Experimental & Numerical Analysis of Composites with Delaminations

Mr. Y.V.Bangade[1], Dr.V.V.Kulkarni[2]

[1] P.G. Student, Dept. Of Mechanical Engineering, SGI Atigre, Maharashtra, India
[2]Professor, Dept. Of Mechanical Engineering, SGI Atigre, Maharashtra, India

---

Abstract - *Composite materials are widely used in modern industries like aerospace, aircraft, marine and automobile because of its characteristics such as high strength, high stiffness and low weight. In composites, damages may be created during manufacturing or during service. Delamination is one of the serious defects observed in the composite structure. It is invisible from external view but it affects the performance of composite. The presence of delamination reduces stiffness of composite and changes its vibration characteristics. In this work, the effect of delamination on the natural frequency of the composite with different % of delamination is investigated experimentally and numerically.*

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

1. INTRODUCTION

In today's modern industries like aerospace, aircraft, marine and automobile there is an increasing demand for the lightweight structure which requires an accurate analysis and the prediction of the desired responses. Because of the high specific strength and stiffness the use of laminated composites has increased drastically in last few decades.

Delamination is the major observed failure mode in reinforced composite structures. It is usually barely visible from external view since the delaminations are frequently embedded within the composite structures. Delamination can be often pre-existing or generated during service life. The delamination in the laminated composite structure arises because of one or many reasons i.e., the incomplete wetting, trapping of an air bubble in between layers, material discontinuities during manufacturing, or low-velocity impact and fatigue loading during their service life. These initial delaminations can slowly grow under alternating or fluctuating stress leading to a loss in stiffness. It is therefore important to detect and monitor these types of damages to receive an early warning for a well timed maintenance of the composite structure. The delamination reduces the structural stiffness and strength which changes the vibration characteristics of the composite structures. The delamination not only affects the structural integrity but also is responsible for the reduction in the structural stiffness and it directly affects the dynamic behaviour of the structure too. The presence of delamination reduces expected life of material.

2. LITERATURE REVIEW

The contribution of the researchers to analyze the effect of delamination on the dynamic behaviour of laminated composite structure is summarized here.

Aditi Chattopadhyay, et al. (2000) studied the damage detection and vibration control of a delaminated smart composite plate. Jaehong Lee (2000) presented work on free vibration analysis of a laminated beam with delamination using a layer wise theory.

Polimeno and Meo (2009) presented work on detecting barely visible impact damage detection on aircraft composites structures. Ullah and Sinha (2011) carried out experimental vibration study on the healthy and delaminated composite plates. Callioglu and Atlihan (2011) presented work on vibration analysis of delaminated composite beams using analytical and FEM models. Sultan, et al. (2012) studied the delamination identification on composite material by free vibration test. Nasser S. Bajaba (2012) presented work on modeling of composite plates with internal delamination. Sultan, et al. (2012) carried out delamination detection of composite laminates using natural frequency vibration method. Sowjanya and Haritha (2014) presented work on structural and vibration analysis of delaminated composite beams. Thombare, et.al (2014) carried out a review on damage identification in composite structures due to delamination by vibration characteristics. Hammami, et al. (2016) presented work on the experimental analysis of linear and nonlinear behavior of composites with delaminations. Chetan K. Hirwani, et al. (2016) presented work on experimental and numerical analysis of free vibration of delaminated curved panel. Shankar Ganesh et al. (2016) studied free vibration analysis of delaminated composite plates using finite element method. Kharghani and Soares (2016) investigated the behavior of composite laminates with embedded delaminations.

3. THEORY OF FREE VIBRATION

If a structure is defective, there is a change in the stiffness of the structure in the region of the defect. Usually, stiffness of the structure decreases if the damage appears in the structure.

In general the natural frequency is directly proportional to stiffness of the material. Therefore, a reduction in stiffness implies a reduction in the natural frequencies of vibration. Damage in a structure changes the dynamic behaviour of laminated composite structure. Major characteristics of structures, which undergo change due to presence of damage, are

- The natural frequency
- The amplitude response due to vibration
- The mode shapes

Hence it is possible to use natural frequency measurements to detect damage in the composite structure.

4. EXPERIMENTAL ANALYSIS

The experimental work conducted on the vibration analysis of E- glass epoxy composite with and without delamination is discussed here. The schematic representation of experimental setup is shown in Fig.1.

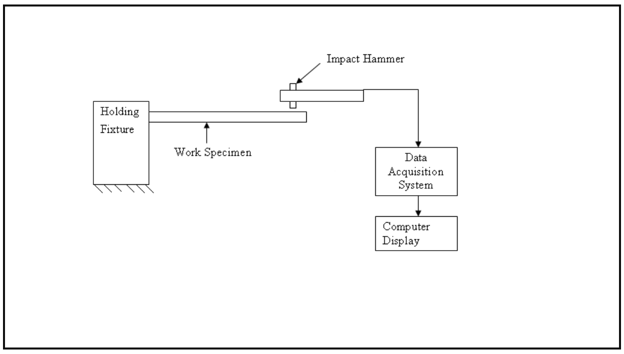

Fig -1: Block diagram of experimental setup

The composite specimens of dimensions 230mm×25mm×3mm are fabricated for the experimental work. An aluminium foil was introduced at mid plane 10%, 20%, 30% & 40% central delamination of specimen during fabrication. The experimental analysis has been carried out to measure the natural frequencies of the composite with and without delamination.

4.1 Steps In Experimental Analysis

1. Fix the specimen in cantilever position that is one end fixed and other end is free.
2. The connections of the impact hammer, vibration analyzer and user interference (computer) were properly made.
3. The cantilever beam was struck with an impact hammer and is excited by means of it.
4. Perform the impact test by using Fast Fourier Transformation (FFT) on the cantilever beam to measure the frequency response.
5. Repeat the impact testing procedure and calculate natural frequency of the structure.
6. Post process the modal data through the transfer function plots and take reading from response graphs which are in the user interface (computer).

Fig -2: Experimental setup

5. NUMERICAL ANALYSIS

ANSYS is a general purpose finite element modeling package for numerically solving a wide variety of mechanical problems. The modal analysis is used to calculate the vibration characteristics such as natural frequency and mode shape of a structure. The proposed work is related to determine the natural frequency of composite beam. A composite beam of 230mm×25mm×3mm dimensions is modeled with different % of delamination in the mid plane of composite using ANSYS 16.0. The material properties for E glass epoxy composite are E_1=10.5Gpa, E_2=E_3=3.5Gpa, μ=0.25, and modulus of rigidity G=3Gpa. Steps for numerical analysis are as given below.

5.1 Steps In Numerical Analysis For Modal Testing:

1. Create the model of cantilever beam into ANSYS Workbench.
2. Define element attributes like element types, real constants and material properties to composite beam.
3. Define meshing attributes and generate a mesh for the model.
4. Apply boundary conditions (one end fixed for cantilever structure) and define number of modes to be extracted.
5. Obtain the solution.
6. Review the results.

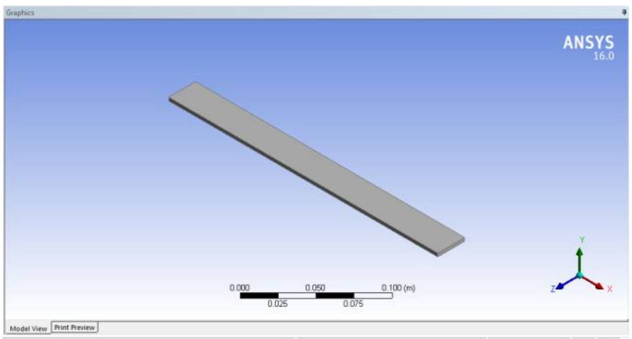

Fig-3 Model for the analysis

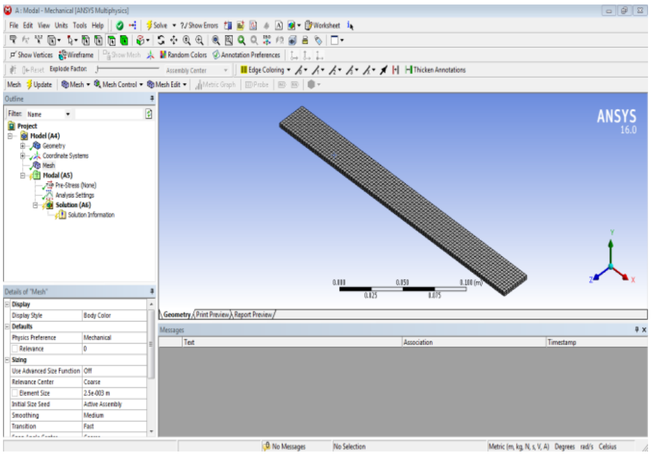

Fig-4 Mesh generated for the model

6. RESULTS AND DISCUSSIONS

The effect of different % of delamination along length (size of delamination) on the vibration behaviour of composite beam is analyzed. The variations in natural frequency with different % of delamination are shown in the Table 1.

Table -1: Natural frequency of composite with different % of delamination along length

Sr. No	% Delami -nation along length	Experimental Natural Frequency			FEA (ANSYS) Natural Frequency		
		ω1 (Hz)	ω2 (Hz)	ω3 (Hz)	ω1 (Hz)	ω2 (Hz)	ω3 (Hz)
1	0	13.5	77.5	99.5	12.13	75.97	99.93
2	10	13.0	76	97.5	12.00	75.18	98.9
3	20	12.5	75.5	95.5	11.88	74.39	97.86
4	30	12.0	74	94.0	11.75	73.58	96.80
5	40	11.0	73.5	92.5	11.62	72.76	95.73

With the help of these readings the results are plotted which shows the vibration behaviour of composite with different % of delamination.

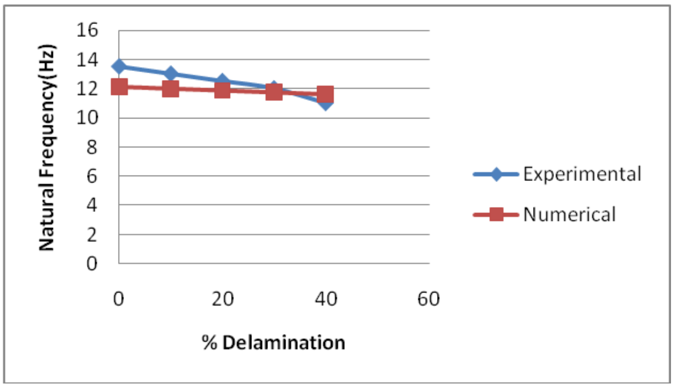

Fig -5 First Mode % Delamination Vs Natural Frequency

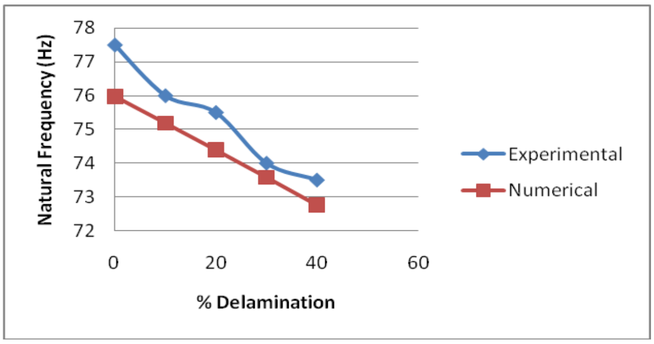

Fig.6 Second Mode % Delamination Vs Natural Frequency

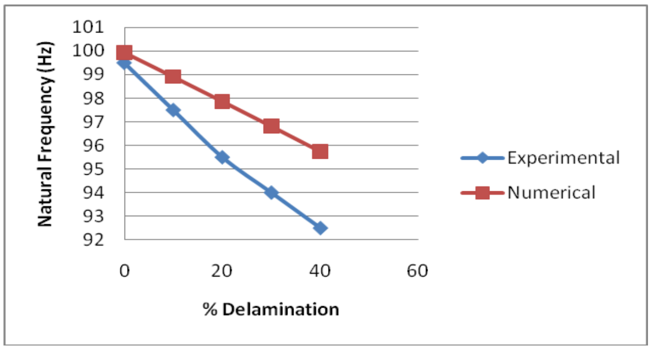

Fig.7 Third Mode % Delamination Vs Natural Frequency

Fig.8 shows FRF of composite with 0% delamination & Fig. 9 shows FRF of composite with 10% delamination.

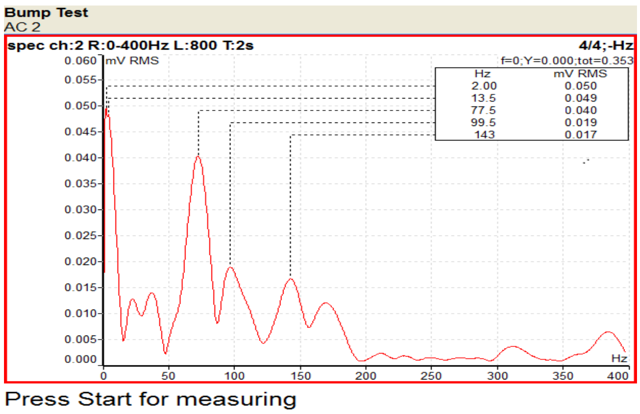

Fig.8 FRF of Composite with 0% delamination

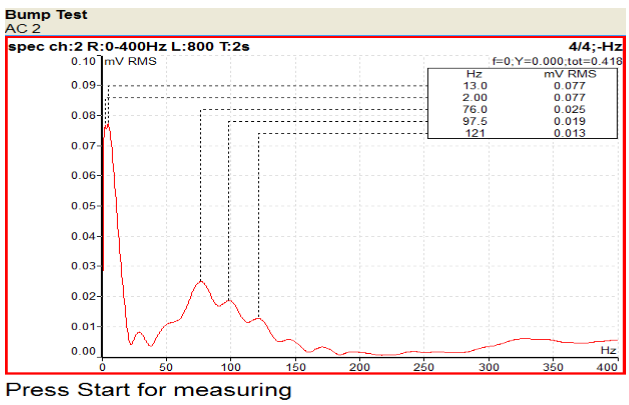

Fig.9 FRF of Composite with 10% delamination

Mode shapes of composite with different % of delamination is as given below. Fig.10 – Fig. 12 shows mode shapes of composite with 0 % delamination.

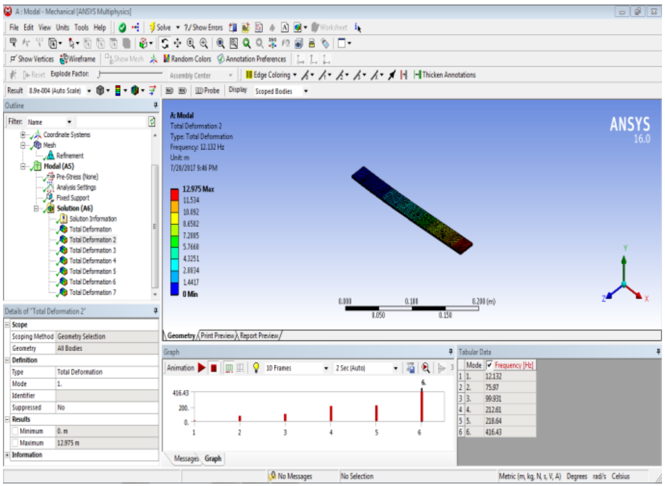

Fig.10 Deformed shape for 1st mode natural frequency for 0 % delamination

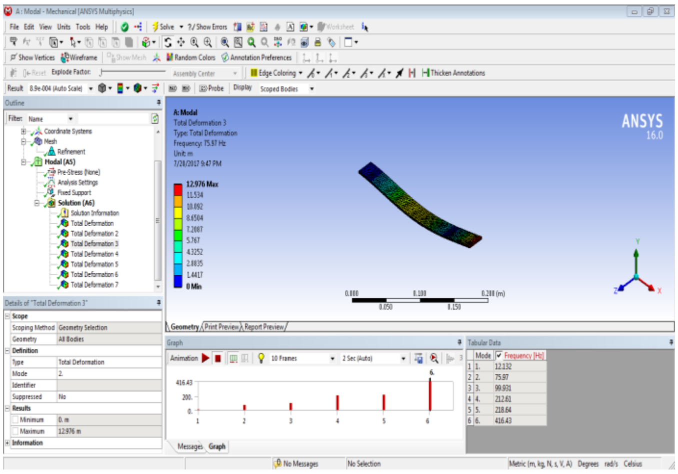

Fig.11 Deformed shape for 2nd mode natural frequency for 0 % delamination

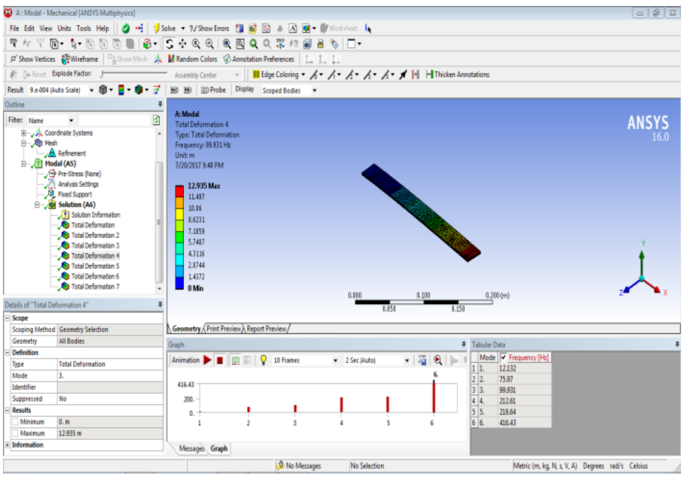

Fig.12 Deformed shape for 3rd mode natural frequency for 0 % delamination

Also Fig. 13 - Fig. 15 shows mode shapes of composite with 10 % delamination.

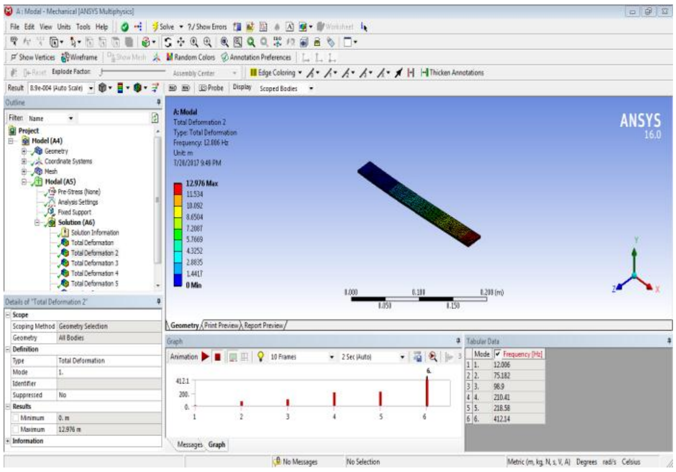

Fig.13 Deformed shape for 1st mode natural frequency for 10 % delamination

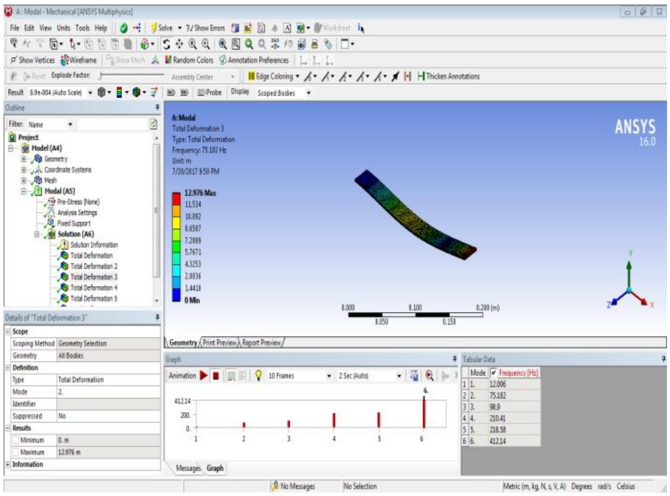

Fig.14 Deformed shape for 2nd mode natural frequency for 10 % delamination

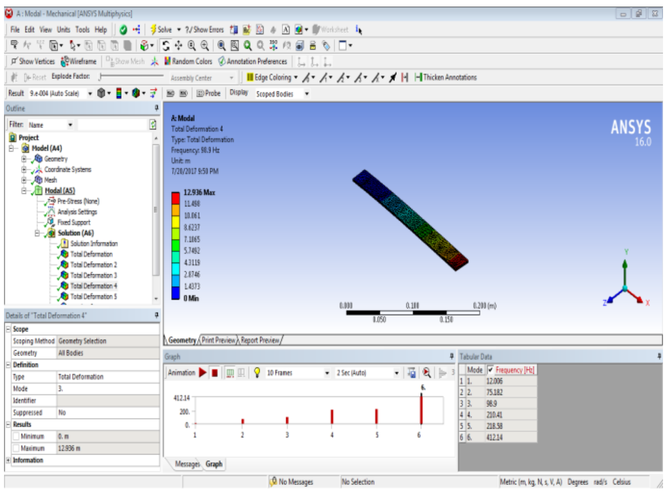

Fig.15 Deformed shape for 3rd mode natural frequency for 10 % delamination

7. CONCLUSION

The purpose of this work is to study the effect of delamination on the vibration behaviour of the composite beam. The natural frequency of composite laminate with different % of delamination is investigated experimentally and numerically. Based on the experimental and numerical results following conclusions can be drawn:

- Results obtained from experimental analysis shows very good agreement with numerical analysis.
- Delamination in the composite results in a decrease in the natural frequencies experimentally and numerically.
- As the size of delamination increases, reduction in natural frequency also increases.
- The presence of delamination in composite reduces its stiffness.
- The use of finite element analysis tool ANSYS is a successful tool to investigate the effect of delamination on the natural frequency of composite.

REFERENCES

[1] M. Hammami, A. El Mahi, C. Karra, M. Haddar, "Experimental analysis of the linear and nonlinear behavior of composites with delaminations", Applied Acoustics, 108(2016), pp. 31-39.

[2] M. Hammami, A. El Mahi, C. Karra, M. Haddar, "Nonlinear behavior of glass fibre reinforced composites with delamination", Composites Part B (2016), pp.350-359.

[3] Chetan K. Hirwani, Rahul K. Patil, Subrata K. Panda, Siba S. Mahapatra, Sanjib K. Mandal, Lokesh Srivastava, Manoj K. Buragohain, "Experimental and numerical analysis of free vibration of delaminated curved panel", Aerospace Science and Technology ,54 (2016), pp. 353–370.

[4] U. Polimeno and M. Meo, "Detecting barely visible impact damage detection on aircraft composites structures", Composite Structures 91, (2009), 398–402.

[5] Shivani Pande, Sunil Kumar, Prateek Verma, "Delamination Analysis of Composite Laminate", IJRMET, Vol. 5, Issue 1, November 2014 - April 2015, pp.76-80.

[6] Aditi Chattopadhyay,Changho Nam, and Youdan Kim, "damage detection and vibration control of a delaminated smart composite plate", Advanced Composites, Vol. 09, Issue 01, 2000.

[7] Narra.Sowjanya and Mulluri.Haritha, "Structural and vibration analysis of delaminated composite beams", International Journal of Computational Engineering Research (IJCER), ISSN (e): 2250 – 3005, Vol. 04, Issue 10, October– 2014, pp.21-26.

[8] Shankar Ganesh, Keshava S. Kumar and Mahato P. K., "Free vibration analysis of delaminated composite plates using finite element method", 12th International Conference on Vibration Problems, ICOVP 2015, Procedia Engineering, 144 (2016) ,pp.1067 – 1075.

[9] Hasan Callioglu and Gokmen Atlihan,"Vibration analysis of delaminated composite beams using analytical and FEM models", Indian Journal of Engineering and Materials Sciences, Vol.18, February 2011, pp.7-14.

[10] R Sultan, S Guirguis, M Younes and E El-Soaly, "Delamination identification on composite material by free vibration test", International Journal of Mechanical Engineering and Robotics Research, ISSN 2278 – 0149, Vol. 1, No. 3, October 2012, pp.227-236.

[11] N. Kharghani, C.Guedes Soares, "Behavior of composite laminates with embedded delaminations", Composite Structures, 150(2016), pp.226-239.

[12] Nasser S. Bajaba, "Modelling of composite plates with internal delamination", International Journal of Mechanic Systems Engineering, Volume 2, Issue 2, May 2012, PP. 71-76.

[13] Jaehong Lee , "Free vibration analysis of delaminated composite beams", Computers and Structures, vol.74, 2000, pp. 121-129.

[14] Israr Ullah , Jyoti K. Sinha, "Experimental vibration study on the healthy and delaminated composite plates", Journal of Physics, Conference Series, Vol. 305, (2011), pp.1-10.

[15] R Sultan, S Guirguis, M Younes and E El-Soaly, "Delamination detection of composite laminates using natural frequency vibration method", International journal of mechanical engineering and robotics research, ISSN 2278-0149, vol. 1, No.2, July 2012, pp.286-296.

[16] Z. Zhang, K. Shankar, M. Tahtali and E.V. Morozov, "Vibration modelling of composite with delamination damage", proceedings of 20th International Congress on Acoustics, ICA 2010, August 2010, pp.23-27.

[17] R. A. Smith, "Composite defects and their detection" , Material science and engineering, vol.2.

[18] S. Gholizadeh, "A review of non-destructive testing methods of composite materials", XV Portuguese conference on fracture, PCF 2016, 10-12 February 2016, pp.50-57.

[19] C K Hirwani, S. S. Sahoo and S K Panda, "Effect of delamination on vibration behaviour of woven Glass/Epoxy composite plate- An experiment study", IOP Conf. Series: Material Science and Engineering, vol.115, (2016), pp.1-14.