Crack Propagation Monitoring for Aircraft Structure

Chaithanya B V[1]
Dept of Electronics & Communication Engineering
GSSS Institute of Engineering Technology for Women
Mysuru-570016, India

Siva Subba Rao Patange[2]
Ph.D. Student, VTU Belagavi & Principal Scientist
Structural Technology Division
CSIR-National Aerospace Laboratories
Bengaluru- 560017, India

Sushma S J[3]
Dept of Electronics & Communication Engineering
GSSS Institute of Engineering Technology for Women
Mysuru-570016, India

Abstract- **Crack propagation monitoring is a structural health monitor which is used to detect the structural health in aircrafts. Generally damage is defined as the change occurs in materials of systems, including changes to the boundary conditions, physical property, dynamic property and system connectivity, which adversely affect the system's performance. PZT sensors are used to identify and even localize damage within the structure. Based on vibration method crack monitoring is done.**

Key word: Piezoelectric sensor, Stress, Non Destructive Testing,

I. INTRODUCTION

As the damage/crack grows, it affects the system's operation which can't be acceptable by the user. Fatigue is the damage commonly occurs in metallic materials. Due to the repeated variation of loads, material changes the stiffness and causes a failure. If a material is in repeated loading the localized and progressive damage will occurs [1].

There are different well developed offline methods like Non Destructive Testing (NDT) are used for inspecting, testing, or evaluating materials. Visual testing, Ultrasonic Testing, Lamb wave testing, Particle testing, Radiographic testing, Magnetic and penetrate testing are some NDT. These offline methods are less efficiency compare to the real time methods [2]. The requirement for damage detection is vibration characteristics methods that can be applied to structures because it investigates and examine changes on the structure. The modal parameters such as mode shapes, modal damping and frequencies are the physical properties of the material those are damping, stiffness and mass. Variation in physical properties, such as reduction in hardness resulting from the initiation of cracks, will detect the changes in the modal properties. Hence changes in modal properties from these quantities are used to detect the crack/damage [3].

The structural crack commonly occurs in aircraft structure due to the repeated variations in stresses or load. The presence of crack changes the dynamic characteristics of the material and leads to catastrophic failure. In order to this catastrophic failure crack length propagation monitoring is done at the initial stages. In the present work, to identify these cracks propagation, PZT sensors are placed on the structure to be monitored. PZT has selected because of its characteristics such as light weight and easy to bound on the structures. It don't have any internal circuit. PZT is made up of material which has capability to sense the strain on structure and get the output in the form of voltage and frequency [3].

II. SPECIMEN DESIGN

Generally Aluminum metal is used in aircraft structure so aluminum plate is used as specimen. Testing is done on three specimens. One is healthy, one is with hole and another one is with hole and crack [4]. Four PZT sensors are mounted on each specimen at different 0 degree and 45 degree. Two are fully mounted and two are half mounted. Each specimen is of 40x20x2.5 cm.

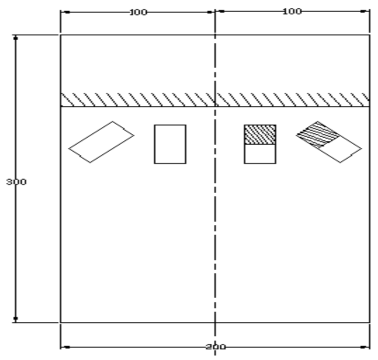

Fig1: Healthy specimen

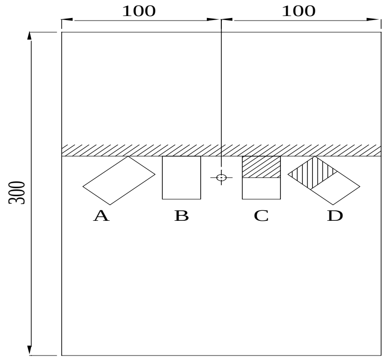

Fig2: Specimen with hole

ISSN: 2278-0181
NCESC - 2018 Conference Proceedings

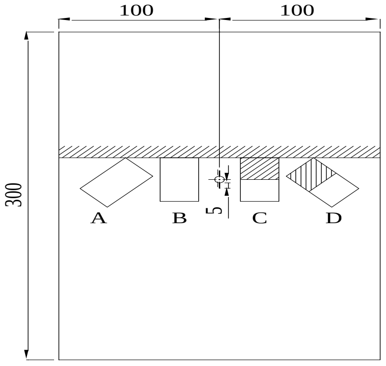

Fig3: Specimen with crack

III. METHODOLOGY

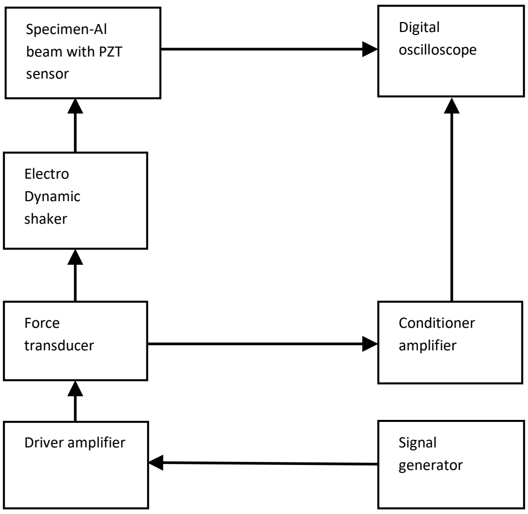

Fig 4: Block diagram of the experiment

Signal generator will generate the sine wave and given as input to vibration generator or driver amplifier. Then output of vibration generator is sent to force transducer [5]. Force transducer send signal to apply force through electric dynamic shaker on specimen used. Force transducer signal is sent to conditioner amplifier to amplify the signal and reduce noise and sent to oscilloscope so that force produced and acceleration can be found [6]. PZT sensor senses the vibration and sent to oscilloscope, which display wave form voltage and frequency can be seen.

Fig 5: Connection set up of experiment

IV. RESULT AND DISCUSSION

A. *Healthy Specimen*

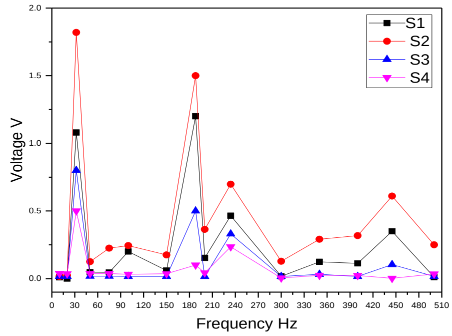

Fig6: output voltage for healthy specimen for 5N

Table 1: Sensors output at different modes

	S1 (V)	S2(V)	S3(V)	S4(V)
MODE1(32Hz)	1.08	1.82	0.8	0.5
MODE2(188Hz)	1.2	1.5	0.5	0.1
MODE3(324Hz)	0.465	0.698	0.33	0.235
MODE4(445Hz)	0.35	0.61	0.1041	0.00234

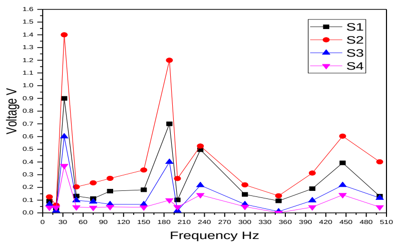

Fig 7: Output voltage for healthy specimen for 10N

Table 2: Sensors output at different modes

	S1	S2	S3	S4
MODE1 (32Hz)	0.9	1.4	0.6	0.37
MODE2 (188Hz)	0.7	1.2	0.4	0.1
MODE3(234Hz)	0.496	0.525	0.217	0.141
MODE4(445Hz)	0.393	0.603	0.2176	0.1411

B. Specimen with hole.

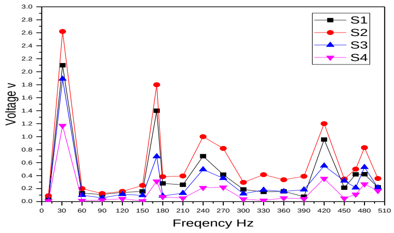

Fig 8: output voltage for specimen with hole for 5N

Table 3: Sensors output at different modes

	S1	S2	S3	S4
MODE1(31Hz)	2.1	2.62	1.89	1.17
MODE2(171Hz)	1.4	1.8	0.695	0.315
MODE3(242Hz)	0.7	1	0.495	0.215
MODE4(420Hz)	0.956	1.2	0.552	0.3545

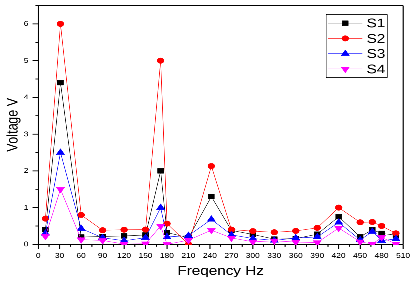

Fig 9: Output voltage for specimen with hole for 10N

Table 4: Sensors output at different modes

	S1	S2	S3	S4
MODE1 (31Hz)	4.4	6	2.5	1.5
MODE2(171Hz)	2	5	1	0.5
MODE3(242Hz)	1.3	2.13	0.68	0.386
MODE4(420Hz)	0.753	1	0.6	0.445

C. Specimen with crack.

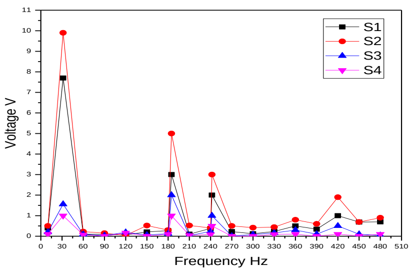

Fig 10: Output voltage for specimen with hole for 5N

Table 5: Sensors output at different modes

	S1	S2	S3	S4
MODE1(31.5Hz)	7.7	9.9	1.56	1
MODE2(184.8Hz)	3	5	2	1
MODE3(242Hz)	2	3	1	0.5
MODE4(420)	1	1.9	0.5	0.1

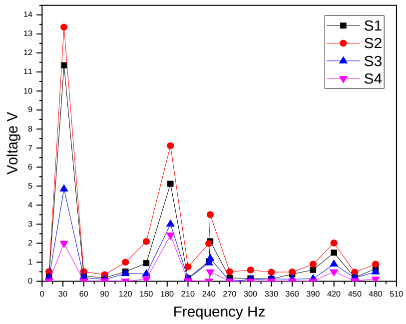

Fig 11: Output voltage for specimen with hole for 10N

Table 6: Sensors output at different modes

	S1	S2	S3	S4
MODE1(31.5Hz)	11.35	13.35	4.85	2
MODE2(184.5Hz)	5.12	7.123	3	2.43
MODE3(242Hz)	2.1	3.5	1.2	0.5
MODE4(420Hz)	1.5	2.01	0.9	0.5

To analyze the practical experimental results the graphs are drawn. Sensor output voltage for different frequencies are shown in below plots for given 5N and 10N in figure6, 8, 10 and figure7,9,11 respectively for different specimens [8][9]. These plots shows the different voltages obtained from each sensor since four sensors are attached in different angle (0^0 and 45^0) and also two sensors are fully bounded and other two are half mounted. In the plots sensor 1 is represented by black line, sensor 2 is represented by red line, sensor3 is represented by blue line and sensor4 is represented by pink line. By comparing voltage value of sensors at modes of frequencies with respect to healthy specimen crack monitoring is done [10].

V. CONCLUSION

In this paper we discussed about monitoring crack propagation on different specimen. As crack propagation increases output voltage of sensor increases. Hence, the crack/damage propagation which is found on the aluminum structure by comparing the healthy structure output voltage and frequency with cracked/damaged structure output voltage and frequency.

ACKNOWLEDGEMENT

The authors would like to thank the Director, Mr. Jitendra J Jadhav CSIR-National Aerospace Laboratories for his persistence to carry out the work and Dr. Satish Chandra, Head Structural Technologies Division (STTD) for providing all the facilities for completing this work and Dr. S. Raja Group Head of STTD for supporting and inspiring to complete the work.

REFERENCES

[1]. C. P.Providakis, K.D.Stefanaki, M.E.Voutetaki, J. Tsompanakis, M. Stavroulaki "Developing a multi-mode PZT sensing solution for active SHM in concrete structures" Department of Applied Sciences Technical University of Crete.

[2]. Walter Katsumi Sakamotoi, Ricardo TokioHiguti, Evelyn BrazolotoCrivelini\ HaraldoNaoyukiNagashimai "Polymer Matrix-Based Piezoelectric Composite for Structural Health Monitoring" Departamento de Fisica e Quimica, UniversidadeEstadualPaulista - UNESP, llhaSolteira, Sao Paulo, Brazil.

[3]. Mike Roellig, Lars Schubert, UweLieske, Bjoem Boehme, Bernd Frankenstein, Norbert Meyendor "FEM assisted Development of a SHMPiezo-Package for Damage Evaluation in Airplane Component" Fraunhofer Institute for NonDestructive Testing (IZFP), Dresden University of Technology, Electronics Packaging Laboratory.

[4]. Sylvia Gebhardt, Markus Flössel, Andreas Schönecker, UweLieske, Thomas Klesse"Robust Structural Health Monitoring Transducers Based on LTCC/PZT Multilayer" Fraunhofer Institute for Ceramic Technologies and Systems Dresden, Germany, Fraunhofer Institute for Nondestructive Testing Dresden, Germany.

[5]. Y.H.Hu, Y.W. Yang, L. Zhang and Y.Lu "Identification of structural parameters based on PZT impedance".

[6]. Charles r. F arrar and Keith worden "An introduction to structural health monitoring" Engineering Science and Applications Division, Los Alamos National Laboratory Los Alamos, Los Alamos, NM 87545, USA.

[7]. RadekHedlJindrichFinda, and Andrew Vechart "Prediction of Fatigue Crack Growth in Airframe Structures" European Conference of Prognostics and Health Management Society 2012.

[8]. E DiGiampaolo, SCaizzone "Wireless Passive RFID Crack Width Sensor for Structural Health Monitoring" IEEE Sensors Journal, DOI:10.1109/JSEN.2015.2457455.

[9]. Hua Yu , Jielin Zhou , Licheng Deng and Zhiyu Wen "A Vibration-Based MEMS Piezoelectric Energy Harvester and Power Conditioning Circuit" College of Optoelectronic Engineering, Chongqing University, Chongqing 400044, China, National Key Laboratory of Fundamental Science of Micro/Nano-Device and System Technology, Chongqing 400044, Chin.

[10]. Jeff Demo, Fritz Friedersdorf, Conrad Andrews, MatejaPutic "Wireless Corrosion Monitoring for Evaluation of Aircraft Structural Health" Luna Innovations Incorporated 706 Forest Street, Suite ACharlottesville, VA 22903 434-220-9443.

[11]. W H Prosser "Development of structural health management technology for aerospace vehicles" NASA Langley Research Center.

[12]. L.Elster "Long period grating-based pH sensors for corrosion monitoring" Virginia Polytechnic Institute and State University.

.