Non Contact Air-Coupled Ultrasonic Based NDT for Flaw Detection in Components

Anil Kumar. P[1], Mr. K. Veeranjaneyulu[2]
[1, 2] Department of Aeronautical Engineering
[1, 2] MLRIT, Hyderabad-43

Abstract- *Structural health monitoring is motivated by the fact that the damage tolerance and fail safe design of structures for corrosion and fatigue damage require substantial amount of inspection and monitoring at regular intervals. An intelligent monitoring is required to minimize the risk of failure and costs of inspection. The non contact ultrasonic based NDT is effective technique in detecting small defects in the structures. A non contact ultrasonic probe is used to excite and receive ultrasonic waves with Air as a medium.*

The main objective of this project is to perform System Characteristics evaluation used for the Non-Contact Ultrasonic applications.

I. INTRODUCTION

All civil, Mechanical and Aerospace structure are subject to damage as result of fatigue, overloading conditions, material degradation through environmental effects and unanticipated discrete events such as impacts or seismic events. Damage compromises the ability of the structure to perform its primary functions. Therefore, to ensure performance standards, extend the operational life span and maintain life-safety, many structural systems undergo routine inspections and maintenance. Common Non-destructive evaluation (NDE) methods for evaluating the integrity of a structural component include the use of Eddy current, Acoustic emission, Ultrasonic inspection, Radiography, Thermography or just basic visual inspection. Depending upon the structural system, the cost associated with systematic time-cased NDT inspection and maintenance can be substantial, relative to the total life-cycle costs of the system. For commercial and military aircraft, it is estimated that 27% of the average life cycle costs are related to inspection and repair. Within the aircraft industry in particular, maintenance procedures are dependent design methodologies are safe life and damage tolerance. For safe life design, the operational lifespan of structural components is estimated through a statistical analysis. Inspection is not necessary for this methodology since the components are simply replaced prior to its specified design life. As a result, safe-life design is the least economical. Currently, many aircraft are designed according to the damage tolerant methodology. NDT inspection and preventive maintenance is performed at frequent time intervals to identify incipient damage and to prevent critical damage growth.

In this work, a system analysis of special type of non-contact ultrasonic based NDT system is presented where studies pertaining to variation of system parameters such as amplitude and transducer spacing are performed to study the operation capabilities of the system.

II. EXPERIMENTAL STUDY

Experimental setup to find SNR

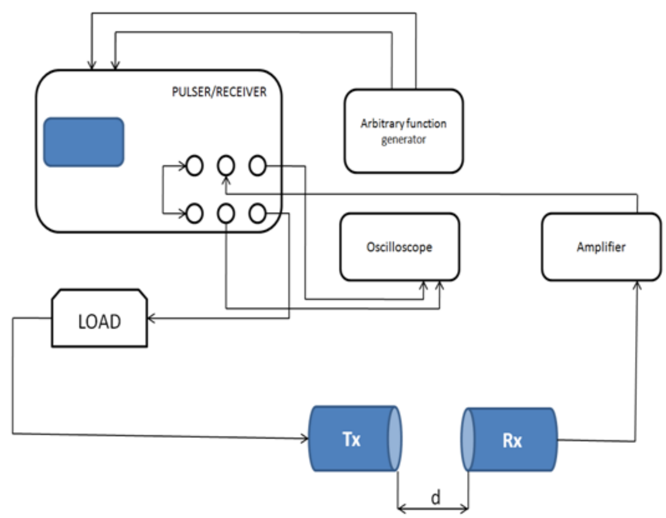

Figure: Experimental setup to find SNR

The above figure shows the Experimental setup to find out Signal to Noise ratio. The Transducers of 2MHz frequency is placed opposite to each other. Arbitrary waveforms generator produce an arbitrary waveform defined by a set of values i.e., 2MHz, 1Vpp, 5cycles wave form. This defined arbitrary wave form is sent to the Pulser and receiver. The Pulser and receiver is a high power ultrasonic measurement system designed for the nondestructive evaluation of materials properties. This Pulser/Receiver have capability of High power RF tone burst excitations up to 8 kilowatts, providing ability to drive inefficient transducers at a maximum duty cycle of 1%. The Pulser sends out signals to the Load where it is amplified to required level of input voltage. The maximum allowed voltage for the input signal is 2000 Volts peak to peak. The required level voltage, which according to the probe specification was 300Vpp, was sent to the Transmitter. The Transmitter with electrical pulses converts it into the mechanical vibrations; this mechanical vibration converse produces an Ultrasound. The ultrasound which travels through an air experiences attenuation in air which leads lo loss of energy in the received signal.

The low energy ultrasound is picked by the receiver converts into the electrical pulses and sends to the Amplifier. Where the low level energy is amplified to the required high level energy. The amplifier which sends high level energy to the Receiver where it is further amplified and sends the amplified signal to the Oscilloscope. Oscilloscope is a type of electronic test instrument that allows observation of constantly varying signal voltages, usually as a two-dimensional plot of one or more signals as a function of time.

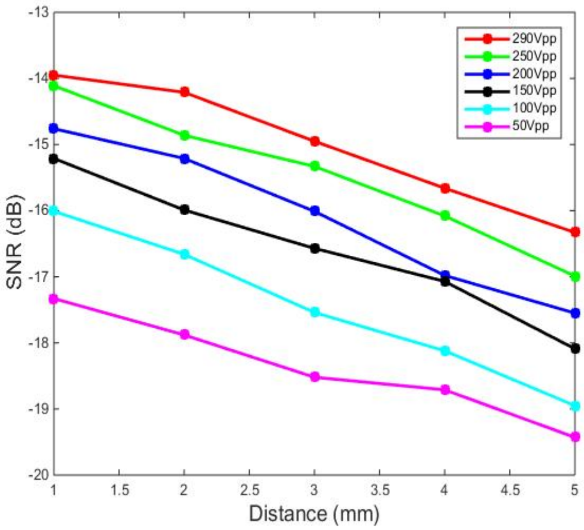

Figure: SNR V/S Distance graph

Above graph shows the Signal to noise ratio at different distance and at different input voltages. In above graph the Signal to noise ratio (SNR) increases with increase in input voltages. The red line in the graph indicates SNR at 290Vpp input with vary in distance. From the graph if the distance between the transducers is 1mm, the SNR value is highest. But this is impractical when actual test is performed with specimen. Due to this reason the suggested distance between the transducers is 5mm. At 5mm the SNR is maximum compare to the all the input voltages.

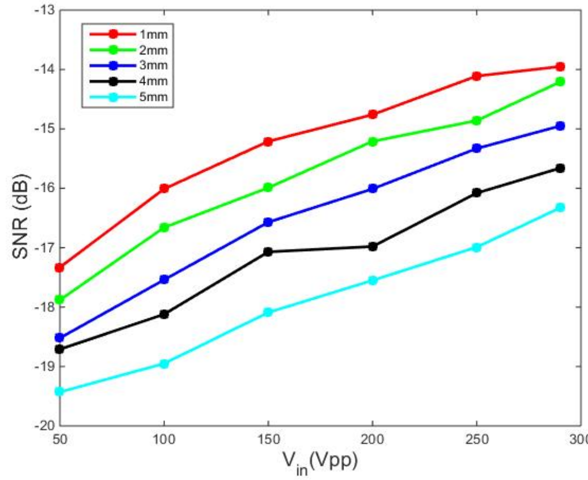

Figure: SNR V/S V_{in} (Vpp) Graph

Above graph shows the signal to noise ratio at different input voltages and at different distance. The Red line in the graph indicates the Signal to noise ratio at 1mm distance between the transducers and varying in input voltages from 50Vpp to 290Vpp. According to the thickness of the specimen which is to be tested the distance between the transducer is defined. The maximum Air column gap between transducers is 5mm.

The Signal to noise ratio can be calculated by the following equation:

$$SNR = 10\log_{10}(V_{out}/V_{in}) \quad dB \qquad (1)$$

Table: Signal to noise ratio (SNR) values

SL No	SNR(dB) @ 290Vpp	SNR(dB) @ 250Vpp	SNR(dB) @200Vpp	SNR(dB) @150Vpp	SNR(dB) @100Vpp	SNR(dB) @50Vpp
1mm	-13.95	-14.11	-14.76	-15.21	-16.01	-17.33
2mm	-14.21	-14.86	-15.21	-15.99	-16.66	-17.88
3mm	-14.95	-15.33	-16.01	-16.57	-17.54	-18.52
4mm	-15.66	-16.08	-16.98	-17.07	-18.12	-18.71
5mm	-16.33	-16.99	-17.55	-18.09	-18.95	-19.43

Above Table gives the signal to noise ratio (SNR) values at different distance with vary in input voltages

Experimental set up for pitch catch mode

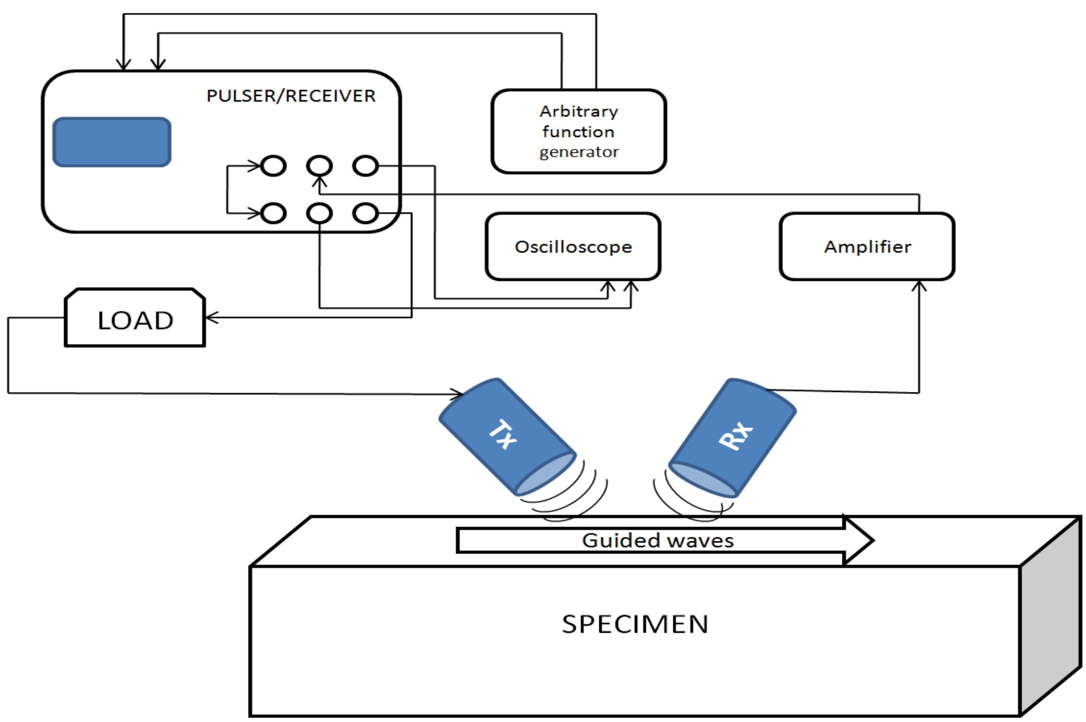

Figure: Experimental setup for pitch catch mode

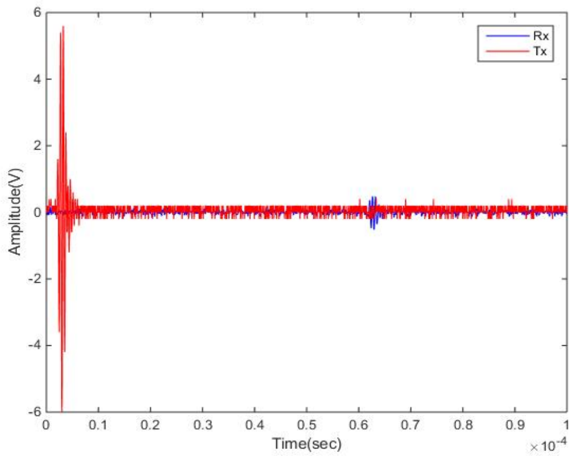

Figure: Pulse echo transmission mode Results

Above graph shows the results of Pitch catch mode of transmission. The Red image in the graph indicates the transmitted signal and Blue indicates the Received signal. The transmitted signal is 5Vpp, 5cycles of 2MHz frequency. By knowing the time interval between Transmitted signal and received signal we found the Distance by following equation;

$D=V*t_{TOF}$ (2)

$t_{TOF}=0.6*10^{-4}$Sec $D=340\times 0.6*10^{-4}$
V=340m/sec D=20.4mm

Where
t_{TOF} is time of flight
V is ultrasound velocity in m/sec
D is Distance between probes

III. CONCLUSION AND SCOPE OF FUTURE WORK

Conclusion

This paper reviews the state of the art in Air-coupled transducers in the context of ultrasonic NDT applications. This paper mainly focuses on system characteristics which are used for Non-contact Air-Coupled NDT Applications.

The Signal to noise ratio (SNR) values has been successfully evaluated at different distances (1mm to 5mm) with varying input voltages (50Vpp to 290Vpp). The SNR value is high with maximum input voltages and minimum distance between the probe. With the increase in distance between the transducers leads to decrease in signal level, this causes the signal to bury inside the noise. So that is difficult to differentiate between noise signal and received signal. The maximum suggested distance between the transducers is 5mm and input voltage is 290Vpp.

Scope of future work

The Non-contact ultrasound mode is among the most significant developments for characterization and analysis of all states of matter. There is no doubt that the uses of this technology will further enhance the causes of material quality, defect detection, process control and health care in our increasingly complex world. This advancement in the field of ultrasound and materials characterization has opened much needed and unprecedented opportunities in research and education.

REFERENCES

[1] C.Boller, and G.R.Tomilison W.J>staszewski, Health monitoring of Aerospace Structures-Smart sensor Technologies and signal processing.: John Wiley & Sons limited, 2004.

[2] Introduction to Nondestructive Testing. (2016) The American Society for Nondestructive Testing. [Online]. https://www.asnt.org/MinorSiteSections/AboutASNT/Intro-to-NDT

[3] The welding Institute. (2016) TWI. [Online]. http://www.twi-global.com/technical-knowledge/faqs/ndt/faq-what-are-the-advantages-and-disadvantages-of-magnetic-particle-inspection-mpi-in-non-destructive-examination-nde/

[4] Jim Worman. (2016) The National Board of Boiler and Pressure Vessel Inspectors. [Online]. http://www.nationalboard.org/index.aspx?pageID=164&ID=374

[5] (2012) flawscan inspections. [Online]. http://www.flawscan.com/#!/page_services

[6] (2014) NDT resource centre. [Online]. https://www.nde-ed.org/GeneralResources/MethodSummary/MethodSummary.htm

[7] Capgo. (2013) Capgo accoustic emissions. [Online]. http://www.capgo.com/Resources/ConditionMonitoring/Acoustic.html

[8] Fenlou Zai,Shanbin Su, Huaqing Wang, Peng Chen and Limei Liu Lixin Gao. (2016) MDPI. [Online]. http://www.mdpi.com/

[9] The Haghemite university. (2016) Ultrasonic testing. [Online].

https://eis.hu.edu.jo/ACUploads/10526/Ultrasonic%20Testing.pdf

[10] Wikipedia. (2016) Wikipedia. [Online]. https://en.wikipedia.org/wiki/Oscilloscope

[11] (2016, March) Wikipedia. [Online]. https://en.wikipedia.org/wiki/Guided_wave_testing

[12] Wikipedia. (2016) Ultrasound. [Online]. https://en.wikipedia.org/wiki/Ultrasound

[13] The physics. (2016) The physics class room. [Online]. http://www.physicsclassroom.com/class/waves/Lesson-1/Categories-of-Waves

[14] MR Bettinos. Haiku learning. [Online]. https://www.saddlespace.org/bettinom/mr.bettinossci enceclass/cms_page/view/20924759

[15] (2016) Sound waves. [Online]. http://www.echocardiographer.org/Echo%20Physics/Sound%20waves.html

[16] (2016) national instrunents. [Online]. http://www.ni.com/white-paper/3368/en/

[17] W., M. Castaings, and C. Bacon Ke, "3D finite element simulations of an air-coupled ultrasonic NDT system.," Ndt & E International, vol. 42, no. 6, pp. 524-533, 2009.

[18] T. H., et al Gan, "The use of broadband acoustic transducers and pulse-compression techniques for air-coupled ultrasonic imaging.," Ultrasonics, vol. 39, no. 3, pp. 181-194, 2001.

[19] E., D. Bulcaen, and F. Declercq Blomme, "Air-coupled ultrasonic NDE: experiments in the frequency range 750kHz–2MHz," Ndt & E International, vol. 35, no. 7, pp. 417-426, 2001.

[20] K., et al Ibata, "An air-coupled ultrasonic sensor applying a bimorph structure," IEEE International Ultrasonics Symposium, pp. 2420-2423, 2012.

[21] R.Gerlach, J.Frickle O.Krur, "Experimental and therotical investigation of SiO2 Aerogel matched piezo-transducers," Ultrasonics, vol. 32, pp. 217-222, 1994.

[22] G hayward, S.P.Kelly, W.galbraith A.Gachagan, "Charecterization of air coupled transducers," IEEE, vol. 43, no. 4, pp. 678-689, 1996.

[23] C.Wykes M.Rafiq, "The performance of capacitance ultrasonic transducers using V-grooved blackplates," Measure science technology, vol. 2, no. 2, pp. 168-174, 1991.

[24] J.hietanen P.Mattil, "Bnadwidth control of an electrostatic ultrasonic transducer," Sensors and actuatrors, vol. 45, no. 3, pp. 203-208, 1994.

[25] Tomás E Gómez Alvarez-Arenas, "Air-coupled piezoelectric transducers with active polypropylene foam matching layers," Sensors , vol. 13, no. 5, pp. 5996-6013, 2013.

[26] M.Castaings, C.Bacon W. Ke, "3D finitee lement simulations of an air-coupled ultrasonic NDT system," Elsevier, vol. 42, no. 6, pp. 524-533, March 2009.

[27] Adrian, et al Neild, "The radiated fields of focussing air-coupled ultrasonic phased arrays," Ultrasonics, vol. 43, no. 3, pp. 183-195, 2005.

[28] WANG Yaoyao, LU Yan*, LIU Yuepeng, WU Bin HE Cunfu, "Design and fabrication of air-based 1-3 piezoelectric composite," College of Mechanical Engineering and Applied Electronics Technology, Beijing University of Technology, Beijing, China, 2014.

[29] Mahesh C Bhardwaj. (2001) High transduction Piezoelectric transducers and introduction of Non-Contact analysis. [Online]. http://www.ndt.net/article/v05n01/bhardwaj/bhardwaj.htm

[30] D.Bulcaen, F.Declercq E.Blomme, "Air-coupled ultrasonic NDE: Experiments in the frequency range 750KHz-2MHz," Science direct, vol. 35, no. 7, pp. 417-426, June 2001.

[31] Mahesh C. Bhardwaj. (2016) Non-contact ultrasound. [Online]. www.secondwavesystems.com

[32] Radio electronics. (2016) Radio electronics.com. [Online]. http://www.radio-electronics.com/info/t_and_m/generators/ awg- arbitrary-waveform-generator.php

[33] Ritec. (2016) ritecinc. [Online]. http://www.ritecinc.com/docs/RT-150.pdf

[34] Wikipedia. (2016) wikipedia. [Online].

https://en.wikipedia.org/wiki/BNC_connector

[35] OLYMPUS. (2016) OLYMPUS. [Online]. http://www.olympus-ims.com/en/ndt-tutorials/instrumen tentation

[36] Wikipedia. (2016) Guided wave testing. [Online]. https://en.wikipedia.org/wiki/Guided_wave_testing

[37] Tomas E. Gomez Alvarez-Arenas, "Acoustic impedance matching of Piezoeletric transducer to the air," IEEE , vol. 51, pp. 624-633, May 2004.

[38] Jim Worman. (2016) The national board of boiler and pressure vessel inspector. [Online]. http://www.nationalboard.org/index.aspx?pageID=164& ID=377

[39] D.A. Hutchinsa, D.R. Billsona, D.W. Schindelb T.H. Gana, "The use of broadband acoustic transducers and pulse compression techniques for air-coupled ultrasonic imaging," Elsevier, vol. 39, no. 3, pp. 181-194, April 2001.

[40] T. Kimura, H. Miyashita, Y. Konishi, S. Inoue K. Ibata, "An Air-Coupled Ultrasonic Sensor Applying a Bimorph Structure," IEEE, pp. 2420-2423, october 2012.