# Ultrasonic Tomography of Guided Wave

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**Abstract**

Ultrasonic guided waves have significant advantages over vibration and impedance methods for structural health monitoring. Presented in this paper is a feasibility study on the visualization of ultrasonic guided wave data. The Lamb wave mode conversion is employed to provide tomography image. The work introduced in here is used to come up with a new feature for guided wave tomography for defect imaging. It is shown that defect location can be successfully predicted by tomography algorithm with the mode conversion data.

**Keyword(s):** Tomography, Guided Waves, Mode conversion.

## 1. Introduction

Nondestructive Evaluation (NDE) technique for detecting hidden corrosion or other damage which exist inside or out side of structures is very crucial to monitor the health of the structure and to predict its remaining life time.

Numerous earlier works have been reported by using various ultrasonic waves such as bulk and guided waves to detect defects of structures in time domain with RF waveform while much less effort has been done for guided wave imaging compared to bulk wave C-scan techniques.

The use of guide wave is well known as a cost and time effective technique over a conventional bulk wave one but it is still needed to be improved as a more quantified NDE tool. The guided wave tomography becomes a promising alternative to convert guided wave raw data obtained from time or frequency domain over to visualized results for better signal interpretation.

This paper addresses a new concept to combine the guided wave tomography with the mode conversion, its unique feature which can not be found in bulk wave inspections.

## 2. Characteristics of Guided Wave mode conversion

This section presented the Lamb wave scattering for the plate-like structures using the Boundary Element Method (BEM) to illustrate how to obtain mode conversion features from defects. The defect defined in plate surface is 0.7mm deep V-notch. From the steel dispersion curvature, the frequency range of 0.244 ~0.756MHz is selected. The frequency band is uniformly divided into 64 sampling data with respect to 0.5MHz center frequency for later time domain data reconstruction via the Inverse Fourier Transformation. The S0 guided wave modes in the above frequency range propagate through the plate with a thickness of 1mm over 100mm as seen in Fig. 1.

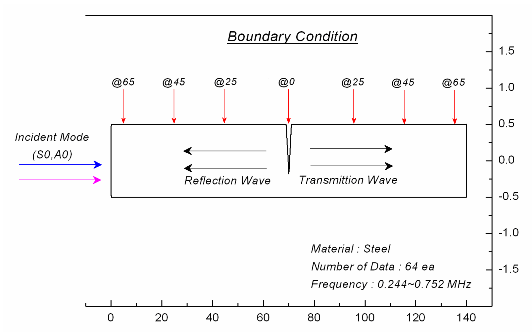


**Fig. 1 BEM model of a plate with V-notch**

Fig. 2 shows that result of IFFT when the incident guided waves interact with defect zone. It turns out that after guided wave scatters at the location of defect, the mode conversion occurs from S0 to A0 as presented in Fig. 2.

Due to the limited propagation distance, the S0 and A0 modes appeared as one wave envelope although the incident S0 mode is clearly separated from the mixed reflected field in Fig. 2.

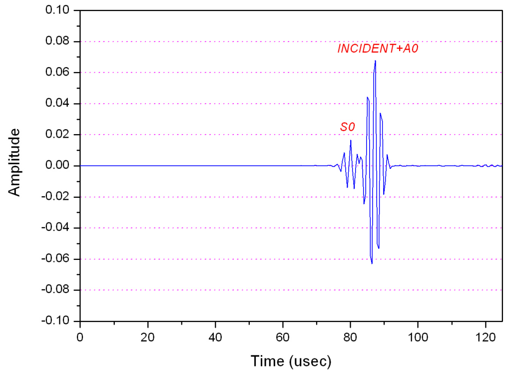


**Fig. 2 The reflected time domain signal for S0 mode incidence at 45mm from defect location**

In addition, S0 wave propagation through the same plate without defect is also simulated to be compared with the mode converted signal in the tomography algorithm as illustrated in Fig. 3. It is shown that no mode conversion takes place.

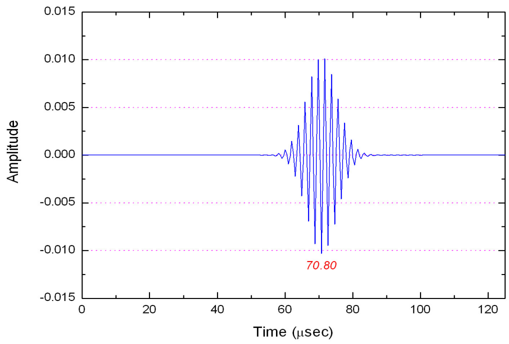


**Fig. 3 S0 Mode propagation result**

## 3. Lamb Wave Tomography

Figs. 4 & 5 show the configuration of ultrasonic tomography with 6 transducers circumferentially placed around the V-shaped defect located in the center.

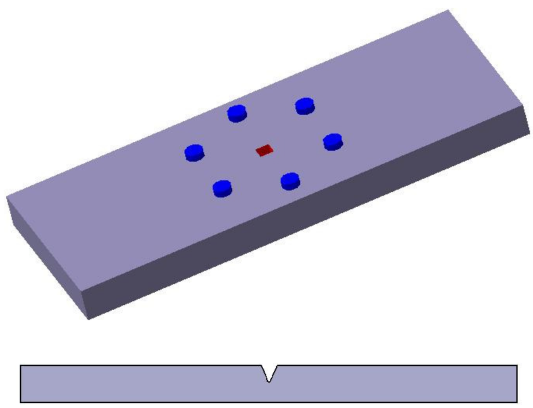

**Fig. 4 A schematic of guided wave tomography model**

In order to obtain the tomography, the reference signal, the S0 mode propagation signal is compared with the scattered one containing the mode conversion from S0 to A0. Each of the transducers is located at different angle around the defect. After collecting the guided wave data along all those paths illustrated in Fig. 5, the signal difference coefficient (SDC) is calculated via the convolution integral between the reference signal and the mode conversion using the following equation. Then, the signal difference values are plotted by the colored data matched with corresponding SDC as shown in Fig. 6.

$$C_{xy}(\tau) = \lim_{T \to \infty} \frac{1}{T} \int_0^T \{x(t) - \mu_x\}\{y(t-\tau) - \mu_y\} dt = R_{xy}(\tau) - \mu_x \mu_y$$

$\mu_x, \mu_y$ : *Mean Value of x, y Data*

$T$ : *Period of The Signal*

$R_{xy}$ : *Cross – Correlation Function*

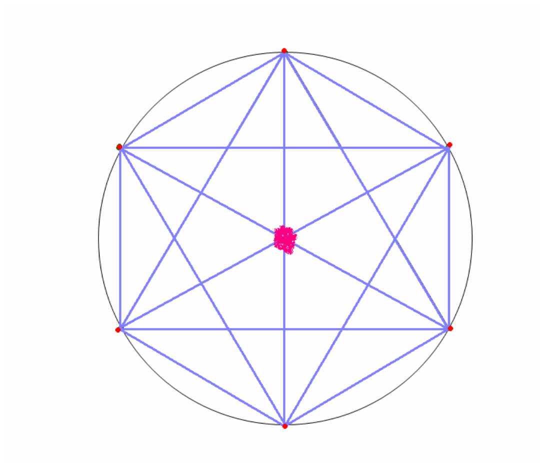

**Fig. 5 The guided wave ray paths in the tomography**

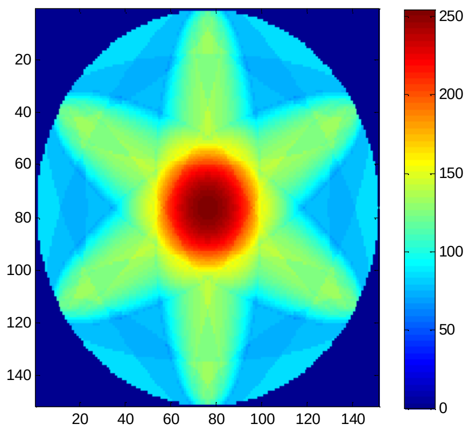

**Fig. 6 The tomography of V-notch located in the middle with 6 transducers**

The resolution can be also improved by increasing the number of transducers as seen in Fig. 7.

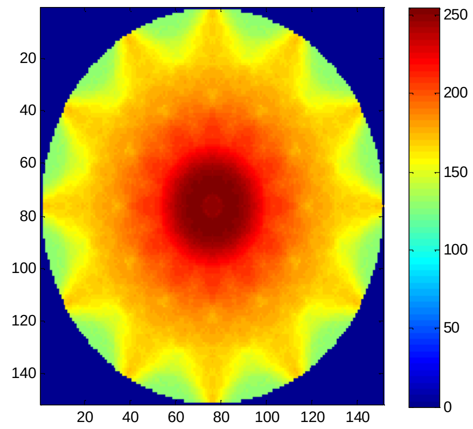


**Fig. 7 The tomography of V-notch located in the middle with 12 transducers**

## 4. Concluding Remarks

This paper investigated the feasibility of combining the ultrasonic guided wave tomography with its mode conversion data. The time domain modeling data for guided wave mode conversion was obtained and employed as the input for subsequent visualization of defects. It turns out that the mode conversion data can be successfully used for defect imaging via tomography algorithm even in the case the defect signal is not clearly separated in time domain. The further study is underway to enhance reliability in analyzing guided wave tomography with respect to feature variation.

## Acknowledgements

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