International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 05 | May-2018 www.irjet.net p-ISSN: 2395-0072

Static and Dynamic Analysis of Delaminated Composite Plates

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Abstract - *Composite materials are widely used in the industries such as marine, automobile, aerospace, civil, aviation. Etc. Because of their excellent mechanical properties also for light in weight and easily mould in any shapes and size as per requirement but one of the serious defect occur in the laminated composite plate is delamination. For experimental analysis the test plate is made from Glass fibre and epoxy resin by using hand layup method. The natural frequencies of laminated composite plate with and without delamination are finding out by using FFT Analyser and these natural frequencies are comparing with the finite element method using ANSYS software.*

Key Words: **Composites, Delamination, Free vibration, Natural frequency, ANSYS.**

1. INTRODUCTION

Composite material is widely used material in engineering industries for their excellent for their incredible lightweight, stiffness to weight and strength to weight ratios. We can achieve any type of difficult structures, complex shape or design with the help of composite material. They are also used in the construction of nuclear, ships, submarine etc. But one of the common defects is occurring in composite material called as delamination. Delamination is nothing but separation of two layers of composites. Delamination occur in composite plate is invisible because it occur inside of the material. Delamination also develops due to repeated cyclic stresses, manufacturing defects, low velocity impact, unlike environment condition. Due to delamination in composite plates may reduce mechanical properties such as loss in strength, toughness, stiffness, and material unbalance. So, it is very important to detect such type of damage for reducing material failure. Therefore detecting such type of damage by using non-destructive test for composite. But such types of method are time consuming. So, to solve such type of problem by using various approximate techniques in which finite element method can be used by using software ANSYS 18.1 for damage monitoring of laminated composite plates.

2. PROBLEM DEFINATION

Now- a -days, composite material are widely used in the engineering industries but one of the type of damage occur in composite plate called as delamination. With the presence of delamination plates fails during the service orthotropic-ally, sometimes cracks are observed and the structure becomes weak, also sometimes its fail due to vibrations. So, it is very important to detect the delamination in the composite plate in the time to take remedial action in advance and to reduce the effect of delamination.

3. MATHEMATICAL MODEL

Now, the earlier developed higher order models are further extended for the plate with delamination. For this, a typical laminate with *'p'* number of delamination is considered as shown in Figure 1. For the delaminated element, the local coordinate system is considered to be *0'*, *x'*, *y'* and *z'* which is analogous to the coordinate system used for the segment without delamination. The displacement field of the delaminated element is assumed to be of the following form relative to its own local coordinate system.

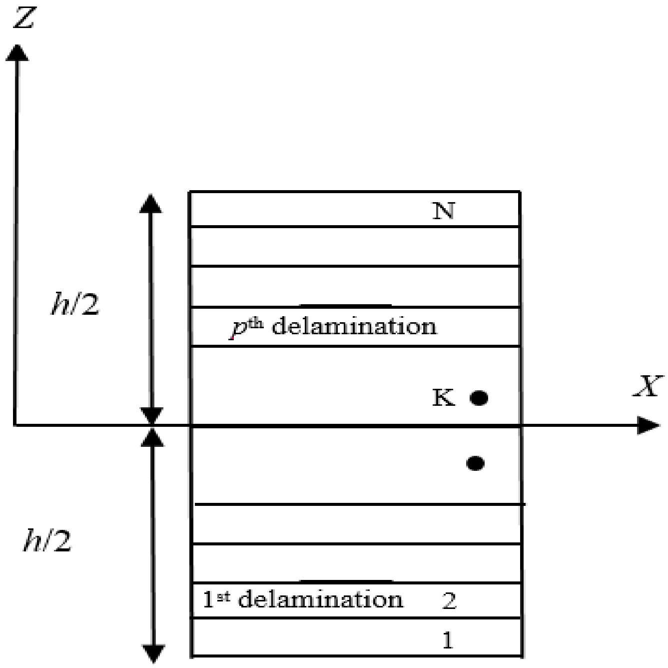

Fig -1: Laminated plate with delamination

3.1 Model-1

The first model for the delaminated segment of the plate is developed based on the HSDT kinematics similar to the laminated segment considering the transverse displacement is constant through the thickness and it results in zero transverse normal strain. The displacement filed is conceded as:

$u'\square x',y',z',t\square\square u_0'\square x',y'\square\square z'\square_x'\square x',y'\square\square z'^2\square_x'\square x',y'\square\square z'^3\square_x'\square x'y'\square$

$v'\square x',y',z',t\square\square v_0'\square x',y'\square\square z'\square_y'\square x',y'\square\square z'^2\square_y'\square x',y'\square\square z'^3\square_y'\square x',y'\square$

$w'\square x',y',z',t\square\square w_0'\square x',y'\square\square\square$

3.2 Model-2

Also, the second model is developed in a similar fashion considering the linear variation of the displacement along the thickness direction as:

$$u'\square x',y',z',t\square \square u_0'\square x',y'\square\square z'\square_x'\square x',y'\square\square z'^2\square_x'\square x',y'\square\square z'^3\square_x'\square x',y'\square$$

$$v'\square x',y',z',t\square \square v_0'\square x',y'\square\square z'\square_y'\square x',y'\square\square z'^2\square_y'\square x',y'\square\square z'^3\square_y'\square x',y'\square$$

$$w'\square x',y',z',t\square \square w_0'\square x',y'\square\square z'\square_z'\square x',y'\square$$

where, t is the time and u', v' and w' are the displacements of any point along the x', y' and z' coordinate axes, respectively. u_0', v_0' and w_0' are corresponding displacements of a point on the mid plane and $\square_x'$ and $\square_y'$ are the rotations of normal to the mid-surface, i.e., $z'=0$ about the x' and y' axes, respectively. The functions $\square_x'$, $\square_y'$, $\square_x'$, $\square_y'$ and $\square_z'$ are the higher order terms in the Taylor series expansion.

4. EXPERIMENTAL ANALYSIS

Free vibration responses of Glass fiber with epoxy resin plates are found out experimentally and it is compared with Finite Element Method by using ANSYS Software. Glass fiber with epoxy resin composite plate is fabricated using hand layup method with delamination at any desired location.

4.1 STATIC RESPONSE

The static responses are computed via a Three-point bend test on a Universal Testing Machine (UTM), INSTRON 5967 with 30 KN load cell at PRAJLAB Kothrud the laminated composite plate for the experimental analysis have been prepared as per ASTM standard (D 3039/D 3039M). The recommended loading rate for the analysis is fixed as 2 mm/minute.

4.2 FREE VIBRATION RESPONSE

The experimental study is also performed for the free vibration analysis by using the same composite laminated composite plate with and without delamination. The natural frequency of laminated composite plate with and without delamination is recorded experimentally through the SVANTEC FFT Analyser. The vibration responses of the laminated composite plate with and without delamination under cantilever type (CFFF) support condition, with the help of a fixture are recorded via an accelerometer that is mounted on the centre of the plate. The composite plate is excited with the help of an impact hammer on any random points and through the accelerometer, the signal is received and the accelerometer is senses the vibration and converts it into the analogue voltage signal.

5. NUMERICAL ANALYSIS

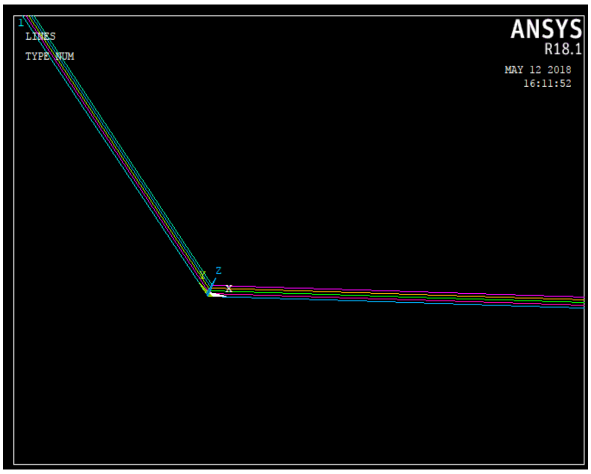

Fig -2: 4 layer healthy grid node

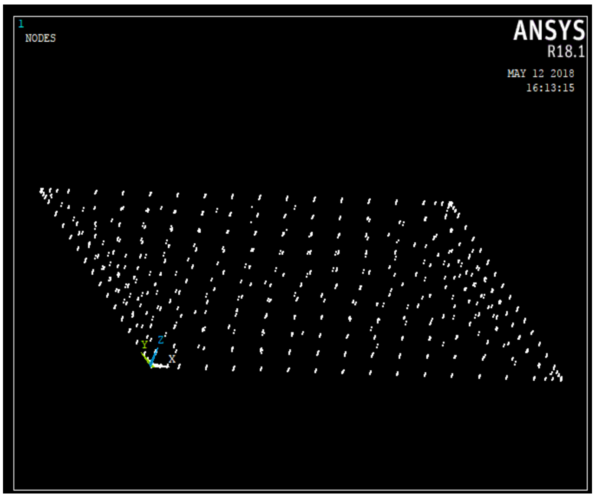

Fig -3: 4 layer healthy model line

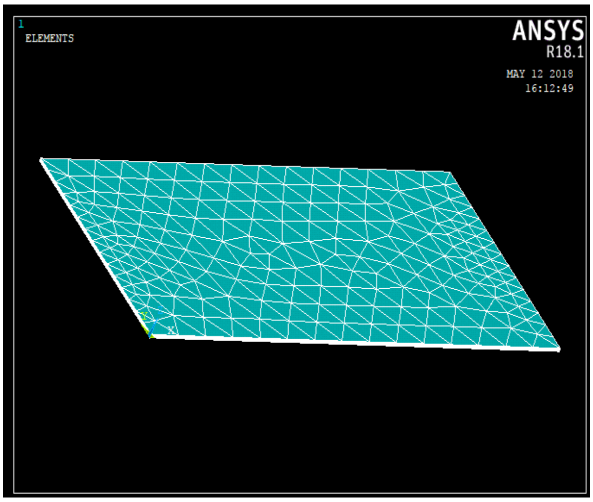

Fig -4: 4 layer healthy meshed model

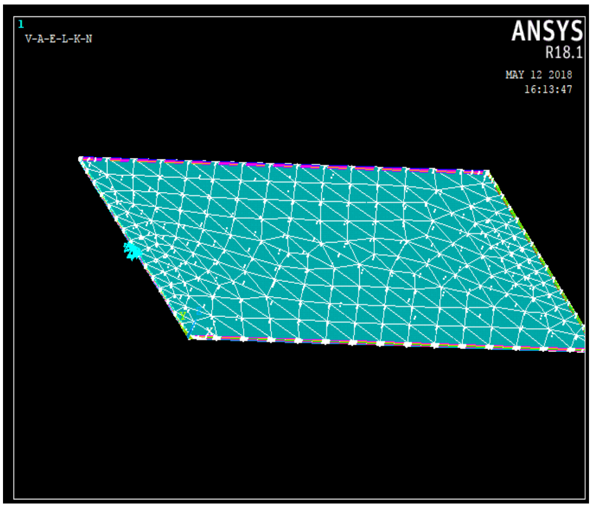

Fig -5: 4 layer healthy BC

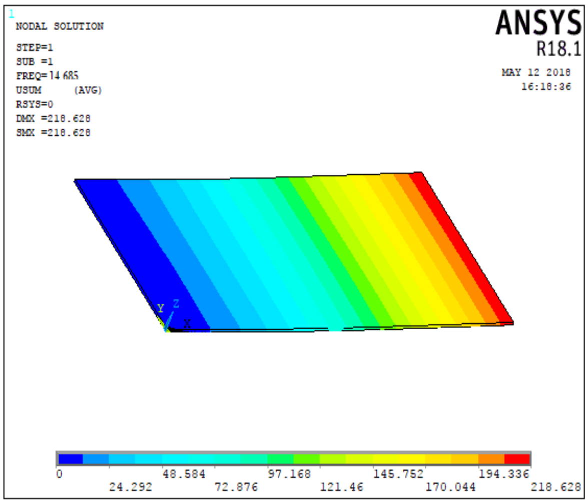

Fig -6: 4 layer healthy Mode 1

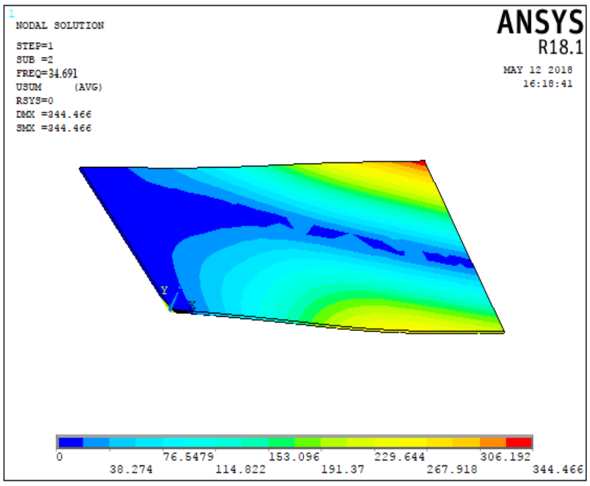

Fig -7: 4 layer healthy Mode 2

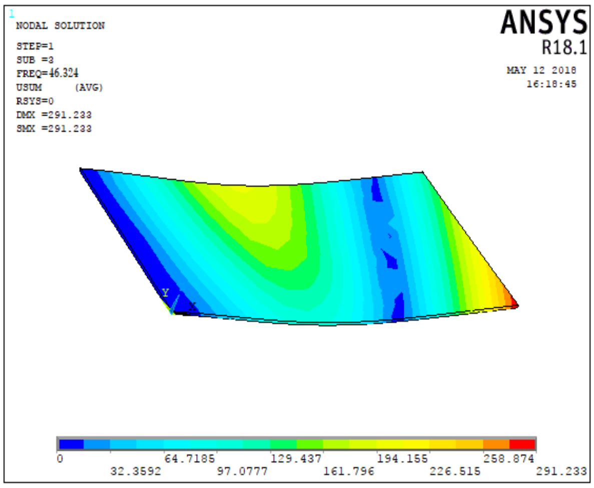

Fig -8: 4 layer healthy Mode 3

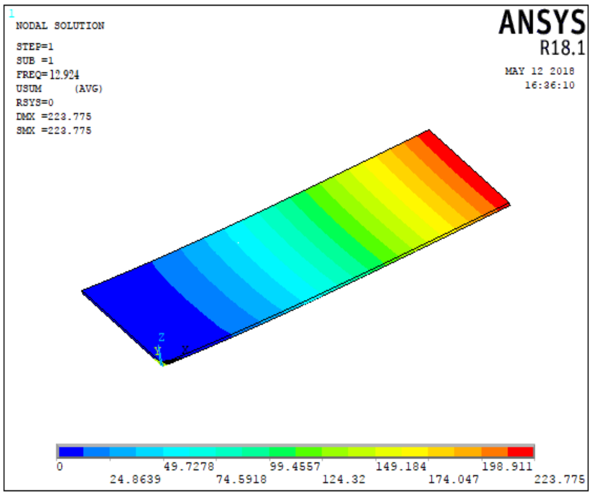

Fig -9: 4 layer 1 delamination Mode 1

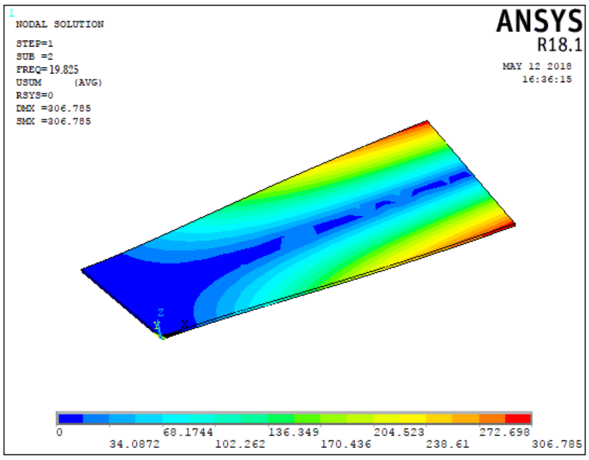

Fig -10: 4 layer 1 delamination Mode 2

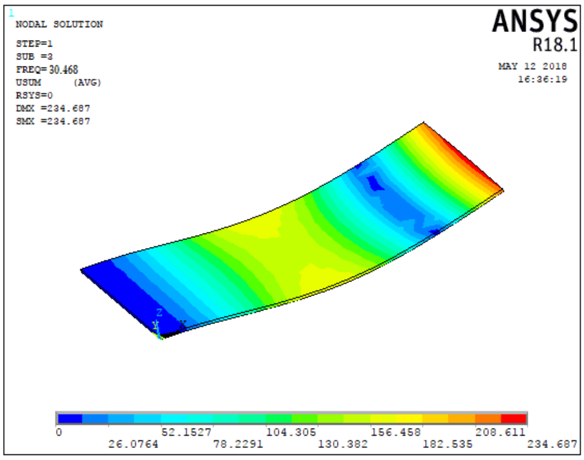

Fig -11: 4 layer 1 delamination Mode 3

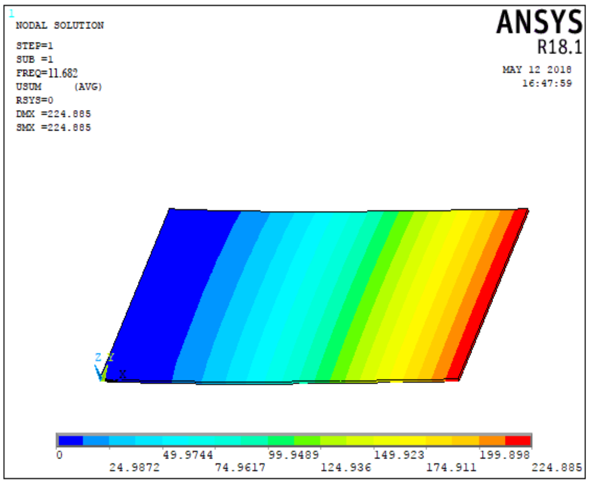

Fig -12: 4 layer 2 delamination Mode 1

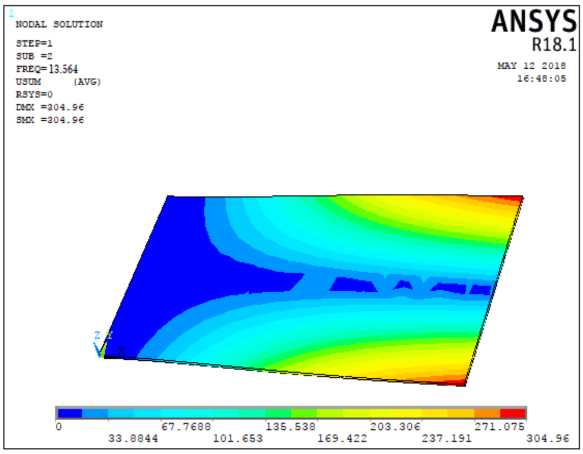

Fig -13: 4 layer 2 delamination Mode 2

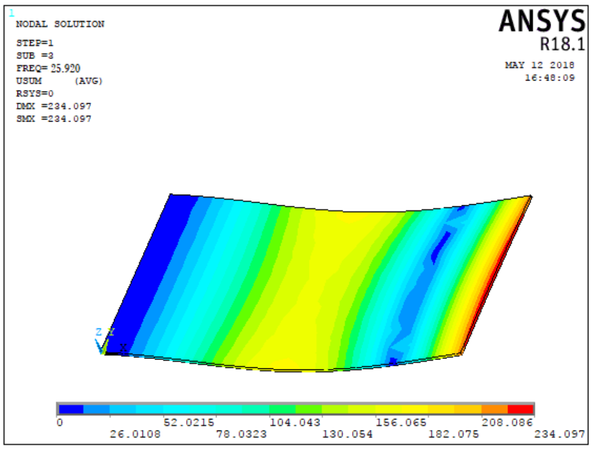

Fig -14: 4 layer 2 delamination Mode 3

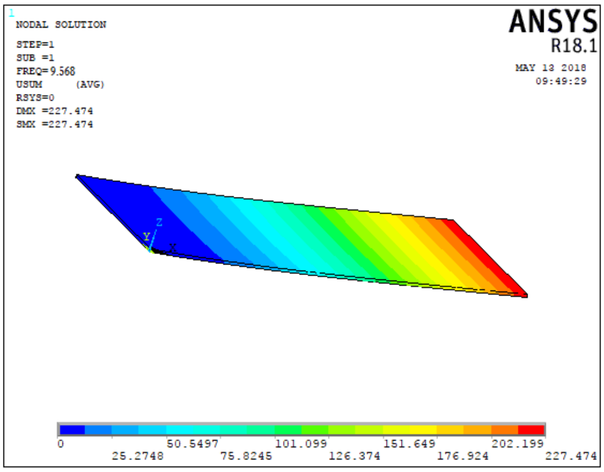

Fig -15: 4 layer 3 delamination Mode 1

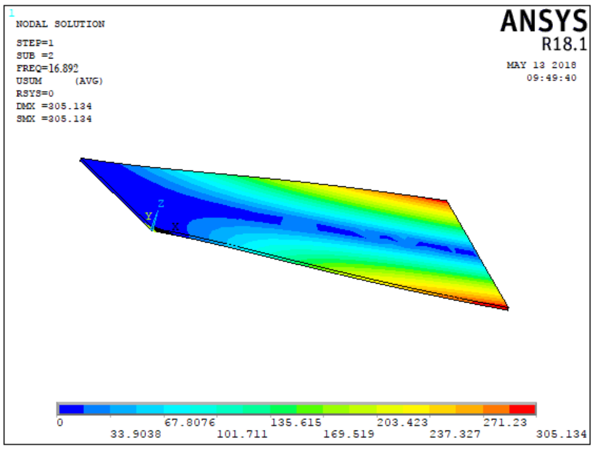

Fig -16: 4 layer 3 delamination Mode 2

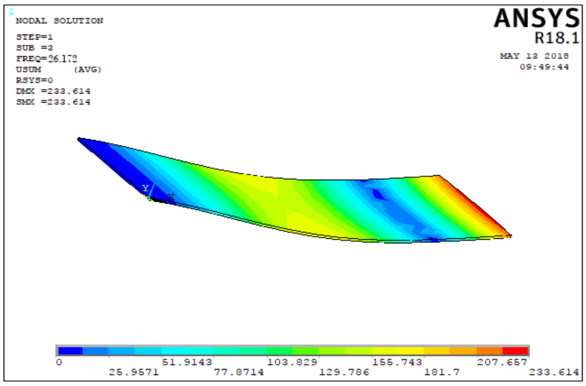

Fig -17: 4 layer 3delamination Mode 3

6. RESULTS

No. of Layers	Mode Number	NATURAL FREQUENCY			
		Healthy	P1	P2	P3
		Exp.	Exp.	Exp.	Exp.
4	1st	14	12	11	9
	2nd	34	19	13	17
	3rd	45	29	25	26

Table1: Natural frequencies for laminated composite plate with delamination.

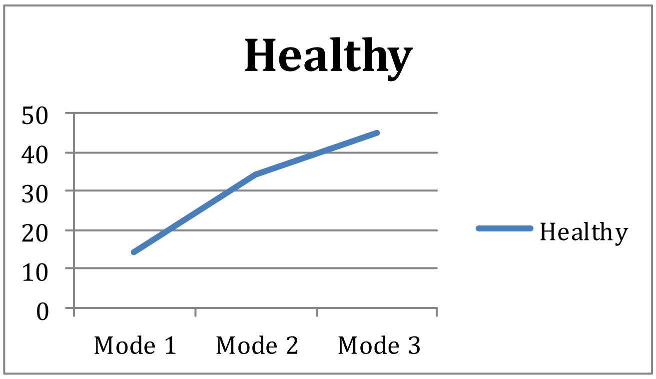

Chart - 1: Frequency Vs Mode for Healthy composite plate.

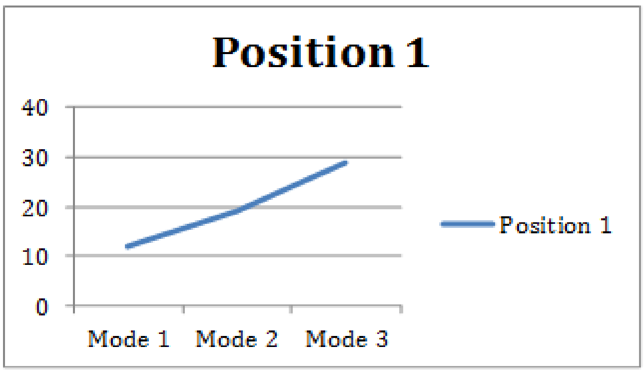

Chart - 2: Frequency Vs Mode for delaminated composite plate with Position 1

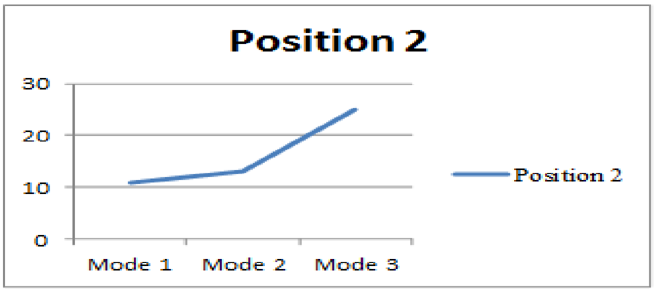

Chart - 3: Frequency Vs Mode for delaminated composite plate with Position 2

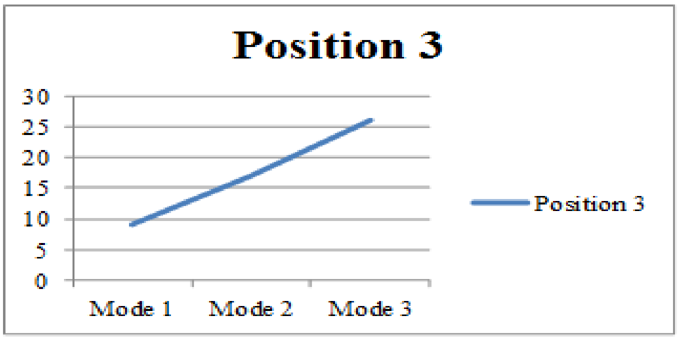

Chart - 4: Frequency Vs Mode for delaminated composite plate with Position 3

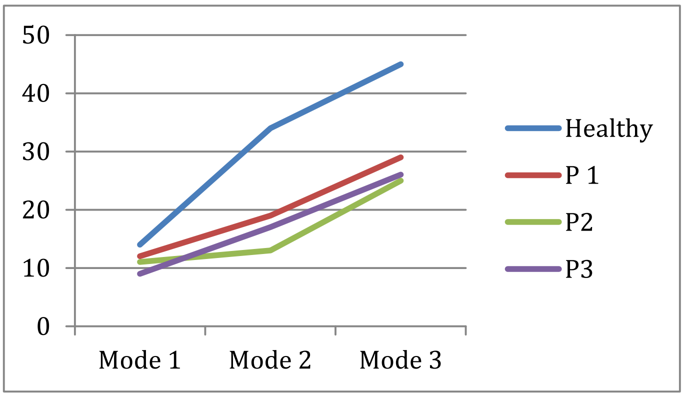

Chart - 5: Frequency Vs Mode between healthy and delaminated plates.

6.1 COMPARE WITH FEA (ANSYS)

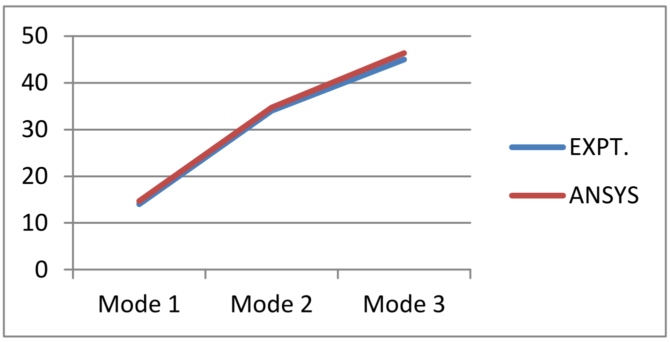

Chart - 6: Frequency Vs Mode for Healthy composite plate

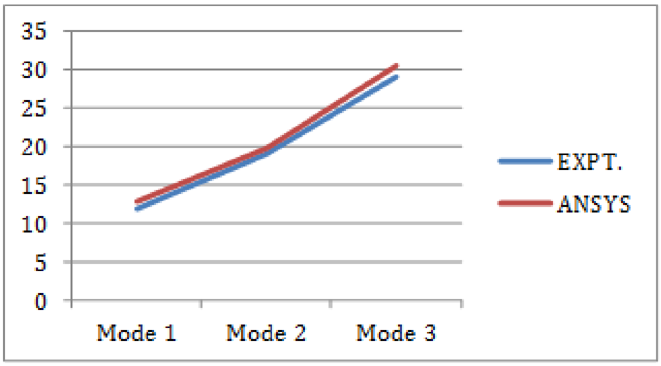

Chart - 7: Frequency Vs Mode For delaminated composite plate with position 1

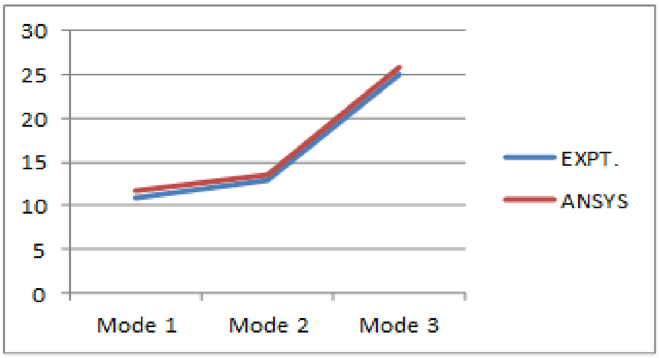

Chart - 8: Frequency Vs Mode For delaminated composite plate with position 2

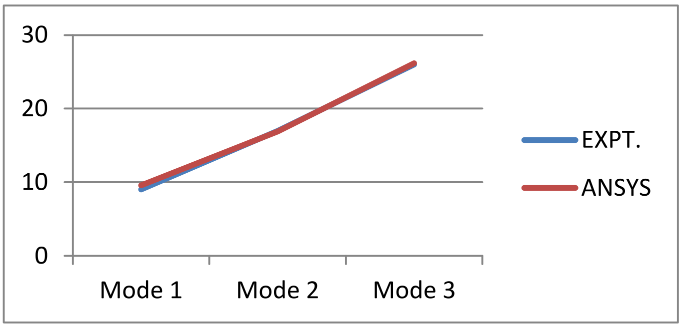

Chart - 9: Frequency Vs Mode For delaminated composite plate with position 3

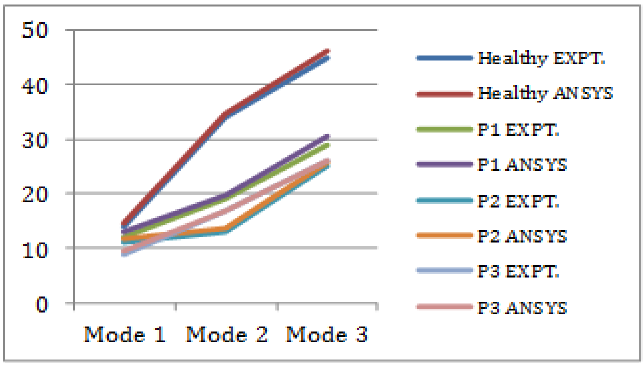

Chart - 10: Frequency Vs Mode Comparison between EXPT and ANSYS for delaminated composite plate.

6. CONCLUSIONS

- Free vibration behaviour of the laminated composite plates greatly depends on the geometrical and material parameters and the support conditions.
- It is clearly exhibited that the dynamic response of the delaminated composite plates is greatly affected by size and location of delamination and also by the geometrical and material parameters and the support conditions of the plate
- Frequency of a delaminated simply supported homogeneous plate decreases with increase in delamination length
- The presence of delamination at the mid-plane of the laminated structure affects the free vibration responses of the delaminated plate significantly than the other.
- Frequency of a delaminated simply supported homogeneous plate decreases with increase in delamination length..
- Frequency increases with increase in mode of vibration. For higher mode of vibration, the frequency will be higher.

ACKNOWLEDGEMENT

Author is very much thankful to all Department of Mechanical Engineering at J T Mahajan College of engineering, Faizpur for his invaluable guidance and support.

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