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Non Destructive Evaluation of Material Defects by Laser Based Ultrasonic's

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Abstract: Non-contact generation and detection of ultrasound waveforms is of practical importance, since it permits making ultrasonic measurements at elevated temperatures, in corrosive and other hostile environments. The use of ultrasonic sensors to detect flaws in aluminum specimens and the advantage of Lamb wave for their characterization has been proved.

Lamb waves are bounded by the plate surface causing a wave guide effect. In this experimental study a 2mm thick aluminum plate was chosen with different induced defects. Ultrasonic lamb waves were generated by an EMAT and PZT transducers and received by an optical He-Ne laser system. A frequency of 200 KHz was used to generate ultrasonic lamb waves to propagate within the material without attenuation. Laser-based configuration was used to quickly locate the defect. Guided Lamb waves allow inspection of the complete thickness with only one scan, permitting to detect and to size both internal and surface defects. Moreover B-scan configuration was used to inspect single-side access structures which reduce the inspection time. Velocity dispersion was plotted using dispersion software and the experimental results were in good agreement with the dispersion curve.

Keywords: PZT Transducer, He-Ne Laser; Lamb waves; Laser generation; Non-contact ultrasonic inspection

1. INTRODUCTION

The use of ultrasonic for testing of components is widespread in industry. It is one of the important techniques available for nondestructive evaluation (N.D.E) of materials [1]. Conventional ultrasonic evaluation method involves use of piezoelectric transducers for generation and detection of ultrasonic wave pulses in the material being tested. The use of piezoelectric transducers in conventional ultrasonic testing creates some inherent disadvantages which severely limits it's applications in industry. Laser based ultrasonic technology being a non-contact measurement technique addresses the defects in conventional ultrasonic testing methods. Laser based ultrasonic technique works on the principle of generation of ultrasonic waves in the material being tested by irradiation of sufficiently powerful laser beam on the material surface [2] .T

he mechanism of generation of ultrasonic waves in the material is controlled by the surface absorption characteristics of the material and also the energy density of the laser beam being used. The generated waves get reflected at discontinuities inside the material and generate echoes. These echoes are then detected by using a suitable non-contact measuring technique like interferometry [3, 4]. The analysis of these detected ultrasonic echoes provides important information about the flaws present inside the material. Apart from flaw detection the velocity of the waves generated also gives information about the material properties like Young's modulus, rigidity modulus, Poisson's ratio etc. Thus this method is highly suitable for non-destructive evaluation of materials and finished products [5].

2. METHODOLOGY AND EXPERIMENT

The experiment was carried out in an aluminium plate of thickness 2mm.The length of the plate is 500mm and breadth is 220mm. Two defects like notches were induced in the specimen of 1mm and 0.5mm depth. The length of the notch defect is 100m**.** Figure1. shows the block diagram for a laser EMAT ultrasonic lamb wave generation. The EMAT meander coil is placed upon the aluminium plate which is connected to a pulsar receiver in which the frequency can be adjusted.

The pulsar receiver is connected to the laser vibrometer controller which is in turn connected to a Helium Neon laser source. Here the EMAT acts as a transmitter which generates ultrasonic lamb waves along the surface of the material and the lamb wave is received using a low power helium neon laser. The wavelength of He-Ne laser is 633nm. The laser pointer is adjusted for proper focusing and kept at a particular standoff distance to get maximum amplitude. The received vibration is displayed in a cathode ray oscilloscope (CRO) which shows an A scan amplitude signal. Before proceeding the experiment a dispersion curve was plotted using a disperse software for the 2mm thick aluminium plate. From the dispersion curve the phase velocity and group velocity was found out for different frequency of the meander coil. The experiment was done using three different frequencies like 500 KHz, 750 KHz and 1150 KHz.

3. EXPERIMENTAL RESULTS

A. Defect free region (increased frequency)

Designed meander-line coil EMAT generated lamb waves on the Aluminium sample. Initial approach is transmitter to receiver distance was kept on constant (100mm) and increased frequency. Dispersion curves are more useful to understand these signals figure 2.1(a). The S_0 mode has high velocity than A_0 mode. At 0.5 MHz and 0.7 MHz frequency the signal response is shown in the figure 2.1(b)

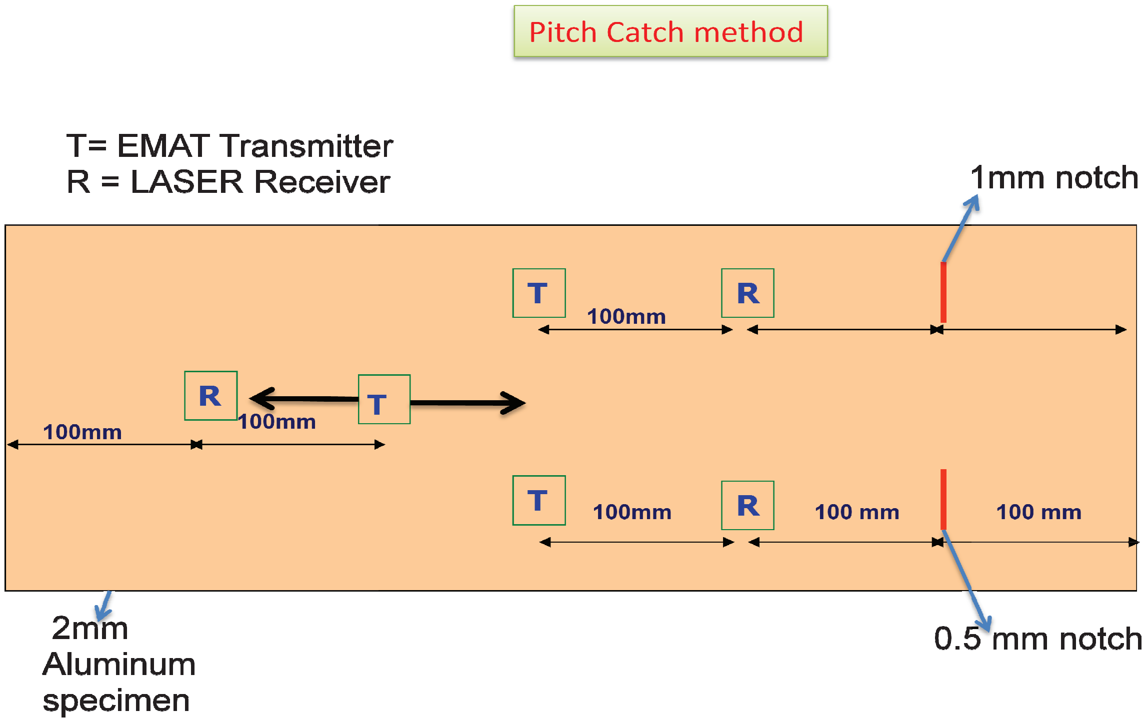


Fig. 1. Schematic Block Diagram of Lamb wave generations and their positions

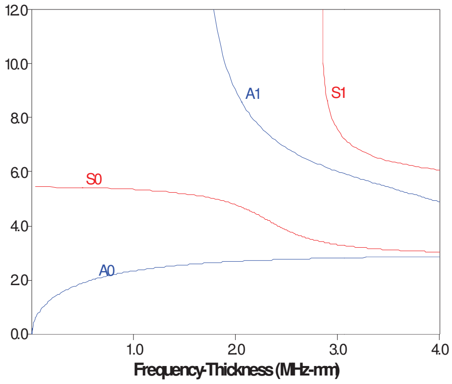
Here this figure represents the two direct signals i.e. fundamental modes like S_0, A_0 and edge reflections of the modes.

3.2 Defect Characterization with proper Lamb wave

Here frequency (0.5MHz), transmitter to receiver distance (100mm) was constant. Aluminium specimen has 2 artificial notches with dimensions 20×1×0.5mm and 20×1×1mm.At 0.5MHz frequency these lamb waves capture the two notches as shown in the figure 2.2. Here lamb waves acts like a guided waves and transmitter to receiver distance is 100mm, receiver to notches distance is 100mm and receiver to edge of the Aluminium plate is 100mm. Whenever these lamb waves hit the defects then mode conversion has appeared i.e. S_0 mode is converted into two modes (S_0 and A_0) and A_0 mode is converted into two modes (S_0 and A_0). These lamb waves travels through the defects and reflected back from the edge of the Aluminium plate. These reflections once again travels through the defects and captured by the Receiver. Here amplitude of the mode converted signals increases with respect to defect depth.

3.3 Set Up and procedure for PZT –LASER B-Scan imaging

The experiment was also carried out using a PZT transducer placed on the plate to generate ultrasonic waves. The frequency of the PZT crystal is 200 KHz. A dispersion curve is also plotted for this particular frequency and material thickness. The laser source is mounted on a scanner for scanning the entire region of the specimen. So the generated ultrasonic wave is monitored using this line focused laser source which is scanned over the entire defective specimen. The PZT sensor acts as a transmitter and laser as receiver. The depth of the defect is 2mm. The PZT transducer of frequency 200 KHz generated ultrasonic lamb waves and they were detected by a scanning laser source and a B-scan image is captured which showed change amplitude in the defective region shown in the figure 2.3.



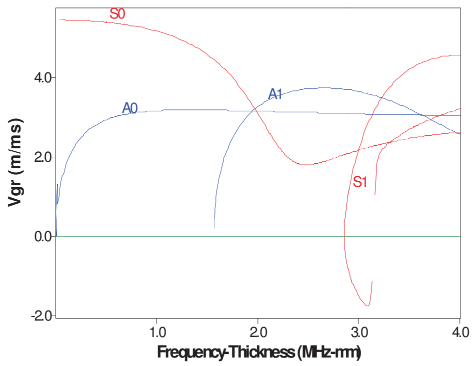
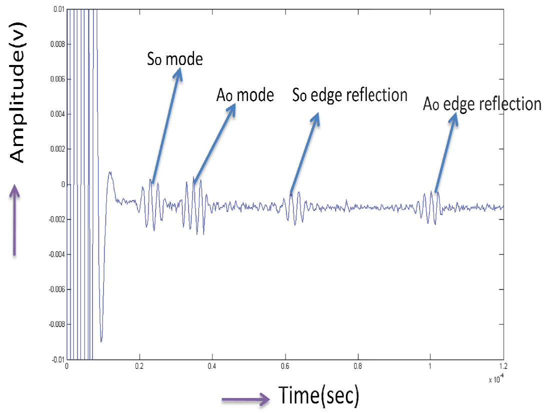


Figure 2.1. (a) Dispersion Curves for a Phase Velocity and Group Velocity for Aluminium 2mm Thickness.



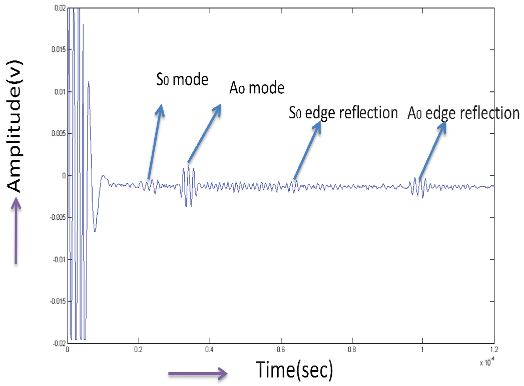
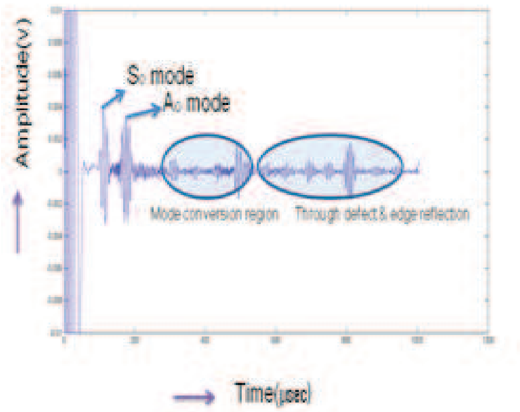


Figure 2.1(b). At 0.5 MHz and 0.7 MHz Lamb Wave Generations.



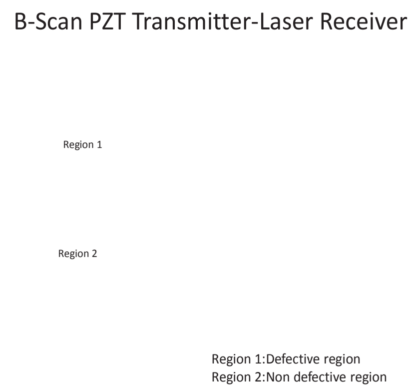


Figure 2.2. Defect Free regions of 0.5 mm Figure 2.3.PZT-Laser B-SCAN Image.

4. CONCLUSIONS

The use of non-contact ultrasonic technique based on laser generation and reception using transducer detection has been proved to detect defects on Al plates. The convenience of ultrasonic Lamb waves to classify the defects has been demonstrated by the Guided waves, propagating in thin structures, are more efficient than bulk waves as they allow a quicker inspection. It has been possible to detect and to quantify defects in any welded Al specimens that usually can appear during the welding process. In the experimental configurations used, EMAT source and LASER receiver were used on the same side of the structure to demonstrate the applicability of the technique when there is one-side access. This study has proposed a new technique for visualizing the propagation of ultrasonic waves in general solids, including composite laminates. A combination of a laser scan for ultrasound generation and a fixed receiver provides a moving diagram (or a series of snapshots) of wave propagation, using an easily operated measurement system.

5. REFERENCES

[1] A. D. W. McKIE & R. C.ADDISON Jr., Rapid inspection of composites using laser based ultrasound in Review of Progress in Quantitative Evaluation, Vol. 12 1993

[2] S. Dixon, C. Edwards, S.B. Palmer**.,** "A laser–EMAT system for ultrasonic weld inspection" Ultrasonics, Volume 37, December 1998 Pages 273–281.

[3] P. B. NAGY & G. BLAHO, Random speckle modulation technique for laser interferometry in Journal of Nondestructive Evaluation, Vol. 11, No. 1,1992

[4] Hongjoon Kim, Kyungyoung Jhang, Minjea Shin, Jaeyeol Kim., "A noncontact NDE method using a laser generated focused-Lamb wave with enhanced defect-detection ability and spatial resolution",NDT & E International, Volume 39*, Issue 4*, *June 2006*, *Pages 312-319*.

[5] G. BRINBAUM & G. S. WHITE, Laser Techniques in NDE in Nondestructive Testing, Vol.7

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