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Automated Ultrasonic Measurements in Thin Samples

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ABSTRACT
Pulse echo technique is widely used for ultrasonic velocity measurements in solids and liquids, but fails to measure ultrasonic velocity in thin samples. In such situations total reflection technique is extremely useful. In the present work, PC based total reflection technique is developed using ultrasonic transmitting and receiving transducers, operated at 1MHz, fitted to the two opposite walls of water tank. The thin sample under study is suspended between the transmitting and receiving transducers; and rotated about an axis perpendicular to the direction of wave propagation. The angle of rotation of the metallic plate is controlled precisely by stepper motor with additional gear arrangement to the resolution of 0.25°. Critical angles for longitudinal and shear components of an ultrasonic wave correspond to the maxima observed at two angles of longitudinal and shear wave component, respectively. This technique has been found to be very effective in thin samples in the light of dating.

Keywords: Longitudinal velocity, shear velocity, metal plates, Microcontroller (PIC16F72), total reflection technique

I. INTRODUCTION

Ultrasonic technique is powerful, effective and reliable in characterization of matter. Ultrasonic waves may be transverse or longitudinal, depending upon the cut of the PZT crystal. A longitudinal wave contains both the pure shear and compression components. Shear wave easily gets scattered within the material, due to its lower velocity of propagation. Hence, rotation of sample or transducer induces the polarization effects. Longitudinal wave propagates adiabatically and the local temperature of the medium alters in phase with change in volume. This forms the basis of the present work. Continuous wave and the pulse techniques are widely used to measure ultrasonic absorption and velocity. The total reflection technique is the most classical among the continuous ultrasonic techniques and has been found quite sensitive to detect variation in velocity of propagation. This classical experimental setup needs some extra efforts and skills to perform the measurements, hence the technique is not so popular.

In the present work, we have designed an automated technique for shear and longitudinal ultrasonic velocity measurements in thin samples, leading to single click operation for the entire measurements. This technique is simple, reliable and cheaper as compared to other techniques. It is effective in the measurement of ultrasonic longitudinal and shear velocities in thin plates, simultaneously.

II. EXPERIMENTAL

Experimental setup consists of double walled tank, matched pair of PZT transmitter and receiver transducers, transmitter driver module, receiver module and rotational arrangement (Fig.1). The tank is filled with double-distilled water as a medium of propagation. Metallic plate under investigation is suspended between the two transducers in such a way that it can be rotated about an axis perpendicular to the direction of propagation of ultrasonic waves. The system is incorporated with an initial position sensor arrangement to avoid error in initial position alignment. The rotation of metallic plate is precisely controlled using stepper motor and gear arrangement with the resolution of 0.25°.

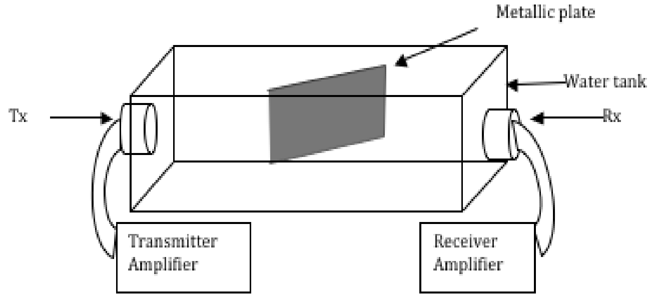

Fig.1: Block Diagram of the Experimental setup

When the plate is held perpendicular to the direction of the waves, longitudinal component of the wave is entirely transmitted. The angle between the metallic plate and the incident waves is decreased from 90^o, or when the angle of incidence increases from 0^o, a position is reached when there is no further transmission of longitudinal waves. This is the first critical angle. The plate is rotated to the second critical angle till the shear component of the wave ceases to be transmitted. There will be no transmission of ultrasonic shear waves beyond this critical angle. The Microchip microcontroller (PIC16F72) is used to digitize the received signal, stepper motor control and initial angle position detection of the plate, under study. The measurement data is then transferred to generic PC for further calculations and plot the graph.

III. INTRODUCTION HARDWARE AND OPERATION

Fig. 2 shows the block diagram of the designed system in our laboratory. It consists of transmitter, which generates 1MHz pulses using crystal oscillator operated at 5V, further amplified up to 15V using LM311. The narrow-beam IR-Optocoupler is used in rotational zero angle position sensor. The gear and stepper motor control is achieved with the help of microcontroller, PIC16F72. The received signal is digitized using an in-built 8-bit ADC of PIC16F72 microcontroller. Digitized output of the microcontroller is serially fed to the PC (using RS-232). PC is used to store the experimental data, calculate velocity and display graph.

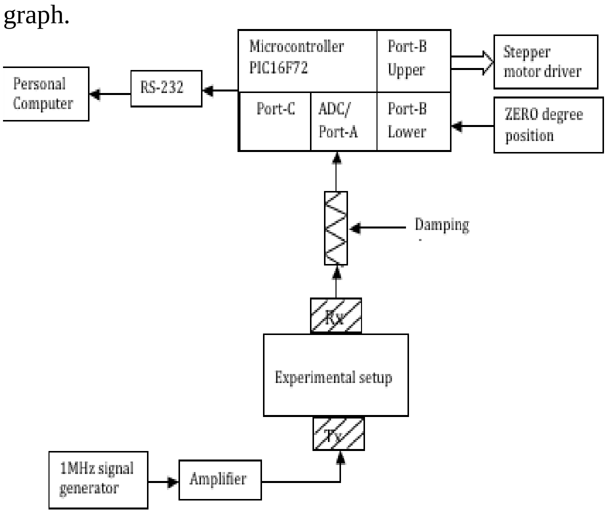

Fig. 2: Block diagram of the Designed System

IV. SOFTWARE

Software for position sensing, stepper motor control and digitization of received signal is developed in our Lab. User interface program is written in Visual Basic, to transfer data from microcontroller to PC via RS-232. It is used to store the measurement parameters, calculate the shear and longitudinal velocity and display the graph. Step angle and amplitude measurements are achieved with the help of assembly language programming of PIC microcontroller.

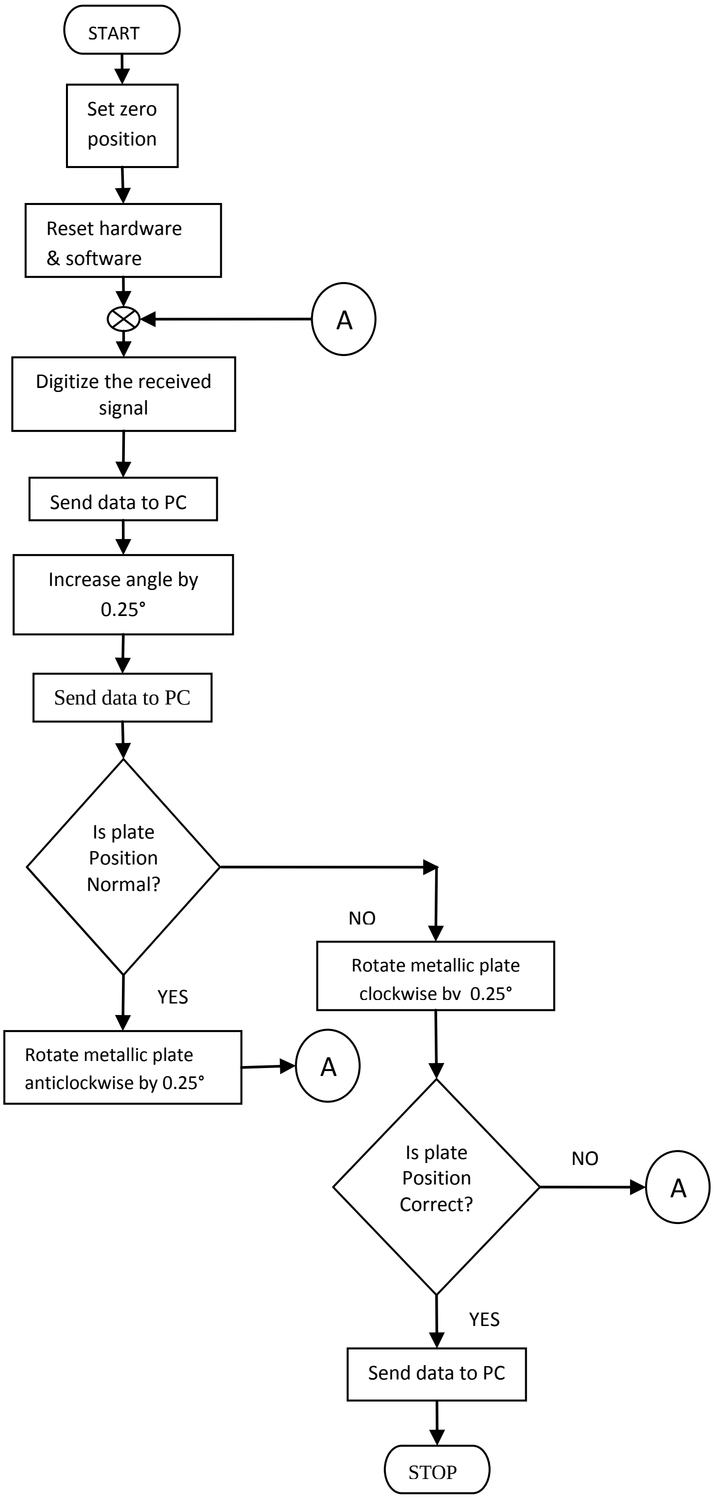

Fig. 3: Flowchart of Data Acquisition using Microcontroller PIC 16F72

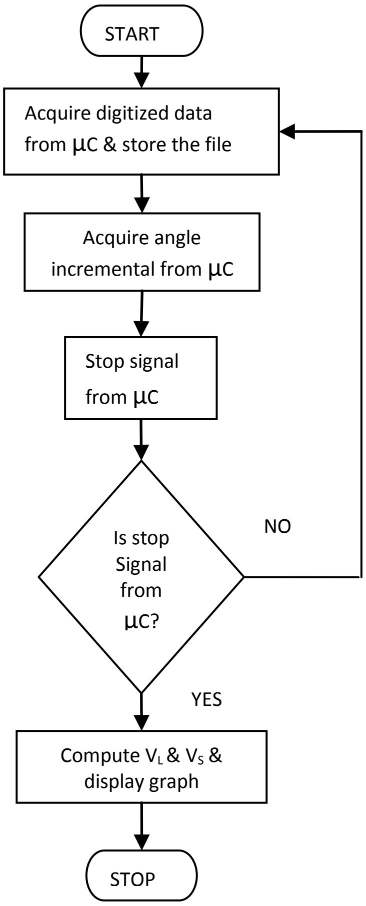

Fig. 4: Flowchart of GUI control panel

V. Results and Discussion

The shear velocity is calculated using

$Vs = V_{LW} / \sin \theta_2$

and

The longitudinal velocity is calculated using

$V_L = V_{LW} / \sin \theta_1$

where,

Vs = Shear velocity component in solid

V_L = Longitudinal velocity component in solid

V_{LW} = Longitudinal velocity component in water

θ_2 = Second critical angle in water

θ_1 = First critical angle in water

Table 1: Experimental results

Sr. No	Sample	Temperature (^oC)	V_L (m/s)	Vs (m/s)
1.	Aluminum	31.2	4125.19	2541.74
2.	Copper	31.2	3118.52	1959.37

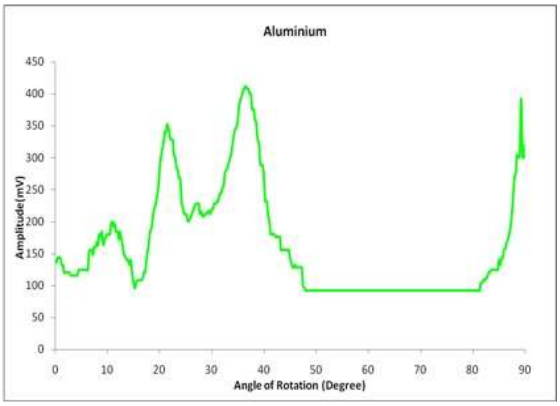

Fig.5: Variation of Signal Amplitude with Angle of Rotation of Aluminum Plate

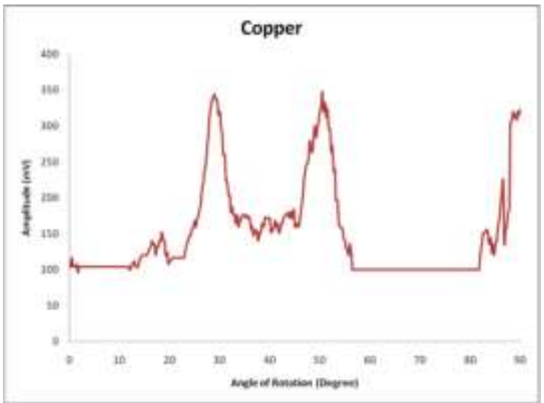

Fig. 6: Variation of the Signal Amplitude with Angle of Rotation of a Copper plate

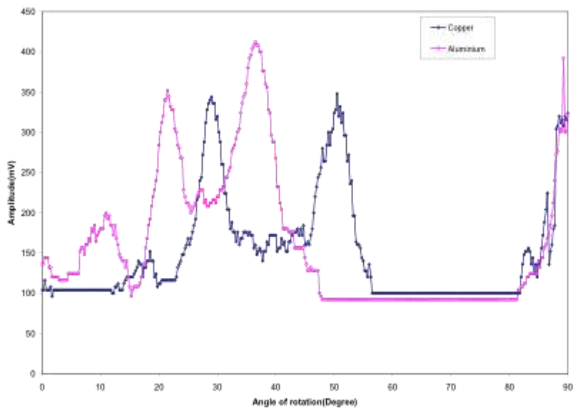

Fig.7: Variation of the Signal Amplitude with Angle of Rotation

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