Handbook on the Emerging Trends in Scientific Research
ISBN: 978-969-9952-05-0
homepage: http://www.pakinsight.com/?ic=book_detail&id=10
Conference venue : Pearl International Hotel, Kuala Lumpur, Malaysia

Vol.3 , 2015
(25-26, April)

Experimental Study Damage in a Composite Structure by Vibration Analysis- Glass / Polyester

Missoum.L[1] --- Djermane.M[2] --- Labbaci. B[3] --- Abdeldjebar. R[4] --- Moudden. B[5]

[1,2,3,4,5] *Civil Engineering Department, University of Bechar, Algeria*

Abstract

The basic components of a composite material made him very sensitive to damage, which requires techniques for detecting damage reliable and efficient. This work focuses on the detection of damage by vibration analysis, whose main objective is to exploit the dynamic response of a structure to detect understand the damage. The experimental results are compared with those predicted by numerical models to confirm the effectiveness of the approach.

Keywords: Experimental, Composite, Vibration analysis, Damage.

1. Introduction

The choice of composite materials is no longer restricted to specific applications. In other fields, using these new materials as innovation tool and performance rising of their products such civil engineering.

Replacement of metallic materials by composite one is often based on an economy of mass (relatively low density). In addition, they offer to their low density, high mechanical properties and some cases; specific and adapted.

It is important first to have the best possible knowledge about these materials in somehow to monitor any changes in these properties and consequently their influence on the structure behaviour. And next, early detection of damage is not necessarily visible from the external face and even when it is the case of visual inspection does not realize its case state.

In order of reliable and efficient use, these new materials, the development of a measurement system that can answer the following two questions of primary importance is required:

Can measured directly in non-destructive and reliable mechanical properties of a composite structure.

Is it possible to detect damage as quick as possible in order to monitor, evaluate and repair if necessary the structure. This kind of controls is part of a framework for the structure health monitoring (SHM).

To achieve these two goals, it is possible to rely on methods based on vibration tests.

2. Literature Review

The damages are inevitable in structures. The causes are varied. At the time of manufacturing, the material may be defects: cracks also others such as delamination and fatigue are introduced at the time of the structure service. For this purpose, the modern practice of engineers no longer considers the presence of damage as a tragedy. But to avoid failure, the control and monitoring of this type of structure becomes an absolute necessity. This ability to detect damage as quickly as possible will provide the required remedy and repairs.

The field monitoring is done at four levels. It mainly consists in obtaining information about the existence, location, extent of the damage and the prediction of the service life of a structure. These techniques often use algorithms based on non-destructive methods has improved as measured by the integration of various technologies [sensor, signal processing, modeling and correlation].

Historically, non-destructive controls techniques [CND] are very old methods. They are developed in laboratories testing as a tool for the evaluation and improvement of material properties.

An extensive bibliography on the use of non-destructive methods is presented in the work of Scott [1].

The majority of these experimental methods are using physical and non-destructive procedures [2]. They became, thereafter, practical tools to meet specific needs of reliability and safety. The non-destructive techniques with an important field for the evaluation the anomalies and forming a basis for any decision of repair, rehabilitate or replace a structure [3].

CND also allows monitoring structures damage in real time by a predictive maintenance. These investigative techniques differ from one method to another.

Choosing a method for a given application is important and it is conditioned by a several criteria: area of application, accessibility to anomalies locations, composition of the structure to test, microstructure of the material, implementation of material and the nature of the anomaly to identify [2]. With the current possibilities of data analysis, signal processing, image and deep understanding of the phenomenon of damage, the CND has developed efficient algorithms in the context of monitoring structures. Actually, many non-destructive techniques are used as a monitoring tool in industry and in civil engineering [4].

Some of these techniques use ultrasonic, radiographic or magnetic methods [5].

In recent decades, the use of data from a vibration test has received particular attention [6]. Dice 1738, studies in this area seem to be highly accelerated. [7] This area has a very rich and diverse literature. It can be divided into two parts:

A. The use of vibration tests in order to identify the modal parameters to estimate the mechanical properties of a material [8].

Table-1. Component Properties

Component	**E(Mpa)**	**ν**
Polyester	3800	0.37
glass ***(E)***	73000	0

ν = Poisson coefficient. E=Young module

Modal Parameters are also used in the field of reset of analytical solution, numerical and experimental [9]. In this context, Kim et al have improved the performance of an experimental method by comparing experimental and analytical solution [10]. Collins has used statistical vibration data to change the rigidity and mass matrix in a finite element formulation [11]. General Control of the integrity of structures can be for the purpose of extracting the dynamic characteristics [12]. Adams et al [11] investigated the parameters influencing the damping of a structure. The same authors subsequently used as a tool of vibration in several studies to investigate the structures behaviour [13]. They showed later and through the literature review, the effectiveness of vibration as a tool of non-destructive control [11].

B. Principles based on modal indicators: significant research has been conducted and the studies were focused mainly on the possibility of using the modal response [14] and variations in the dynamic characteristics for damage detection of structures [15]. Certain works of Adams et al [16] showed a good correlation between the presence of damage in a structure and the appearance of its modal parameters change.

Doebling et al gave one of the most detailed reports on the techniques proposed in this field; detection. They presented a state of the art methods used in vibration monitoring of structures [HMS] and a rich bibliography on the characterization of the structural damage using techniques that examine changes in modal parameters (props frequency, mode form, damping, fatigue etc. ..) [17].

The change in the shape patterns was also used to detect the damage; we can cite the work of Pandey et al [18] that have validated the approach on damaged beams, advantage by providing sufficient information on a wide frequency band. Other approaches propose to use directly the measured data of FRF to detect damage.

3. Experimental Study

A major problem in damage identification by vibration analysis lies in the accurate determination of natural frequencies that characterize the main modes of a damaged structure. These parameters are unknowns. In the model used in this work, damage by crack where is considered as a geometrical discontinuity.

Presentation of studied materials:

The studied material is glass / polyester composite, with the following physical and mechanical characteristics:

4. Presentation of Specimens

Fig-1. Without defect beam

Fig-2. Pre- defect beam in the middle

5. Experimental Strategy

The general assembly of the test is given in (fig.4) where:

1. The impact hammer is connected to the first input of the analyzer and accelerometer is connected to its second input.
2. The test structure is suspended by flexible son to realize the free-free boundary conditions.
3. The position of the accelerometer is chosen to avoid a vibration node.

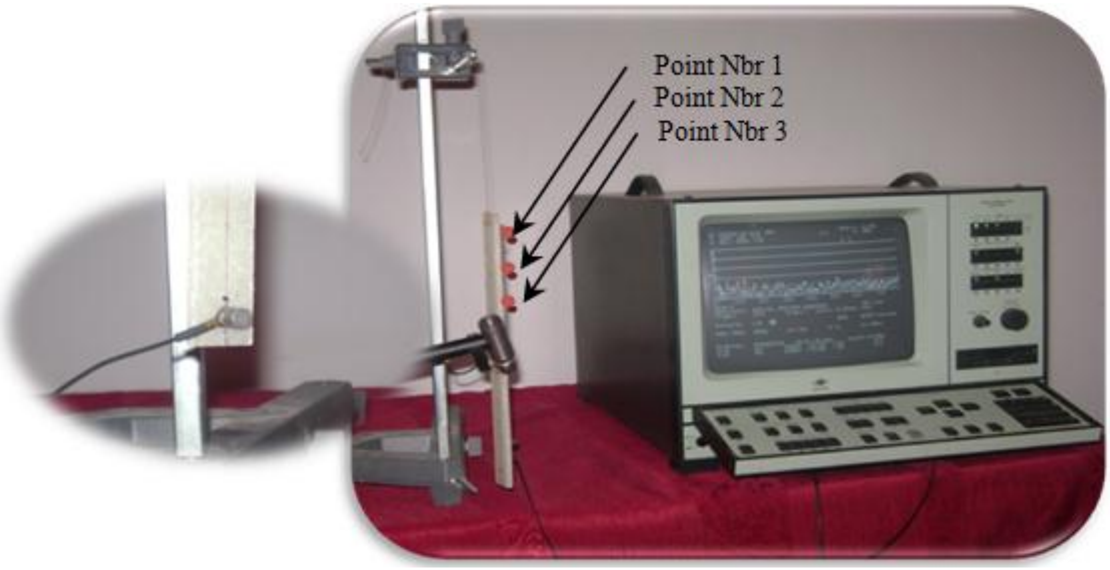

Fig-3. Test general assembly

A. Transversal Vibration, Y Direction

The figures (4, 5 and 6) shows the superposition of the first and second frequencies of the beam measured in points 1.2 and 3 before and after damage by cracking scenario which is the crack in the middle toward the Y direction.

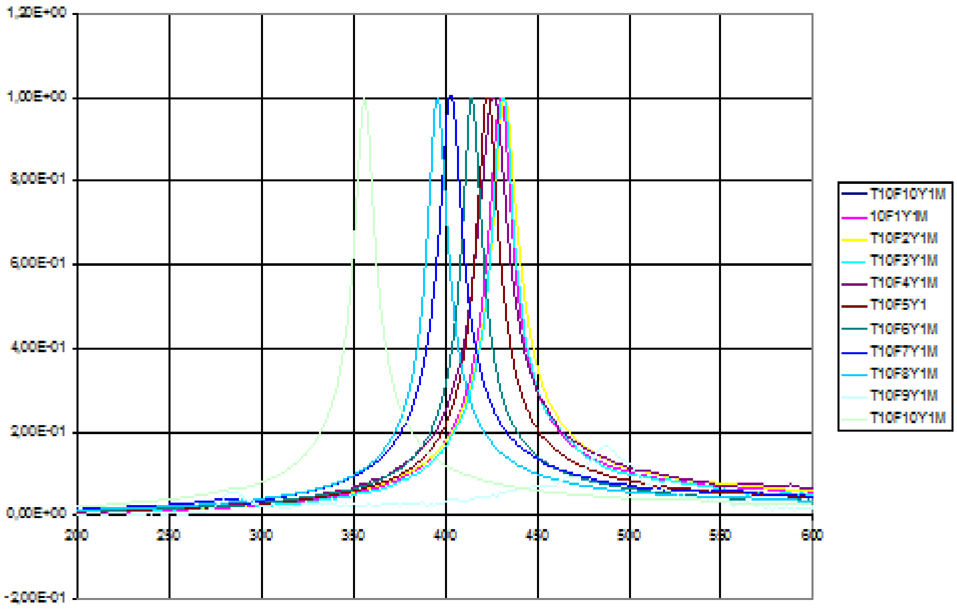

Fig-4. Crack influence in the middle of the beam (first frequency/point 1)

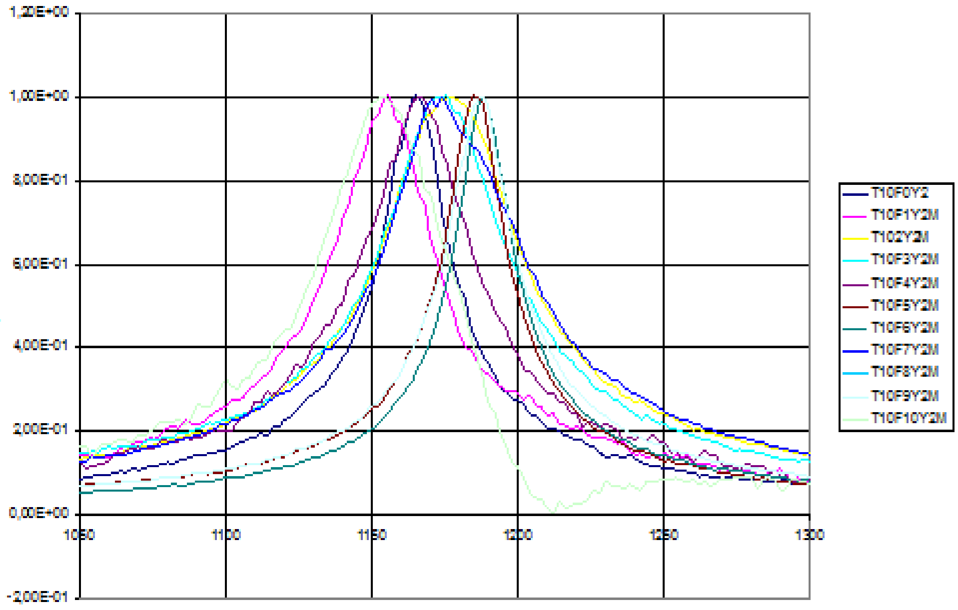

Fig-5. Crack influence in the middle of the beam (second frequency/point 2)

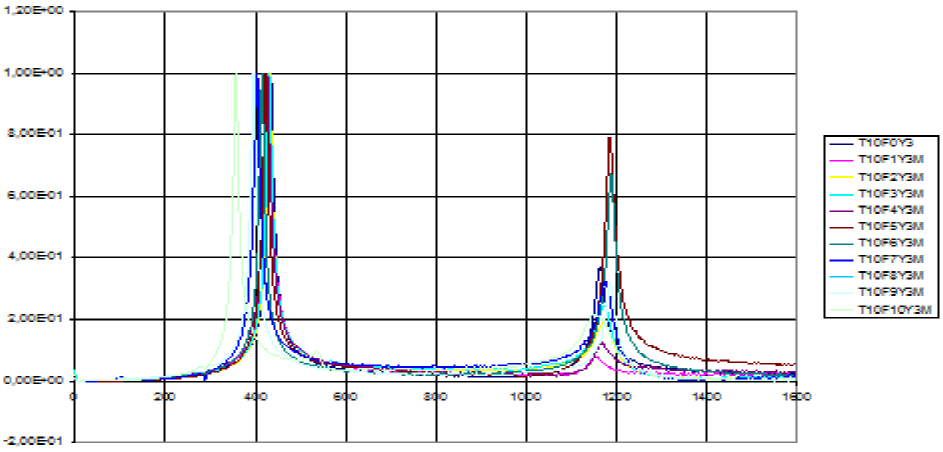

Fig-6. Crack influence in the middle of the beam (first & second frequency/point 3)

B. Transversal Vibration, Z Direction

The figures (8, 9 and 10) shows the superposition of the first and second frequencies of the beam measured in points 1.2 and 3 before and after damage by cracking scenario which is the crack in the middle toward the Z direction.

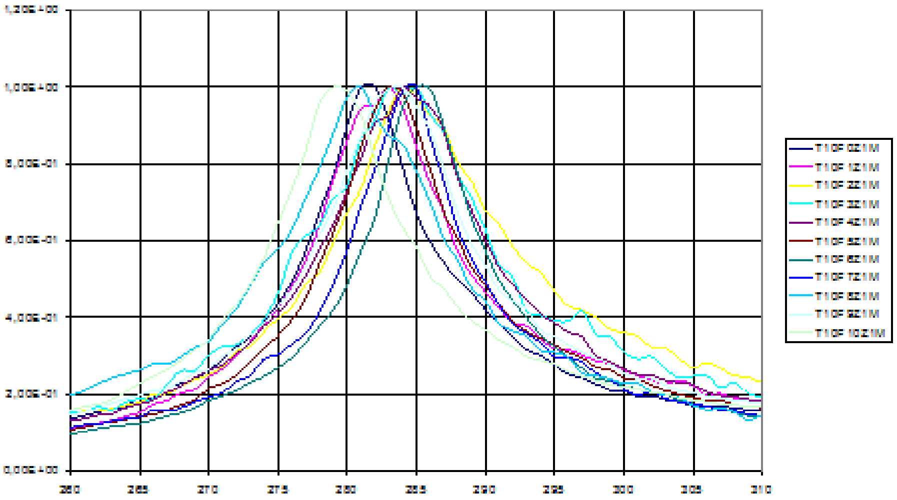

Fig-7. Crack influence in the middle of the beam (first frequency/point 1)

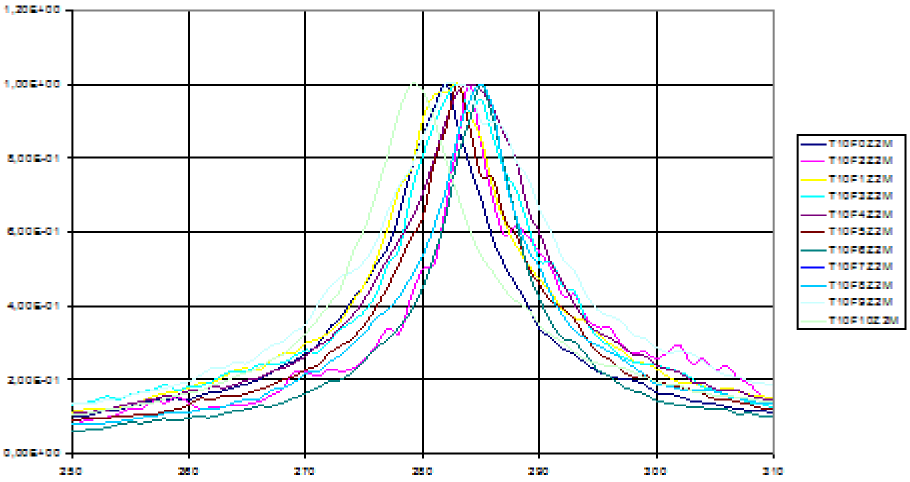

Fig-8. Crack influence in the middle of the beam (second frequency/point 2)

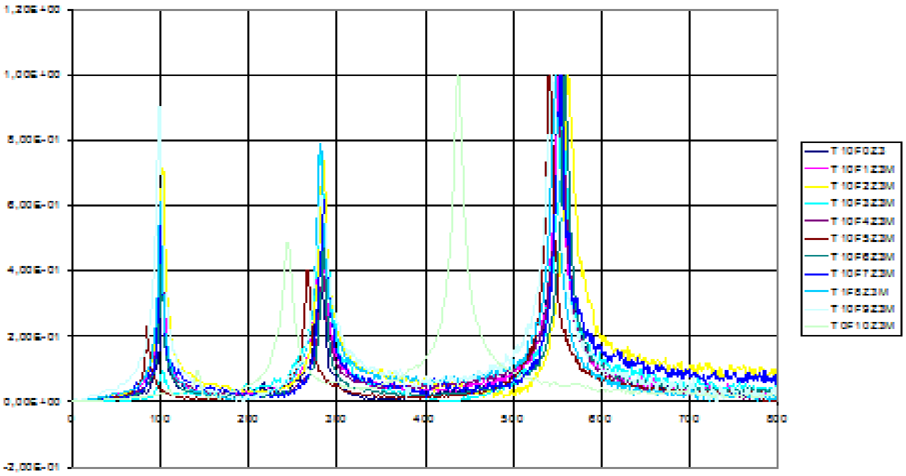

Fig-9. Crack influence in the middle of the beam (first & second frequency/point 3)

6. Interpretation and Discussion

The summary figures are given following the directions of vibration:

Table-2. Modes Sensibility of Crack Importance

Crack depth (mm)	depth/ Width (%)	Freq 1	Freq 2	Freq 3
0	0	1,000	0,999	1,000
2	4.8	0,992	0,999	0,998
4	9.6	0,981	1,004	0,986
6	14.3	0,961	1,000	0,973
8	19.2	0,947	0,998	0,963
10	23.8	0,930	1,000	0,952

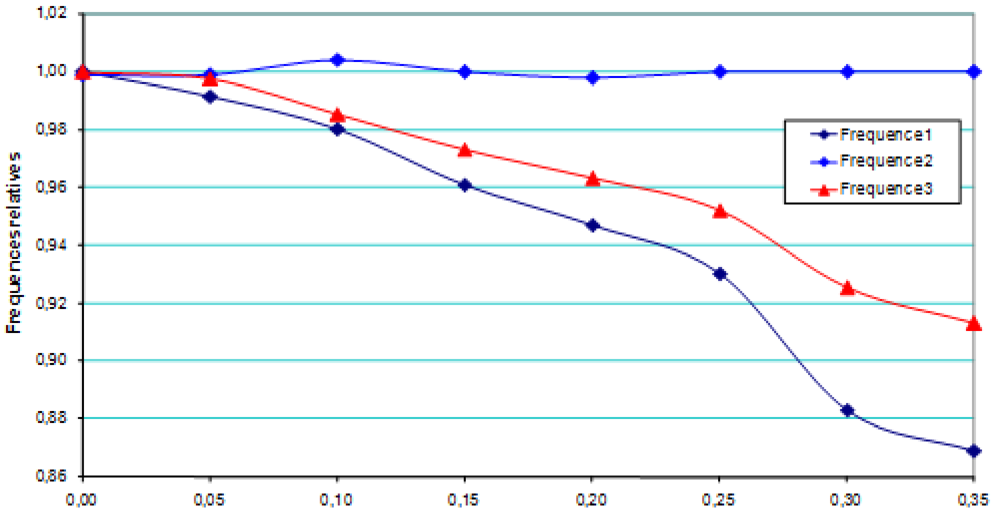

Fig-10. Compared sensibility of damage modes

We found in this companion test that in most cases the presence of a crack results in a decrease in the value of the natural frequency. In addition, this decrease gradually increases with the size of the crack.

It is possible to see through a separate analysis mode by mode that certain frequencies are more sensitive to certain damage scenario than others (Fig.10).

The obtained detection limits at first glance, are 2mm (5% of the width) direction of the fiber Y direction. While in the direction perpendicular to the fiber, detection begins to appear only from 4 mm (10% of the width).

If you wish to implement a reliable approach for the detection of damage by vibration tests, it is imperative to refine the results by ridding them of inherent errors in the experimental procedures. Particular attention will be given to:
- Implementation of the material.
- Repeatability tests.
- The experimental simulation of boundary conditions.

7. Conclusion

At the beginning of this work, we sought above all a tool to detect defects in structures. The area of fault detection by vibration method relies on very different work. Some models require, others are choosing to work without a priori information. Yet these works have in common the multidisciplinary aspect and state of knowledge of the behavior of a damaged structure such as the type of composite beam.

Attempts in this section to answer the following questions:
- How to use a rational behavior of the natural frequency vis-à-vis the importance and location of damage.
- What is the level of influence of other sources outside of the damage on the final detection results?

To refine our analysis, we considered a set of scenario depth cracks.

The choice of impact points and influence of damages are very interesting to have an experimental knowledge of this kind of applications.

By analyzing the results of tests it was found that follows:
1. The natural frequency decreases as the degree of degradation of the rigidity (EI).
2. The position of the crack is probably detectable by comparing a specific vibration mode, i.e. if the crack is to be submitted on a vibration node, none enough significant variation in natural frequencies.
3. The experimental conditions are significant on the dynamic behavior of the structure.

The beam geometry can also be affected by the direction of change of cracking.

The heterogeneity of the structure gives always critical sections that can foster the embrittlement and propagation of micro cracks. These may change by the vibration effect and shocks, causing the structure damage.

References

[1] Guan- Liang Qian,Suong V.Hoa & Xinran Xiao, “A vibration method for measuring mechanical properties of composite, theory and experiment,”. *Composite Structures* 1997; Vol.39, No.1-2, pp.31-38, (103).

[2] Joël Cugnoni, “Identification par recalage modal et fréquentiel des propriétés constitutive de coques en matériaux I.G. Scott and C.M. Scala,” *A review of non-destructive testingof composite materials* NDT INTERNATIONAL. APRIL 1982. 0308-9126/82/020075-12 $03.00 (112).

[3] Encyclopedia of Materials: Science and Technology, “Nondestructive Testing and Evaluation: Overview,” *Elsevier Science* 2001; Ltd. pp. 6177±6185.

[4] Jeong-Tae Kim , Yeon-Sun Ryu , Hyun-Man Cho, Norris Stubbs, “Damage identification in beam-type structures: frequency-based method vs mode-shape-based method,” *Engineering Structures* 25 2003; 57–67. (120).

[5] Christophe, “BOIS.Mesure et prévision de l’évolution des endommagements dans les composites stratifiés,” *Thèse docteur.* Soutenue 17 décembre 2003.

[6] Alireza Alvandi, “contribution à l'utilisation pratique de l'évaluation dynamique pour la détection d'endommagement dans les pond, ” *Ecole nationale des ponts et chaussées* 2001.

[7] J.-T. Kim, “Crack detection in beam-type structures using frequency data ,” *.Journal of Sound and Vibration* 2003; 259(1), 145–160 (100).

[8] [8] Guan- Liang Qian,Suong V.Hoa & Xinran Xiao, “A vibration method for measuring mechanical properties of composite, theory and experiment, ” *Composite Structures* 1997, Vol.39, No.1-2,103:31-38.

[9] Joël Cugnoni, “Identification par recalage modal et fréquentiel des propriétés constitutive de coques en matériaux composites,” 2004 Ecole polytechnique fédérale Lausanne.

[10] S.Gopalakrish namurthy, “Structural integrity inspection using dynamic responses,” *University of Missouri*- Colombia 2003.

[11] A. Frederick, A. just agosto, “Damage detection based on the geometric interpretation of eigenvalue problem,” *Virginia polytechnic institute* 1997.

[12] Adams, R. D.; Cawley, P.; Pye, C. J.; Stone, B. J, “A vibration technique for non-destructively assessing the integrity of structures, ” *Journal of Mechanical Engineering Science* 1978; vol. 20, p. 93-100.

[13] P. cawley R. D. adams. The location of defects in structures from measurements of natural frequencies, ” *Journal of strain analysis* 1979; vol 14 no 2.

[14] Seth S.kessler, S.Mark Spearing , Mauro J.Atalla, Carlos E.S. Cesnik, Constantinos Soutis, “Damage detection in composite materials using frequency response method, ” *Composites*: part B 33 2002; 121:87-95.

[15] Cawley, P., Adams, R.D, “The predicted and experimental natural modes of free-free CFRP plates*,” Journal of Composite Materials* 1978; Vol 12, pp336-347.

[16] Adams, R. D.; Cawley, P.; Pye, C. J.; Stone, B. J, “A vibration technique for non-destructively assessing the integrity of structures,” *Journal of Mechanical Engineering Science* 1978; 93-100.

[17] Scott W. Doebling, “Minimum-Rank Optimal Update of Elemental Stiffness Parameters for Structural Damage Identification,” *IAA Journal* 1996; Vol. 34, No. 12.

[18] A. K. Pandey, M. Biswas, and M. M. Samman, “Damage detection from changes in curvature mode shapes,” *Journal of ound and vibration* 1991; 145:321-332.