatigue testing of cantilever beam as shown in figure below.

Fig. 1 Flow diagram of solution procedure

IV. NUMERICAL ANALYSIS:

Three Crack cantilever beam model prepared in CAD software, in CATIA V5. This imported in ANSYS workbench 14.5.

1. Firstly specifying the material property for all the part that is beam material, composite patch and adhesive material. Then take one of the sample that is notch cantilever beam and imported to ANSYS workbench then click on generate command.

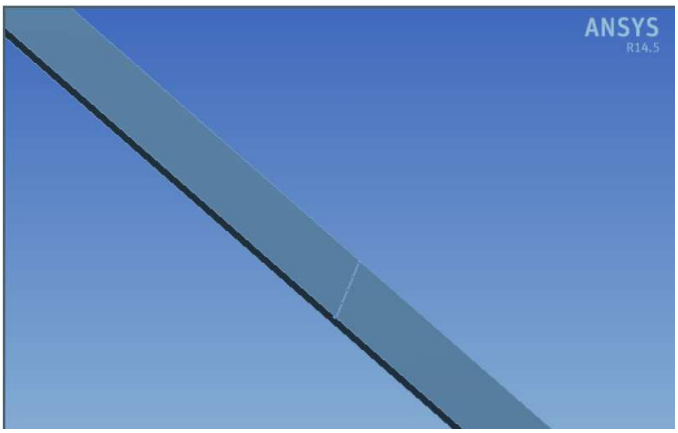

Fig.2 Notch cantilever beam

2. Then the meshing is performed and boundary conditions are applied as shown in figure.

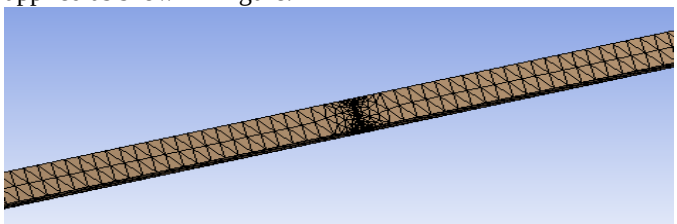

Fig.3 Finite element meshing of notch cantilever beam.

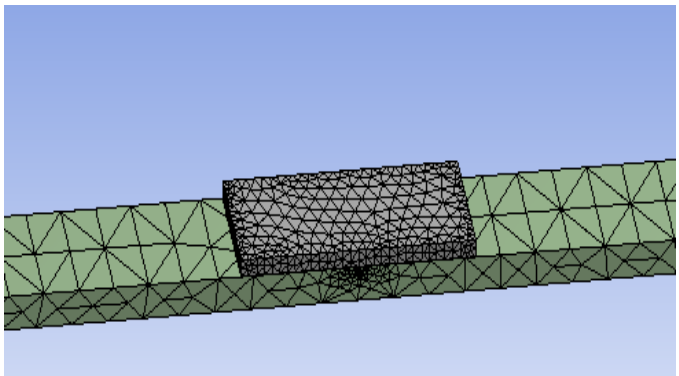

Fig.4 Finite element meshing of crack cantilever beam with patch.

A) MODAL ANALYSIS

Table 1:-1st Mode, Natural Frequencies of Notch Depth to Notch Position.

Crack Depth/Position	100 mm	200 mm	300 mm	400 mm	500 mm	600 mm	700 mm	800 mm	900 mm
1 mm	8.1585	8.1629	8.1663	8.1692	8.1711	8.1726	8.1737	8.1744	8.175
2 mm	8.1231	8.1379	8.1499	8.1591	8.1657	8.1788	8.1733	8.1751	8.1761
3 mm	8.0619	8.0936	8.1199	8.1409	8.1562	8.1662	8.1722	8.1755	8.1775
4 mm	7.9585	8.0225	8.0729	8.1129	8.1406	8.1593	8.1702	8.1759	8.1785
5 mm	7.8006	7.9007	7.9994	8.0633	8.1133	8.1469	8.1666	8.1756	8.1798

Table 2:- Natural Frequencies of beam with and without patch

Natural Frequency	Mode 1	Mode 2	Mode 3
With Patch	10.054	32.636	51.741
Without Patch	8.16	32.598	50.997

By using natural frequency plot the graph, notch position Vs notch depth is as follow. This graph indicates that notch position increases from fixed end then natural frequency increases.

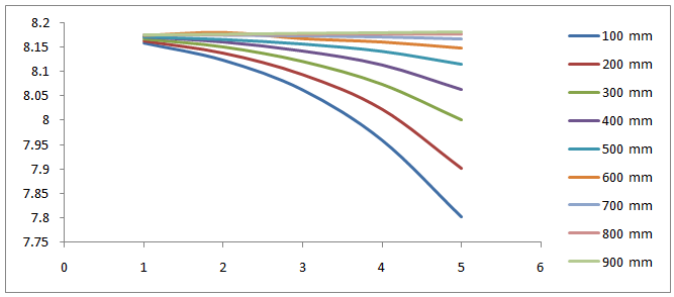

Fig.5 Graph of notch position Vs natural frequency

B) FATIGUE ANALYSIS

When natural frequency approximately reaches with numerical analysis, analytical and experimental value. Then take an acceleration from impact hammer testing, used this value for fatigue analysis. Starting from 10 m/s2.

Table 2 –Fatigue cycle of notch cantilever beam by increasing notch position and notch depth

Crack Depth/Position	100mm	200mm	300mm	400mm	500mm	600mm	700mm	800mm	900mm
1mm	20841	38316	103260	162770	162340	177900	159920	168220	170130
2mm	8240	18320	48262	136160	162650	162450	160000	167800	172440
3mm	4028.2	7266.6	15229	71556	162970	173960	160090	159870	181560
4mm	1738.2	2682.1	8297	27426	113200	173750	160240	168050	172890
5mm	1100.3	1798.9	5370.1	11282	32027	162710	159480	168180	175690

Table 3 –Fatigue cycle of notch cantilever beam by increasing acceleration and notch depth (Notch width 1mm).

Acceleration (m/s2)	Central Crack Depth (width of crack 1 mm)				
v	1 mm	2 mm	3 mm	4 mm	5 mm
30	1000000	1000000	1000000	1000000	211100
40	519000	520650	522270	292900	72614
50	162340	162650	162970	113200	32027
60	83616	83781	83948	58073	16624
70	47500	47594	47689	32990	9823.6
80	29104	29162	29220	20214	6501.7
90	18965	18999	19035	13494	3262
100	13220	13244	13268	9462.3	1370.2

Table 4 –Fatigue cycle of notch cantilever beam with Patch and without Patch.

Acceleration 60 m/s2	With Patch	Without Patch
Fatigue Cycle	96232	83781

By using fatigue cycle value plot the graph, acceleration Vs fatigue cycle. This graph indicate that acceleration increases then fatigue cycle decreases and vice-versa.

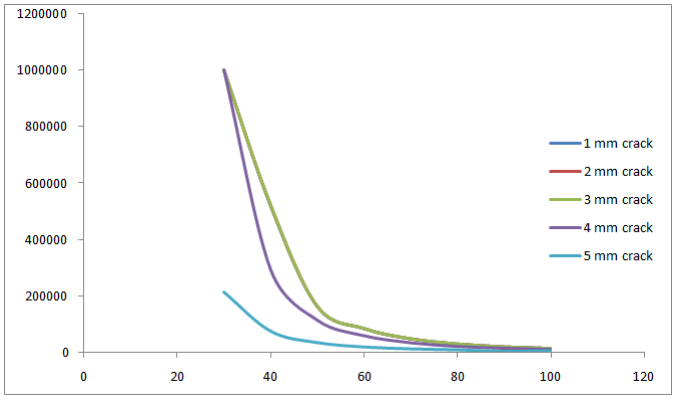

Fig.7 Graph of Acceleration Vs fatigue cycle. (varying notch)

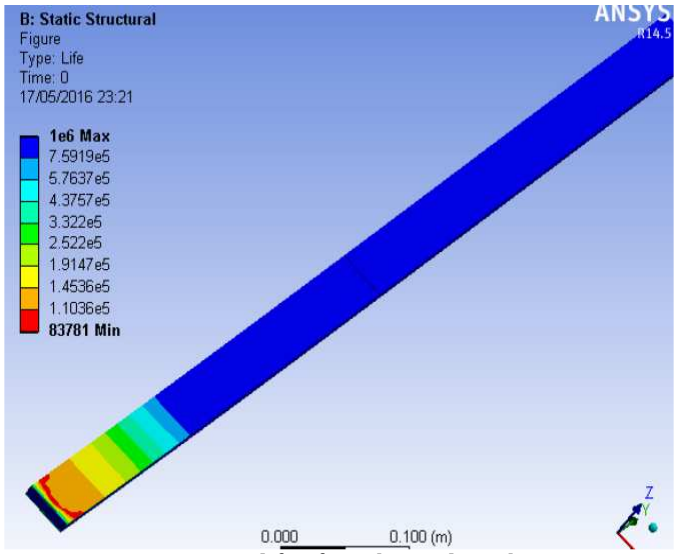

Fig.8 Fatigue life of notch cantilever beam

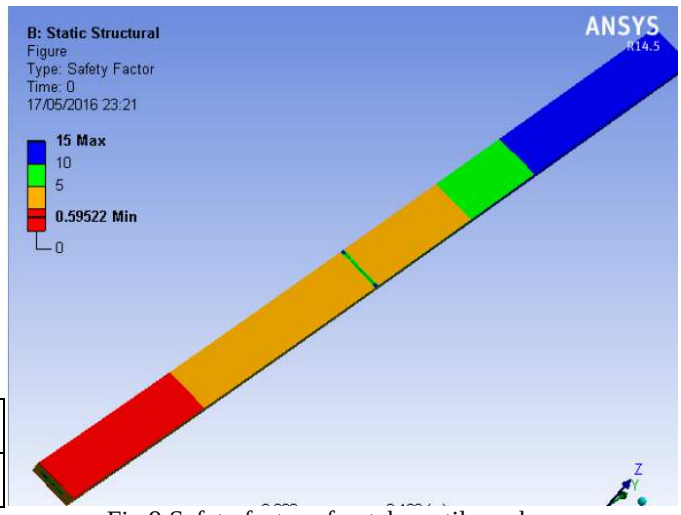

Fig.9 Safety factor of notch cantilever beam

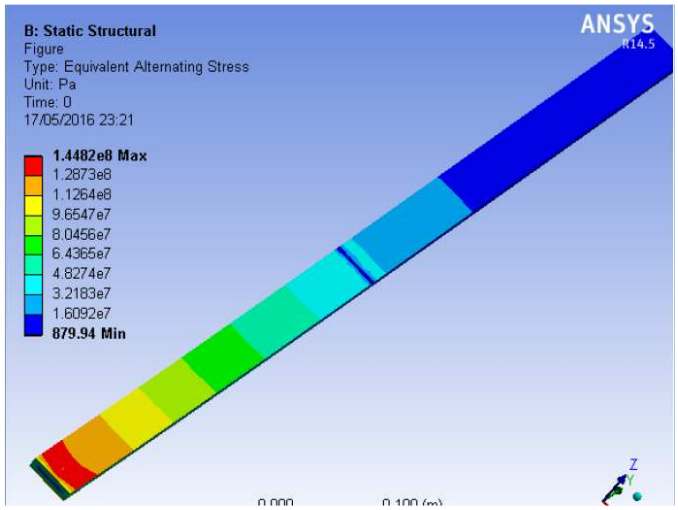

Fig.10 Alternating stress of notch cantilever beam

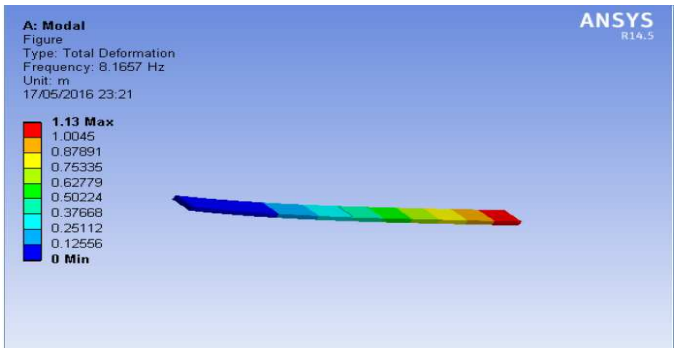

Fig.11 Total Deformation of notch cantilever beam

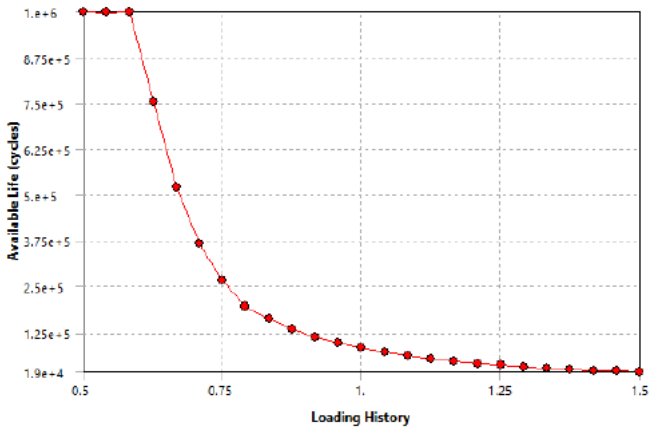

Fig.12 Fatigue sensitivity

Above graph show that loading increases then fatigue cycle decreases, and loading decreases then fatigue cycle increases.

V .EXPERIMENTAL STUDY

Analysis of fatigue life improvement using composite patch for crack arresting, is the study of fatigue failure of notch cantilever beam. Also the effect of composite patch bonded on notch cantilever beam. Experimental setup is as follow.

Fig. 13 Experimental setup

A) Notch cantilever Beam material

Consider a structural steel cantilever beam, 1000mm long, 40mm width, 10mm thickness. Provide a central notch having depth 2 mm and 1mm width rectangular in shape. Also attach a composite patch on the notch cantilever beam.

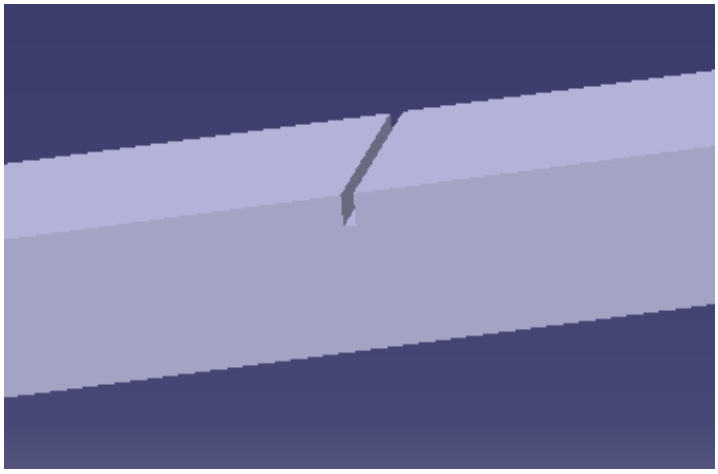

Fig.14 Geometry of notch cantilever beam

B) Composite materials

Composite patch material consists of 59% fiber and 41% epoxy. The density of composite material patch is 2.026g/cm3. Composite material patch having dimension is 80 mm length, 40 mm width and 5 mm thickness. Since composite patch bonded centrally on the notch cantilever beam with the help of lactate rapid adhesive.

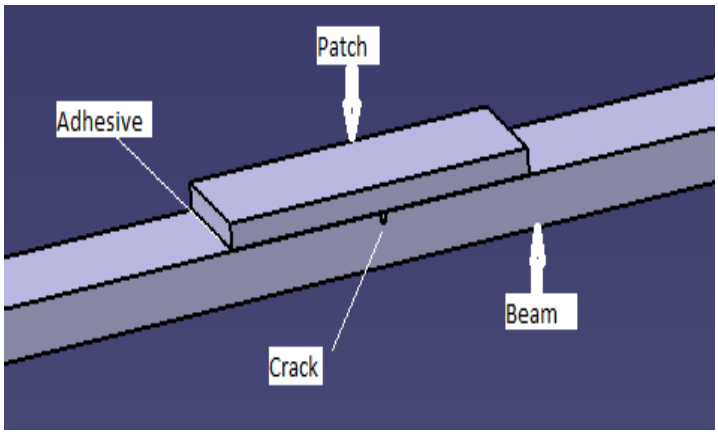

Fig.15 Crack cantilever beam with composite patch.

C) Adhesive: - ESP-110 Loctite rapid adhesive used for bonding of composite patch

D) Accelerated fatigue testing

All numerical analysis condition should be applied for experimental purpose. The sample of the notch cantilever beam should be prepared using cleaning technique. The surface of the sample of notch cantilever beam should be cline that is dust and oil, where the patch is to be attached. Then composite material patch should be bonded centrally on one of the cantilever beam unidirectional. These beams mounted on shaker and give the acceleration and maintain natural frequency 8 Hz up to the failure of notch cantilever beam. Test the each sample one by one and find a fatigue cycle of each sample and compare the result. Analyze fatigue cycle and effect of composite material patch.

VI. IMPACT HAMMER TESTING

To find the natural frequency experimentally modal analysis of cantilever beam is carried out by using impact hammer test. Take a notch cantilever beam mount on fixture as shown in figure. Then attach an accelerometer at free end of cantilever beam in x direction and give the force by impact hammer, and take a five to six reading of natural frequency up to closure value of numerical result.

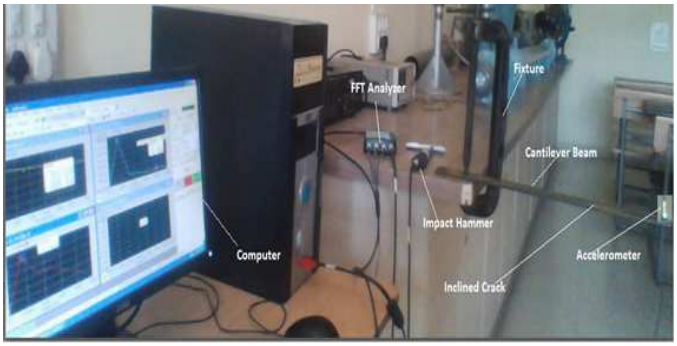

Fig.16 Setup of Impact hammer test

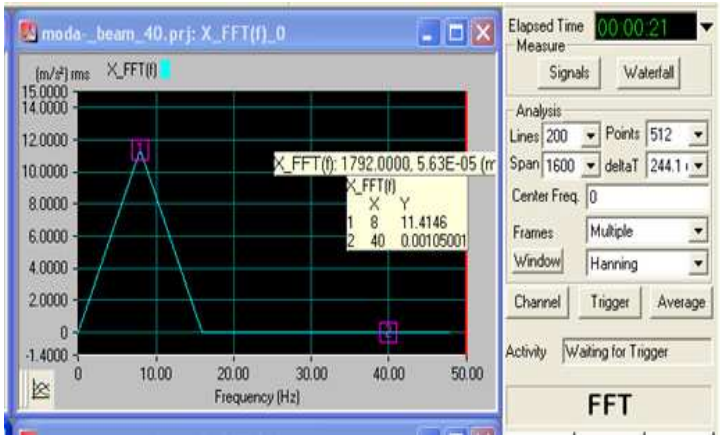

Fig.17 Natural Frequency

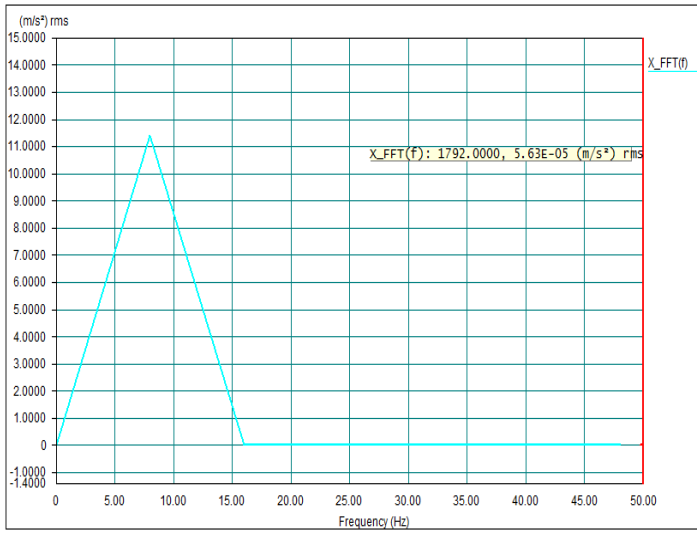

Fig.18 Natural frequency Vs Acceleration

Above graph show that natural frequency and acceleration, that is natural frequency is directly proportional to acceleration up to first mode frequency.

CONCLUSION:

By comparing the result composite patch bonded cantilever beam has 23.21% increases natural frequency and 15% increases fatigue life as compare to notch cantilever beam and plane cantilever beam.

If notch position increases from fixed end of cantilever beam then fatigue cycle increases.

If notch depth increases at particular point fatigue cycle increases after that fatigue cycle decreases due to stress distribution.

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