EXPERIMENTAL STUDY OF LAMB WAVES USING ACOUSTO-ULTRASONIC TECHNIQUE

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Abstract : Non Destructive testing is a wide group of analysis techniques used in science and industry to evaluate the properties of a material components or system without causing damage. NDT methods include visual inspection, dye penetrant method, radiographic method, magnetic particle method, eddy current testing method, ultrasonic testing method. Acousto-Ultrasonics is also one of the NDT methods which can overcome most of the disadvantages of other methods. The term ―acousto-ultrasonics denotes a combination of some aspects of acoustic emission methodology with ultrasonic characterization. In acousto-ultrasonic technique, a broadband ultrasonic wave is injected onto the surface at one location of the test plate with the help of a piezoelectric sensor coupled to the same surface at another location. Thus, understanding the propagation characteristics of the ultrasonic wave is essential for successful application of the technique. The dominant acousto-ultrasonics waves produced experimentally in thin plates were multi-mode Lamb waves. The broadband generation and detection of Lamb waves has been performed in aluminium plate using the acousto-ultrasonic method. Using the same procedure, experiments are conducted on non-defective and defective plates with transducers of different frequencies. By comparing the results obtained in both the cases, defects can be detected. Similar plots can be obtained with the transducers of different frequencies.

IndexTerms **- Lamb wave, Piezoelectric sensor, Transducers**.

I. INTRODUCTION

Acousto-Ultrasonics is a highly sophisticated and advanced technique using digital signal processing and pattern recognition algorithms. As such it is orders of magnitude superior to any other conventional ultrasonic technique, where the human recognizance capability is much inferior to modern data processing, or where automatic scanning systems are limited by considering only the amplitude in a small portion (gate) of the ultrasonic signal. Acousto-ultrasonics considers the entire ultrasonic response, in time as well as in frequency, of the entirely insonified material In acoustic-ultrasonics. a stress wave factor (SWF) is used to characterize acousto-ultrasonic waves The SWF based directly on acoustic emission practice such as energy, peak voltage or waves. The SWF It indicates the energy of the received signal in the given time domain or frequency domain. The modes of the ultrasonic waves in the plate are complicated because of the element of the transducers in the acousto-ultrasonic approach. It may be thought that. In the tested plates, there are lamb waves and the waves, which arc reflected many times between the surface of the Plate.. But, the SWF often used disregards the nature of the ultrasonic propagation. This greatly limits the utilization of the acousto-ultrasonic technique. In ultrasonic wave propagation properties In the thick (relative to the wavelength of the ultrasonic wave) plates .It was found that the resonance mode that resulted from multiple reflections of the longitudinal waves between the top and bottom surfaces was appropriate for this analysis. This project analyzed experimentally the ultrasonic wave propagation under the acousto-ultrasonic mode when the tested plates are relatively thin. The work helps to understand the wave propagation when the acousto-ultrasonic method is used to test the thin plates.

On the other hand, Acousto -Ultrasonic using PZT have been effective in making online assessment of a structure. The main advantage of Acousto-Ultrasonic technique being,

- Large coverage area of inspection (global)
- Coverage of inaccessible areas of the structure
- Rapid inspection without disassembly.
- Adjustable frequency range for interrogation for various size/types of damage.

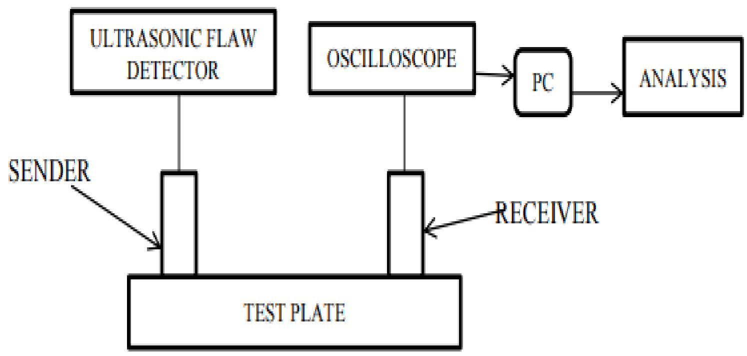

Fig.1 Schematic diagram of setup.

II. WAVES UTILIZED IN THIS PROJECT

LAMB WAVES

The theory of lamb waves was originally developed by Horace Lamb in 1916 to describe the characteristics of waves propagating in plates. Frequently, they are also referred to as a plate waves. Lamb waves can be generated in a plate with free boundaries with an infinite number of modes are also called longitudinal modes because the average displacement over the thickness of the plate or the layer is in the longitudinal direction. The anti- symmetric modes are observed to exhibit average displacement in the transverse direction and these modes are called flexural modes. The infinite number of modes exist for a specific plate thickness and the acoustic frequency which are identified by their respective phase velocities . the normal way to describe the propagation characteristics is by the use of dispersion curves based on the plate mode velocity as a function of the product of frequency times thickness. The dispersion curves are normally labelled as S0,A0,S1,A1 and so forth, depending on whether the mode is symmetric or anti-symmetric .Although the dispersion diagrams are very complex ,they can be dominant . A particular lamb wave can be excited if the phase velocity of the incident longitudinal wave is equal to phase velocity for the particular mode**.**

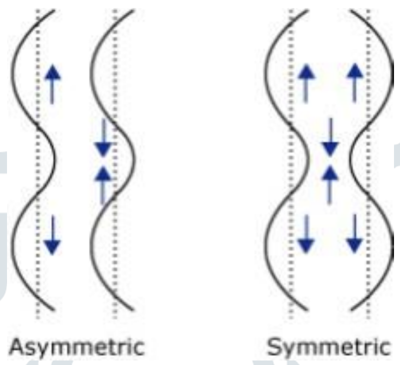

Fig.2 Symmetric and Asymmetric lamb waves

LAMB WAVES IN ACOUSTO-ULTRASONIC TESTING

Acousto-ultrasonic testing differs from ultrasonic testing in that it was conceived as a means as of assessing damage (and other material attributes) distributed over substantial areas, rather than characterizing flaws individually. Lamb waves are well suited to this concept, because they indicate the whole plate thickness and propagate substantial distances with consistent patterns of motion.

LAMB WAVES IN ACOUSTO-EMISSION TESTING

Acoustic emission uses much lower frequencies than the traditional ultrasonic testing and the sensor is typically expected to detect active flaws at distances up to several meters . A large fraction of structures customarily testing with acoustic emission are fabricated from steel plate-tanks, pressure vessels, pipes and so on .Lamb wave theory is therefore the primary theory for explaining the signal forms and propagation velocities that are observed when conducting acoustic emission testing. Substantial improvements in the accuracy of AE source location (a major techniques of AE testing) can be achieved through good understanding and skillful utilization of the lamb body of knowledge.

III. COMPARISION

Although it uses aspects of acoustic emission methodology, acousto ultrasonics is basically an ultrasonic technique. Three attributes of acousto-ultrasonics should be noted. Firstly, it is a generalized approach to ultrasonic testing: it uses two ultrasonic probes in a send-receive configuration for material characterization. The sender is optimized for wave generation while the receiver is optimized for signal reception, respectively, as required by unique features of the test piece. Secondly, while the two probes might be on opposite sides of a test piece, as in the straight- through transmission mode, acousto-ultrasonics gains definite advantages by having the probes offset.

The usual and often most convenient arrangement are to have the probes on the same surface of a test piece. Thirdly, at the limit of zero spacing between the two probes, acousto-ultrasonics reduces in principle to the single-probe mode commonly used for pulse-echo flaw detection or attenuation and velocity measurements. From this viewpoint single-probe. pulse-echo ultrasonics is just a subset of acousto-ultrasonics.191 Certainly, conventional pulse-echo and through-transmission ultrasonics can accomplish many flaw detection and materials characterization objectives of acousto- ultrasonics.

There are cases for example, in which pulse-echo attenuation measurements provide data that complement acousto-ultrasonic data relative to evaluating material defect states and diffuse flaw populations. There are also cases in which acousto-ultrasonics provides corroborative information or more complete data than that provided by conventional ultrasonic methods.

IV. EXPERIMENTAL SETUP

The arrangement used in the experimental investigation is shown in figure , the apparatus used to excite ultrasonic waves is an flaw detector. The sender and receiver probe used is a piezo-electric sensor, which is directly connected to an oscilloscope and signal generator . Using single pulse excited the senders to generate the narrow pulse ultrasonic waves. The tested specimens are aluminum plates. The sending and receiving transducers are directly coupled to one surface of the plate with a thin film of couplant. Enough pressure had to be applied to eliminate unwanted observations within the couplant . The received signals are sent to digital oscilloscope for A/D conversion and display

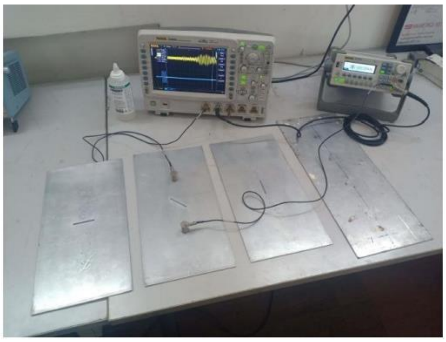

Fig.3 Test Setup

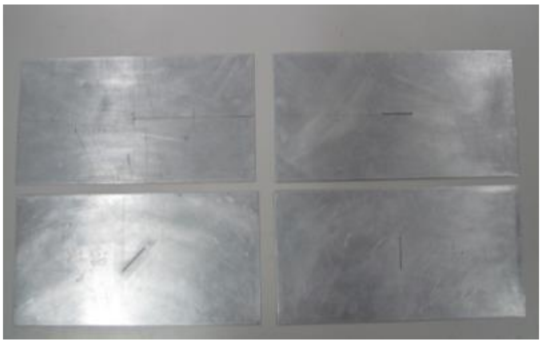

Fig.4 Defect and Defect free plate

V. RESULTS AND DISCUSSION

Results

When the PZT is excited lamb wave is generated at 300 KHz and the reflections from the edges are received by the PZT and displayed in the oscilloscope. The obtained wave form is saved as a CSV file and imported into MS EXCEL for further analysis. Similarly the wave form data's of all the plate's are collected and compared. The raw waveform carries along with useful information, lot of other noises due to interference, coupling etc. The optimally filtered signal is obtained as shown in figure 5.

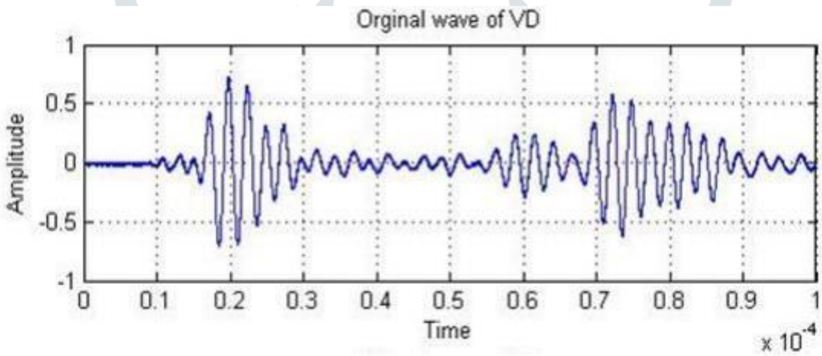

Fig.5 Reference Graph

The waveform of horizontal, vertical and angular defect and the defect free plate are plotted and compared as shown in figure 6.

In the waveform generated two distinct reflections of S_O and A_O mode are visible. The first transmitted S_O mode is seen at 0.15×10^{-4} s and reflected at 0.42×10^{-4} s similarly the transmitted A_O mode is seen at 0.2×10^{-4} s and the reflected wave at 0.75×10^{-4} s. Since the S_O mode waves are faster, the reflection peaks occur much earlier. The A_O mode reflection is much stronger, while the S_0 mode reflection appears to be much weaker due to its highly attenuating nature. Hence S_O signals will not be useful to identify the damage characteristics. Hence care has to be taken such that the reflections from the defects have to occur after the S_O edge reflections.

Fig.6 a shows the waveform from a defect-free plate. We can see the first reception peak (received from the transmitter) of the wave by the receiving sensor occurs at 0.2×10^{-4} s and the next reflection peak (reflected from the edge) occurs at 0.75×10^{-4} s, these two peaks can be taken as reference and any other reflections from defect will occur within this interval.

Fig.6 b shows the waveform from a plate with horizontal defect. The waveform peak corresponding to the defect occurred around 0.5x10-4 s. The amplitude of the peak is quite low on comparison with the reflected wave peak and the detection of horizontal defect becomes difficult as the defect is very small.

Fig.6 c shows the waveform from a plate with angular defect. The waveform peak corresponding to the defect occurred around 0.65×10^{-4} s. The amplitude of the peak is high when compared to both the amplitude of horizontal defect and reflected wave.

Fig.6 d shows the waveform from a plate with vertical defect. The waveform peak corresponding to the defect occurred around 0.57×10^{-4} s. The amplitude of the peak is quite equal on comparison with the reflected wave peak. The comparison of defect and defect free waveform shows that all three types of defects are detected in which the angular and vertical defect can be identified easily since the amplitude of the peak is appreciable on comparison with the reflected wave peak. The detection of horizontal defect becomes difficult as the defect is very small.

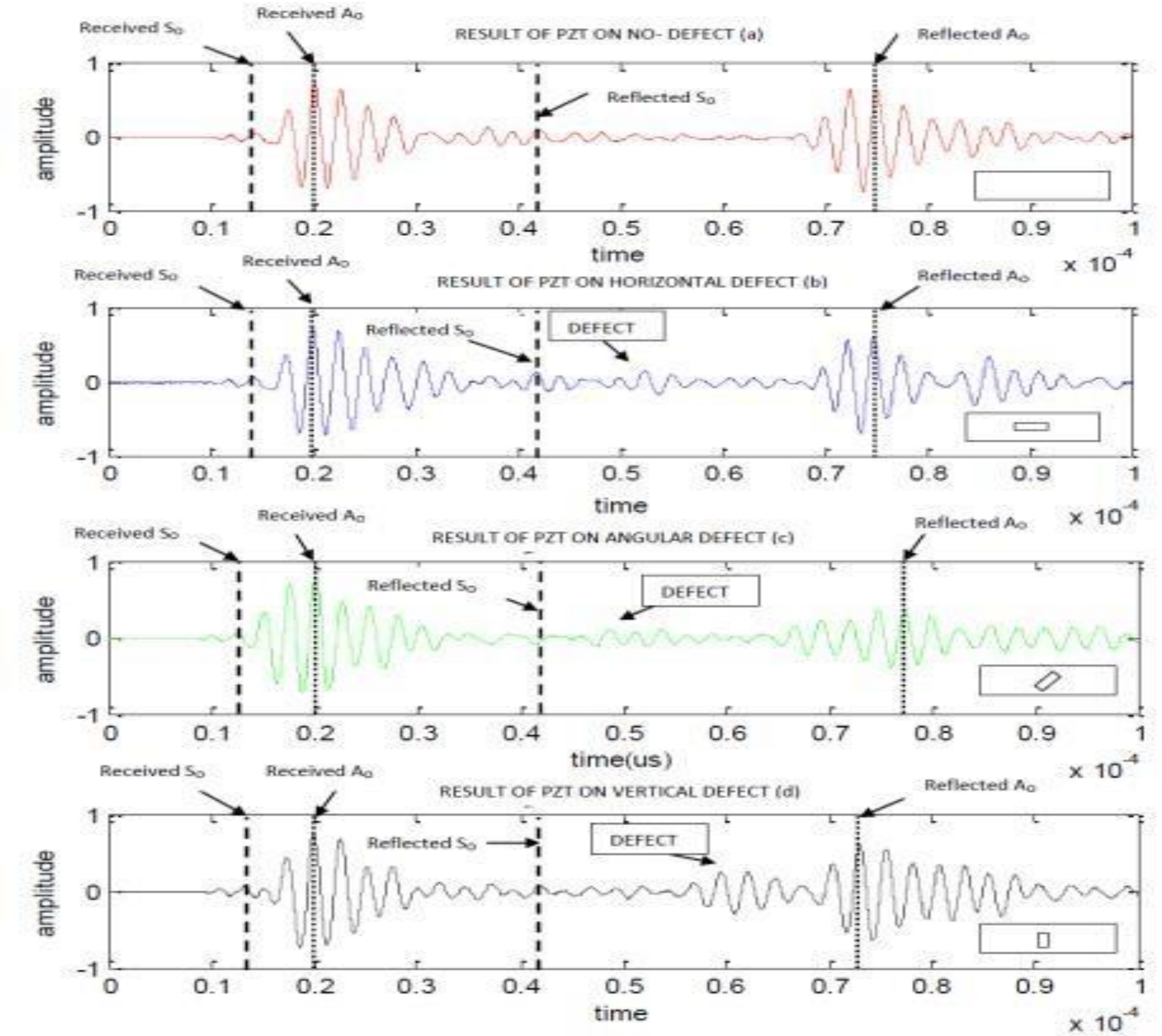

Fig.6 Results shown in Graph

Discussions

Experiments were conducted on aluminum plates with different defect configurations and the signals were extensively analyzed. Clear differentiation between various types of defects has been identified. Lamb waves were generated and received using PZT sensors and the signals were processed. Signals acquired from the plates with various defect orientations are compared with the signals of the defect free plate.

The Aluminium plate is pulsed with a 300 kHz signal and the reflections are received by the receiver PZT. The waveform of horizontal, vertical and angular defect and the defect free plate are plotted and compared. Two distinct reflections S_O and A_O mode are seen ,in which the A_O mode reflection is much stronger, while the S_O mode reflection appears much weaker because of which A_O mode is highly useful for damage identification.

Thus, Lamb waves generated by PZT sensors can could be used effectively for damage detection in aluminum plate. The same study can be extended by using several reception PZT sensors at the same time (phase array technique) thereby increasing the probability of detecting defects. The approach presented here can be very useful in the development of a continuous structural health or condition monitoring system because of its simplicity and can be extended into an automated system with minimal requirement for operator involvement. This ability should result in major reductions in the cost of sustaining current and future advanced structures, extend the service life of aging aircraft fleet, and provide new capabilities for improving structural safety and reliability. Practical implementation of the technique in real structures will, however, require additional research involving laboratory tests and theoretical modeling, decisions on areas to be instrumented, installation of denser sensor arrays and refinement of algorithm for real time applications.

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