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Fault diagnosis of crack structure of composite plate

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Abstract- The objective of this paper is to update the knowledge of vibration based Crack/damage diagnosis techniques presented by numerous researchers for the cracked structures. Physical characteristics changes with damage. An analysis of these method makes it possible to determine the location and depth of cracks. Crack is the discontinuation in a body. The presence of crack in the any structure reduces the natural frequency. In early day non-destructive techniques are used to find out damage in body but this method is time consuming. Here ANSYS2015 software is used for finite element analysis of both crack and un-crack composite plate import file as a CAD design developed in CREO 2.00. Experiments is done for total 10 models of crack composite plate having different cross section of the crack, The proposed methodology has been verified by comparing results obtained from experimental analysis and analytical result.The curve fitting toolbox of the matlab gives the position and depth of the crack .Crack identification can be done by using simple curve in curve fitting toolbox. Here the two composite material is use one is carbon epoxy and second is Glass fibre, and comparison that different material of is done in this work. By using that comparison, how the material properties can affect the damage.

Keywords –CREO2.00, crack, curve fitting, vibration.

I.INTRODUCTION

Composite material are widely used in aerospace field, study of laminated structure of composite material is prime focus of researchers. Due to requirement of high performance material in aerospace and marine structure composite material such as carbon epoxy are widely used.

Catastrophic failure in composite structure can occurs due to presences of manufacturing faults not detected in manufacturing Vibration based method have been proved as fast and very less expensive means for crack identification. In the present study analysis of crack by natural frequency is done in ANSYS and crack location and depth of crack in identified in matlab by using curve fitting toolbox.In this paper two composite material plate is used one is made of carbon epoxy and second is made of glass fibre .Composite plate is made by hand up layer technique, crack is given to composite plate with certain depth and crack location by using water jet technique. Analysis of both crack and uncrack plate is by using ANSYS15 software.Comparison of two material one is carbon epoxy and glass fibre by natural frequency is done

II. MATERIAL AND SPECIMEN

Examination of crack analysis by using different crack structure is shown in the fig.

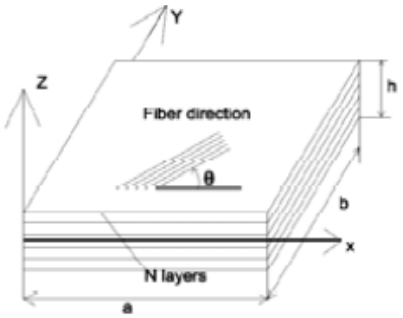

Fig1-Laminated composite plate.

Physical Properties of material are given as follows

Material	(Carbon/Epoxy)		Glass Fibre	
	Ex	Ey	Ex	Ey
Young's Modulus	232	15	73.1	73.1
Shear Modulus	24	24	29.5	29.5
Poisons Ratio	0.279	0.25	0.36	0.36

III-THEORETICAL FORMULATION OF CRACK THEORY

The governing equation of for plate of motion is given in the equation,

$$-D\nabla^4 w=\rho\frac{\partial^2 w}{\partial^2 t}\ ,\quad D=\frac{E.h^3}{12(1-\gamma^2)}$$

$$\nabla^4=\frac{\partial^4}{\partial x^4}+2\frac{\partial^4}{dx^2\,\partial y^2}+\frac{\partial^4}{\partial y^2}\quad (1)$$

As the separation of variable with w where W depends on spatial co-ordinates only and f is a time dependent harmonic function of frequency.

Natural frequency of rectangular slid plate is given by formula,

$$\omega ij=\frac{\lambda ij^2}{2\pi a^2}\left[\frac{E.h^3}{12\gamma(1-\gamma^2}\right]1/2$$

Where a= length of the plate, h=thickness of the plate, γ=mass per unit area and λij is a coefficient for modes and boundary condition and corresponding natural frequency.

$$Wmn(x,y)=Amn\cos\frac{m\pi x}{a}\cos\frac{n\pi y}{a}$$

III. PROBLEM DESCRIPTION

A- Geometric modelling

Geometric modelling of plate is shown in fig. In this problem we have taken five different model of carbon epoxy plate with same cross section area but different crack length and crack depth. Length of plate 130mm and width of plate is taken as 55m mm ,crack length and crack location and crack depth is shown in result and discussion. Composite plates with above dimension are modelled in the CREO 2.0 Software and it is imported in the ANSYS 15 software.

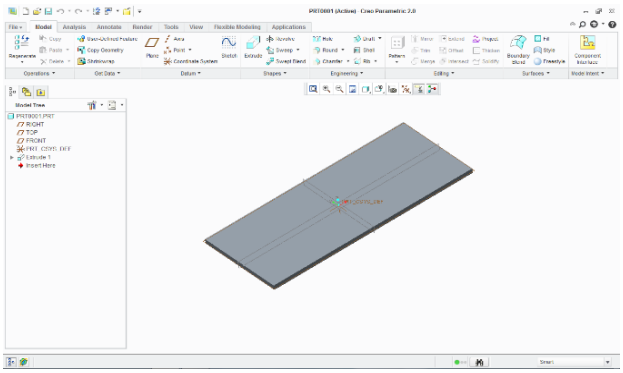

Fig2- Modelling of plate in CREO.

B-Finite element modelling

Element used for present analysis is ANSYS 2015. Software simulation is done for both crack and uncrack composite material plate .Natural frequency is calculated from ANSYS software .free -free boundary condition is for analysis purpose.ANSYS is a general-purpose finite-element modelling package for numerically solving a wide variety of mechanical problem. These problems include static/dynamic, structural analysis (both linear and nonlinear. First 6 modes of natural frequencies are set down and from the resulted data, first three modes of transverse vibration are taken for comparison of 4 composite plate model models. The results are tabulated in table.

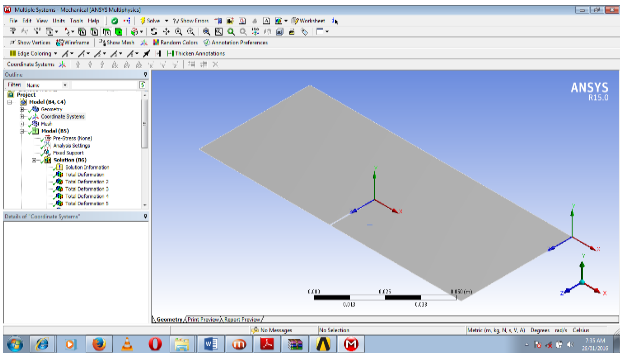

Fig3- Co-ordinate system of plate.

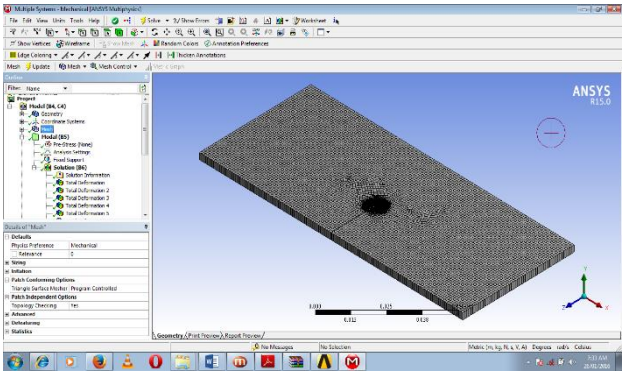

Fig3-Finite element mesh of composite material.

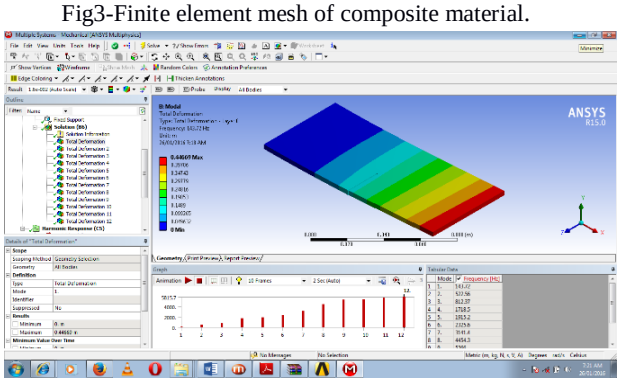

Fig4-Finite element analysis.

C-Frequency responses Analysis

For the finite element model shown in the fig3, Eigen value analysis was performed for various value of w_c/w where wc crack width fig5 shows the result where as the crack width increase in from 10% to 40% then the natural frequency decrease graph show variation between crack width ratio and natural frequency .frequency response is done for validation purpose.

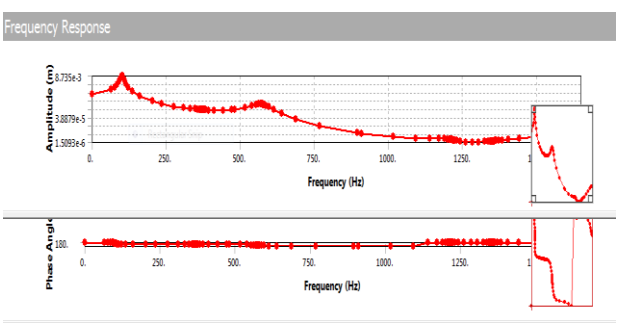

Fig 5-Frequency responses of carbon epoxy.

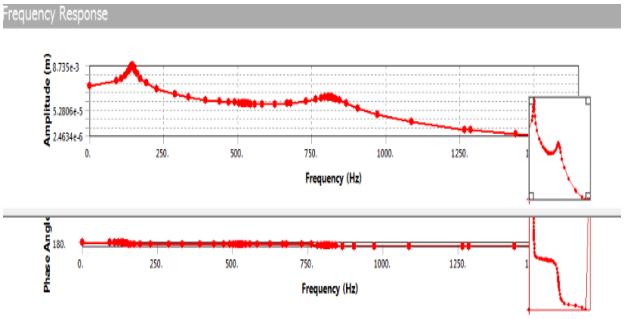

Fig6- Frequency responses of glass fibre.

Frequency responses of both carbon epoxy and glass fibre is done From the graph we have seen that that as crack depth increase the natural frequency of decrease. Natural frequency of carbon epoxy is greater so it does not undergo vibration as early than the glass fibre.

IV. EXPERIMENTAL PROGRAMME

A.Materials

Required for Fabrication of Plates: The material constituent used for fabricating the epoxy/glass fibre plates are, Epoxy resin XR-125 is a liquid, unmodified epoxy resin of medium viscosity which can be used with various hardeners for making fibre reinforced composites. Epoxy curing agent K-6 is a low viscosity room temperature curing liquid hardener.

B. Fabrication Procedure

Composite plate specimen used in this paper made of glass fibre with 0/90 orientation .Specimen are fabricated by hand layup technique. Being rather reactive, it gives a short pot life and rapid cure at normal ambient temperature.

Fig7-Fabrication of composite plate.

C. Experimental Setup and Test Procedure for Free

The vibrational, behaviour of composite plate models has been done by experimental approach with the help of FFT analyser. The FFT analyser is the Fast Fourier Transform analyser contains different electronic components system for measuring natural frequencies of various composite plate of different crack length and crack depth.

Experimental setup for measuring Natural Frequency Details,

1- FFT analyzing machine
2- Composite material plate
3- Impact hammers
4- Microphone sensor
5- Clamping arrangement
6- Vibration Test

Vibratory motion is taken with the piezoelectric types of accelerometer while excitation is given by impulse hammer. Manipulating auto power spectrum of output and input. Three fundamental natural frequency is calculate from the peak of frequency response function .In this experimentation we have done the model test of two crack plate one of carbon epoxy and second is glass fibre, free edged condition is chosen for the test. Because for this experiment we can take the simply supported or fixed.For free boundary condition we suspended plate with elastic string which is shown in the figure.

Fig8-Free free boundary condition of plate.

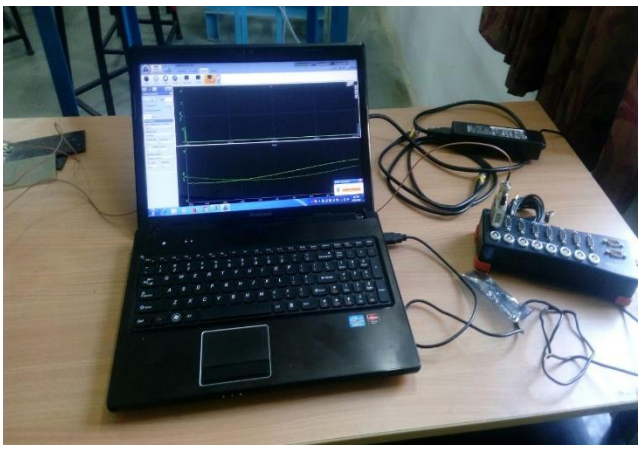

Fig9-Experimental setup of FFT analyser.

Both crack and uncrack plate of both the material is used for experimentation purpose. Crack position crack depth and plate dimension are shown in table 1. First three fundamental natural frequency which FNF, SNF, TNF are calculate by hammering the plate by hammer which shown in the figure 8.Natural frequency of both composite material i.e. carbon epoxy and glass fibre with crack and without crack are calculated.comparision of experimental result and analytical result are shown in the table1.Experimental graph is shown below.

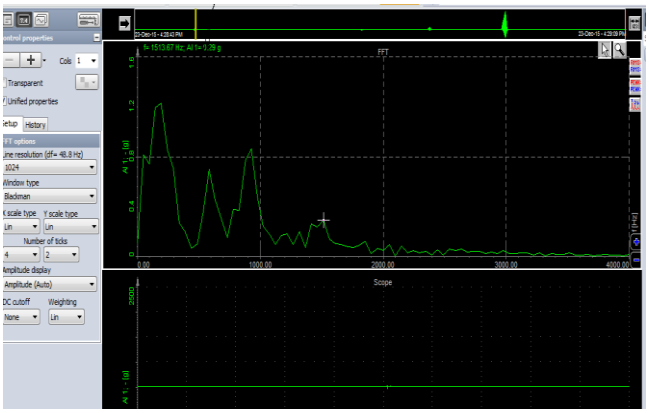

Fig 10- Experimental graph of frequency.

V.CRACK INDENTICATION USING MATLAB

A.MATLAB:-A Tool for engineering Analysis

MATLAB is the high-level language and millions of engineers and scientist use this interactive environment .it explore you and visualize ideas and collaborate across disciplines including signal and image processing, communications, control system, computational finance. Matlab is better and soon became industry standard for data acquisition and mathematical modeling. MATLAB is used in data sciences as a scripting language. The following are the main industry where matlab is used in real life:

Aerospace industry-Mathematical modelling, embedded system-in simulation, Hardware-in-loop simulations.

Automobile industry -Vehicle-in-loop simulation Vehicle networking, simulations.

Computational science -Biological data mining.

Embedded system- Image processing, Digital Signal Processing.

MATLAB uses an array as a basic data dimensioning is not required for that.by using this technique many computing problem can be solved, especially for matrix representations. MATLAB stands for Matrix Laboratory. MATLAB is useful for solving algebraic and differential equation and numerical integration. MATLAB is tool boxes useful for signal processing, image processing, optimization etc. MATLAB provide easy admittance to matrix software developed by the LINPACK (Linear System Package) and EIPACK (Eigen System Package) projects. Today, a MATLAB engine incorporates the LAPACK (LinearAlgebra Package) and BLAS (Basic Linear Algebra Subprogram) libraries, constituting the state of the art in software computation. In university environment, MATLAB is the usual computational tool for basic and advanced developments in mathematics, engineering, and science. In industry, MATLAB is the ideal tool for research and development, and analysis. It is complemented by a family of application specific solutions called toolboxes. The image processing toolbox is a collection of MATLAB environment for the solution of digital image processing problems. Other toolboxes that sometimes complement IPT are Signal Processing, Neural Network, Fuzzy Logic and Wavelet Toolboxes. Curve Fitting and Regression Analysis study was performed with the help of statistical modelling. A curve that could pass through any set of given points has been found out. MATLAB is used to derive equation for best. Fit curve.Missing data point on best fit curve can be found by Extrapolation curve.The purpose of this project was to develop a Matlab program that could execute the operation of finding the Bestfit curve and its extrapolation of any given set of data points.

B.CURVE FITTING:

Curve fitting is the best method to plot curve, by extrapolating series of data points, Curve fitting uses either interpolation or smoothing. For Interpolation an exact data is required to fit to the curve and in smoothing approximate the values to fit data to construct the "smooth" function. The same method is used in the regression analysis, which examine the statistical inference of random data which causes uncertainty in a curve that plotted with the random errors. This approximatedcurve can be used to data visualization, to conclude values of a function where no data are available, and to review the relationships between two or more variables.

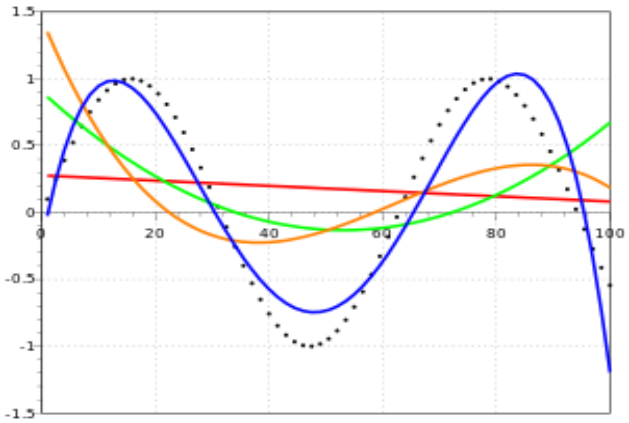

Fig.11.Polynomial curves fitting points generated with a sine function.

Process for Curve Fitting using 'Least-Squares Method'-

The best fit in the least-squares sense minimizes the sum of squared residuals, a residual being the difference between an observed value and the fitted value provided by a model. Least squares problems fall into two categories: linear or ordinary least squares and non-linear least squares, depending on whether or not the residuals are linear in all unknowns. The linear least-squares problem occurs in statistical regression analysis; it has a closed-form solution. The non-linear problem is usually solved by iterative refinement; at each iteration the system is approximated by a linear one.

C. EXTRAPOLATION

Extrapolation is the process of estimating the valuesof variables beyond the experimented observational range, Extrapolation gives the value of a variable by defining the relationship between the experimented variables. It means to calculate the unknown area it require predefined values of variables and the process itself gives

the relation between experienced variables so as to reach at a value of the unknown variables.

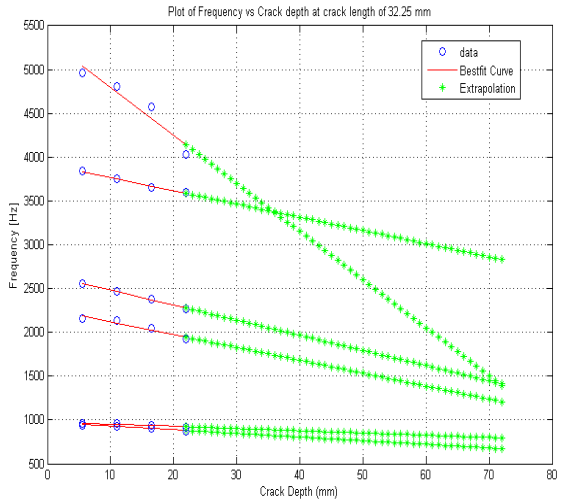

Fig12-Plot of frequency Vs depth at crack location 32.25 of Carbon epoxy.

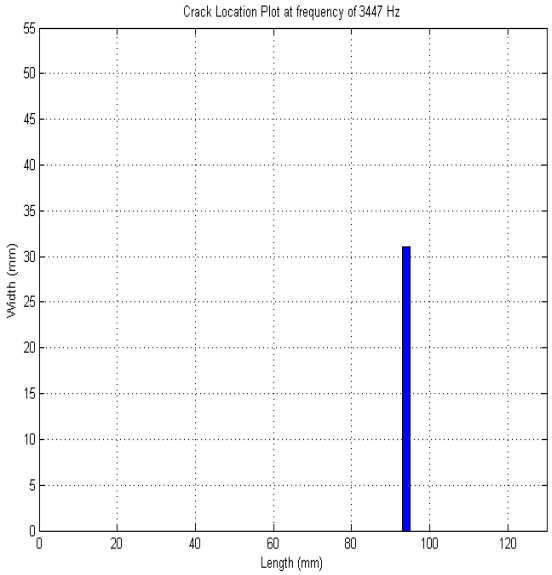

Fig 13- Crack location plot at frequency 3447 of carbon epoxy .

Fig12 show the curve fitting curve, in this technique rotation between natural frequenciesvs. crack depth at location 32.25 shown of carbon epoxy .it seen from the graph that if the depth of increase then the natural frequency decrease.Fig13 show the crack location plot if input frequency 3447 of carbon epoxy gives to maltlab then crack and depth location gives on the plot this show the crack located in between 80-100 mm.

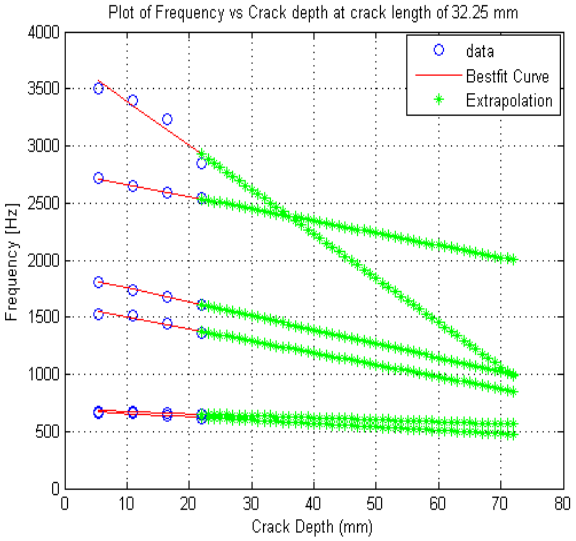

Fig14-Plot of frequency Vs. depth at crack location 32.25 of Glass fibre.

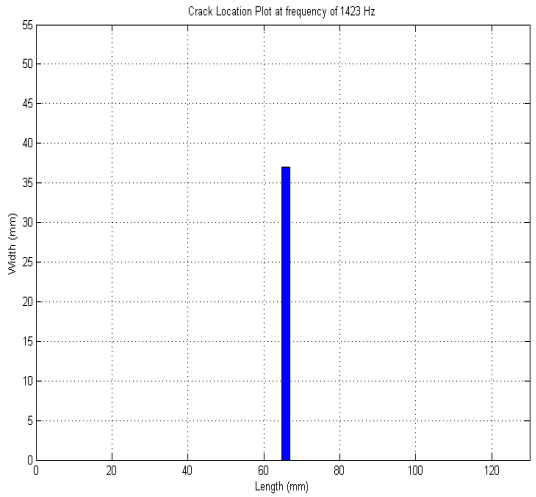

Fig 15-Crack location plot at frequency 1423Of Glass fibre.

Fig14 show the curve fitting curve, in this technique rotation between natural frequencies vs. crack depth at location 32.25 shown of glass fibre .it seen from the graph that if the depth of increase then the natural frequency decrease. Fig15 show the crack location plot if input frequency 1423 of carbon epoxy gives to maltlab then crack and depth location gives on the plot this show the crack located in between 60-65 mm.

VI. RESULT AND DISCUSSION

Frequency of finite element analysis, experimental frequency, and theoretical frequency is given bellow in the table. Natural frequency of carbon epoxy material is greater means carbon epoxy does not undergo the failure. So carbon epoxy is better material than the glass fibre. FRF (frequency responses function) analysis is done for validation purpose ANSYS.Curve fitting graph shown in the figure 12 & figure 14 shows the graph of crack depth vs. natural frequency. Figure 13 & figure 15 shows crack location by giving natural frequency as a input.

Material type	Sr.No.	Crack Location (mm)	Crack Depth (mm)	Analytical Frequency			Experimental Frequency		
				FNF	SNF	TNF	FNF	SNF	TNF
Carbon Epoxy (l=130mm,w=55 mm)	1	64.75	22	790.80	900.72	2079.93	756.80	798.93	1830.33
	2	64.75	16.5	855.44	916.75	2085.70	796.44	813.15	1835.41
	3	64.75	11	900.24	943.62	2113.43	823.12	836.99	1859.81
	4	64.75	5.5	930.39	959.13	2144.27	771.99	850.74	1886.95
	5	32.25	22	872.60	919.70	1923.03	803.75	815.77	1692.26
	6	32.25	16.5	908.50	93527	2042.72	820.09	829.58	1797.59
	7	32.25	11	926.96	957.30	2139.42	833.45	849.12	1882.68
	8	32.25	5.5	942.06	959.07	2161.52	780.05	850.69	1902.13
	9	97.25	22	881.71	906.87	1933.87	771.99	804.39	1701.80
	10	97.25	16.5	872.60	919.70	1923.03	811.81	815.77	1692.26
	11	97.25	11	917.61	979.52	2160.23	832.89	868.83	1901.00
	12	97.25	5.5	941.43	960.52	2166.65	756.80	851.98	1906.65
Glass fibre (l=130mm,w=55 mm)	1	64.75	22	559.18	636.90	1470.73	511.65	582.76	1331.01
	2	64.75	16.5	604.88	648.24	1474.81	553.47	593.13	1334.70
	3	64.75	11	636.56	667.24	1494.92	582.46	610.52	1352.90
	4	64.75	5.5	657.88	678.21	1516.22	601.96	620.56	1372.17
	5	32.25	22	617.02	650.33	1359.79	564.57	595.05	1230.60
	6	32.25	16.5	642.41	661.33	1444.42	587.80	605.11	1307.20
	7	32.25	11	655.46	679.92	1512.80	599.74	622.12	1369.08
	8	32.25	5.5	666.13	678.17	1528.42	609.50	620.52	1383.22
	9	97.25	22	623.46	641.26	1367.45	570.46	586.75	1237.54
	10	97.25	16.5	640.56	666.13	1468.32	586.11	609.50	1328.82
	11	97.25	11	648.85	692.61	1527.51	593.69	633.73	1382.39
	12	97.25	5.5	665.69	679.19	1532.035	609.10	621.45	1386.49

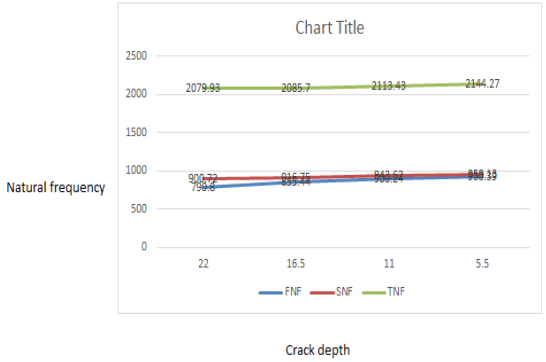

Fig 10 Graphical relation between crack depths Vs. Natural frequency.

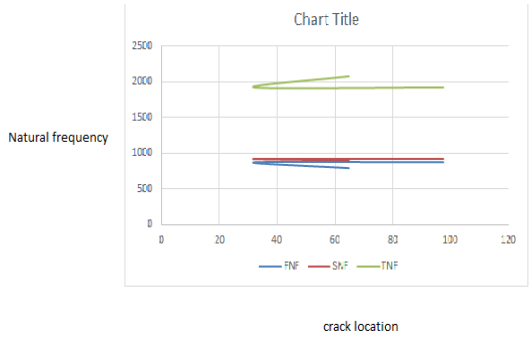

Fig 11 Graphical relation between crack position Vs. Natural frequency

VII. CONCLUSION.

From the result we can draw the conclusion

- When the crack depth increases and crack location keeps constant, then the natural frequency of composite plate reduces.
- Natural frequencies changes with area of crack location.
- When crack depth is constant and crack location increases the then the natural frequency decrease. Crack depth and crack can be predicted by finite element method.
- Natural frequency of analytical and experimental are close to the agreement.
- Carbon epoxy is better material than the glass fibre from result of natural frequency.
- ANSYS and MATLAB , in which natural frequency obtained in ANSYS can be used as input for Curve Fitting & Extrapolation(MATLAB) for calculate the exact value of crack depth and crack location.

VIII. ACKNOWLEDGMENT

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