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Input Signal Recovering Using Regular Time Reversal And Inverse Filtering

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Abstract:*The applicability of the time reversal method to Lamb wave propagation is investigated in order to recover the initial input signal in the long distance propagation of dispersive lamb waves .The simplicity of generation and sensing of the lamb wave make it suitable for structural health monitoring of thin plate-like structure because of their guided waves.Their dispersive properties frequently limit their practise in defect detection in which time arrival and amplitude dimension are not easy to determine. .Time reversal processing can be applied to overcome these problems. Time reversal method using Lamb waves contains of three phases. A signal is produced into a plate structure through a transmitting transducer. Signal becomes dispersive though spreading across the plate. A different transducer acquires the transferred signal. The signal is inverted in time and re-emitted via the first transmitter two techniques are tested: Regular time reversal, inverse filtering and compared*

Keyword:*Time Reversal, Lamb Waves, Dispersion Removal, Inverse Filtering,*

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I.INTRODUCTION

The practice of lamb waves for structural health monitoring has received the widespread attention of researchers in the recent past[1-3].The simplicity of generation and sensing of the lamb wave make it suitable for structural health monitoring of thin plate-like structure because of their guided waves[4].Though, their dispersive properties frequently limit their practise in defect detection in which time arrival and amplitude dimension are not easy to define since of the large time duration and the complex waveform of signal. Usually ,Lamb waves are transmitted and received using a transducers .with a transducers array ,it becomes possible to detect defects on a large range .However, since of their dispersive phenomenon ,the received signal are frequently problematic to interpret. Time reversal processing can be applied to overcome these problems. The theory of time reversibility of Lamb waves has its history in general acoustic [5]. Considerable research has been assumed in this direction to prolong the practice of time reversal for baseline –free damage recognition .The effect of dispersion on the time reversal analysis of Lamb waves was first studied by Ing.al [6].They have shown the capability of time reversed mirrors to self-focus dispersive pulses and to detect in pulse-echo mode in 2D plates.Wang.al [7] have introduced the time reversal operator into the lamb wave equation based on the Mindlin plate theory. Park, sohn, et al [8, 9] have shown that wavelet based signal processing could improve the time reversibility of Lamb waves in thin composite plate.Park et al[10] established that the use of a narrowband tone burst excitation completely restores the original input signal through a single mode Lamb wave time reversal process.Gangadharan et al [11] have presented that under broadband excitation ,time action in metallic structures reversed Lamb waves can be successfully used for temporal recompression and damage detectionXu and Giurgiutiu [12] and more lately Park et al. [13] and jeong [14, 15] proposed a theoretical model for studying the Lamb wave time reversal comportment in single and multiple modes, and confirmed it experimentallyTo alleviate the dispersion issues of Lamb waves for the time reversal method in the current work contain of this phases. An input signal can be restored at another transducer if an output signal recorded at the receiver transducer is reversed in time and re-emitted by initial transducer. If the time invariance is satisfied, then the recorded signal becomes the equivalent the original input signal.

Time Reversal And Inverse Filtering Process

Time reversal method using Lamb waves contains of three phases. Acoustic signal is produced into a plate through a transmitting transducer. Signal becomes dispersive though spreading across the plate. Another transducer obtains the transferred signal.The signal is inverted in time and re-emitted via the first transmitter. If the time invariance is fulfilled, at that moment the recorded signal come to be the similar the original input signal. In this work, one methods were used for retrieval of first input signal or elimination of dispersion. The principal method is founded on the regular time reversal method,

Designating V_1(t) by way of input signal, the output signal measured via the receiver after this excitation is well-defined as

$$V_2(t) = h(t) \otimes V_1 = \int_{-\propto}^{\propto} h(\tau) V_1 \ (t - \tau)\, dt \qquad (1)$$

Where the sign ⊗ means a temporal convolution then $h(t)$ is the impulse response function now the frequency field, Eq. (1) is stated as

$$V_2(\omega) = H(\omega) V_1(\omega) (2)$$

The time reversal process of a signal in the time domain remains corresponding to captivating the complex conjugate of the Fourier transform of the signal in the frequency field. Consequently, the time reversal of the transducer output

$$V_2^*(\omega) = H^*(\omega) V_1^*(\omega) (3)$$

Where the superscript * represents the complex conjugate. Relating this as a new input at the initial transmitter, the output signal after reemission is given by

$$V_{2tr}(\omega) = H(\omega) V_2^*(\omega) = H(\omega) H^* V_1^*(\omega) \qquad (4)$$

Time reversing the last signal, Eq. (4), we have

$$V_{2tr}(\omega) = H^*(\omega) H(\omega) V_1(\omega) (5)$$

Then altering the signal back into the time field

$$V_{2tr}(t) \quad = \quad \frac{1}{2\pi} \int_{-\infty}^{\infty} H^*(\omega) H(\omega) V_1(\omega) e^{-i\omega t} d\omega \qquad (6)$$

If $H(\omega)H^*(\omega) = I(\omega)$ in Eq. (6), the reconstructed signal $V_{2tr}(t)$Would stay identical to the initial input $V_1(t)$.

The inverse filtering (IF) method is founded on the inversion of the transfer function $H^{-1}(\omega)$ later finding out the inversion of transfer function, use of the new input $H^{-1}(\omega)V_2(\omega)$

At the firstsourcewill produce the output signal

$$V_{2IF}(\omega) = H(\omega) H^{-1}(\omega) V_2(\omega) = V_2(\omega) \qquad (7)$$

Where

$$H^{-1}(\omega) = \frac{V_1(\omega)}{V_2(\omega)} \qquad (8)$$

Converting the last signal Eq. (7) back into the time field

$$V_{2IF}(t) = \frac{1}{2\pi} \int_{-\propto}^{\propto} V_1\ (\omega) e^{-i\omega t} d\omega \qquad (9)$$

The last equation recovers the initial input waveforms

II. EXPERIMENT

Experiment were carried out using an aluminium plate of 1.2mm thick,30mm wide and 2mm The system consist of an arbitrary function generator ,a wideband power amplifier send signal to the piezoelectric ,a computer. The generator and oscilloscope were controlled by a computer

III. INVERSE FILTERING

The effects of inverse filtering (IF) method are presented. Gaussian-enveloped signals of five cycles were used as an input source fig.1. The output signal received is shown in Fig. 2. The output signal is composed of very weak S0 mode, main A0 mode, followed by weak signals. Reemission signal through inverse filtering is shown in fig 3.Reconstructed signal after inverse filtering transmission is shown in fig.4, the shape is practically identical to that of the original input

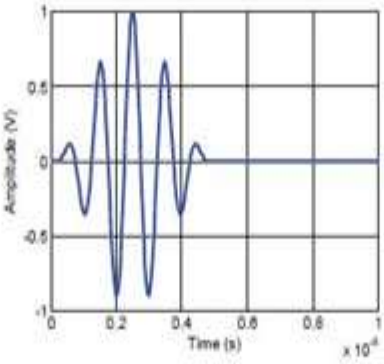

Fig 1. Input signal

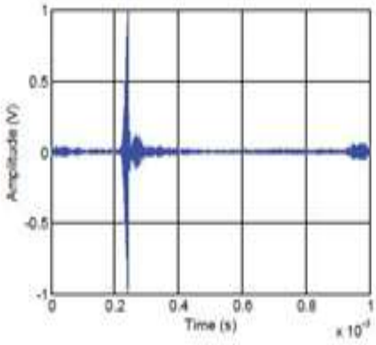

Fig 3.Reconstructed signal through IF

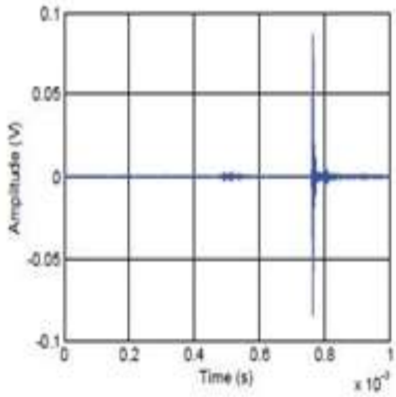

Fig 2.Received signal at the sensor

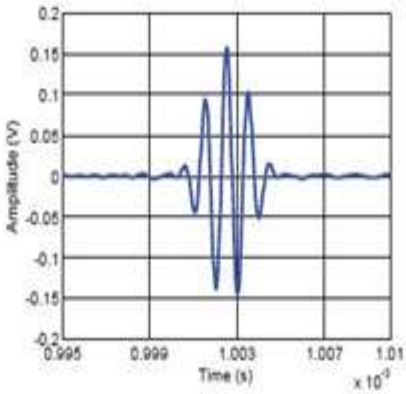

Fig 4.Reconstructed signal after IF

Time reversal technique

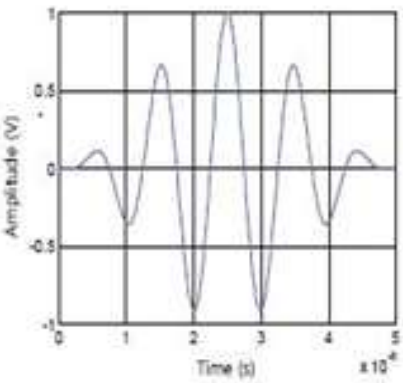

Figure 5. Input signal

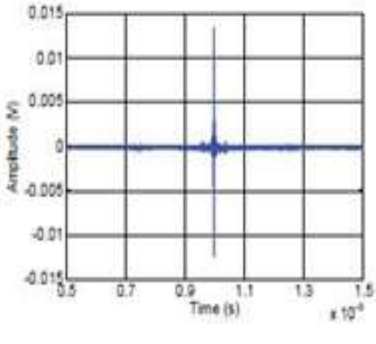

Figure 7. Reconstructed signal after TR

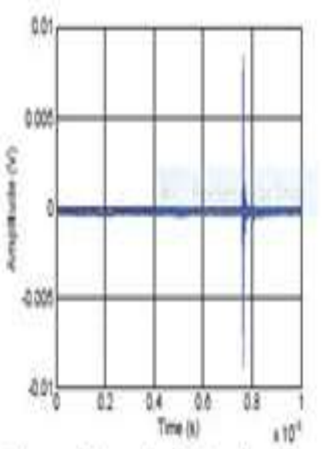

Figure 6.Received signal at the sensor

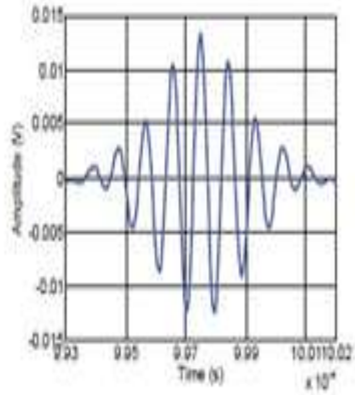

Figure 8.Recontructed signal

Signal with Gaussian envelope and 1MHZ carrier frequency were used as an input source.fig.5.The output signal received is shown in fig.6.The output signal is composed of very weak S_0 mode,main A_0 mode. The received signals were time reversed and reemitted at the initial transmitter. Fig 7 Shown the reconstructed signal after time reversal. The shape of the original pulse is, however, not fully recovered when Time reversal process is used, fig.8.

IV. CONCLUSION

In this paper ,the applicability of the time reversal process to Lamb wave propagation is investigated in order to recovering the initial input waveform in the long range propagation of dispersive lamb waves .Two techniques have been tested: Regular time reversal and inverse filtering. Using time reversal process shown that it does not fully recover the original input signal. Based on the IF approach found that it recovers the original input signal better than the time reversal technique

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