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# Propagation Behaviors of ASF modes Propagating Along Wedge Tips with Defects

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## Abstract

A combined experimental / numerical investigation employing a laser ultrasound technique and finite element analysis is used to characterize the propagation behaviors of ASF modes propagating along wedge tips with defects. More specifically, reflection coefficient and transmission coefficients are modeled and measured for several of defect depths on the wedge tip. Good agreement is obtained between the modeled and measured reflection and transmission coefficients.

## 1. Introduction

Wedge waves are guided acoustic waves propagating along tip of a wedge [1], [2]. Like Lamb waves, wedge waves with their motion antisymmetric about mid-plane of the wedge is called antisymmetric flexural mode (ASF). Its energy concentrates on the range that leaves the tip about one wavelength. Scholars carried on some research to wedge wave in the past, for example the geometirc of wedge[3] and coating[4]. But its also meaningful that study ASF after meeting defect while propagating will turn into what kind of propagation behavior.

According to different defective situations, when the ASF meets the defect in the course of propagating on the tip of the wedge, the energy of the reflection wave and transmmision wave of the incident ASF wave will be chang. This research will define incident wave, reflection wave and transmmision wave its energy of signal of ASF according to time domain picture of the experiment and analysis result. Use to calculate Reflection Coefficient (RC) and Transmmition Coefficient (TC) of different defect deepth. Besides experiment, this research also uses Finite Element Method (FEM) to analyze, contrasts the experiment and analysis result in order to increase exactness and credibility.

## 2. Experimental parameter and specimen

According to Lagasse[1,2] velocities of ASF mode can be expresses as $V = V_R \sin(n\theta)$ with V as ASF velocity and $V_R$ as Rayleigh velocity, θ as apex angle, and n of any positive integer satisfying $n\theta \leq 90$. In this research the apex angle is 60°. Besides apex angle, the most important experimental parameter is the defect depth in this research. It is the important factor of influencing RC and TC of ASF. In this research use brass for material of wedge and have designed 0.2mm, 0.4mm, 0.6mm, 0.8mm and 1mm five kinds of different defect depths. The detailed experimental parameter is shown in **Table I**.

Table I. experimental parameter

| | |
|---|---|
| Material | brass |
| Apex angle (θ) | 60° |
| Defect depth (H) | 0.2mm, 0.4mm、0.6mm、0.8mm、1mm |
| Defect width (W) | 1mm |

## 3. Laser Ultrasound Technique

This research applies LUT to carry on the experiment, use Nd:YAG pulse laser to generate ASF and the laser interferometer to detect the signal. The experiment setup is shown in **Fig. 1**. The position of generate and detect is shown in **Fig. 2**

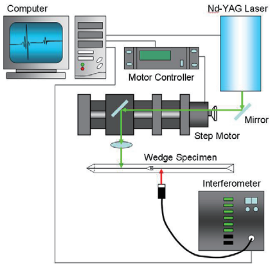

Fig. 1 Experiment setup

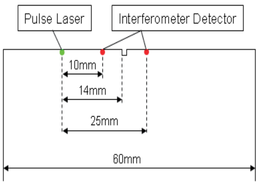

Fig. 2 Position of generate and detect

## 4. Finite element method

Software ABAQUS is used to simulate propagation behaviors in wedges with defect. Using the ABAQUS element library (C3D10M) to partition model, and accord with the formula that Kawashima[5] derives as follows:

$$h/\lambda < 0.06$$

h is the smallest element length, λ is wavelength of the ASF.

Analyze natural frequency at first, in order to confirm model convergence, and define frequency of ASF and imposed diaplacements. And then carry on trensient simulate. The transient analysis result is shown in **Fig. 3**.

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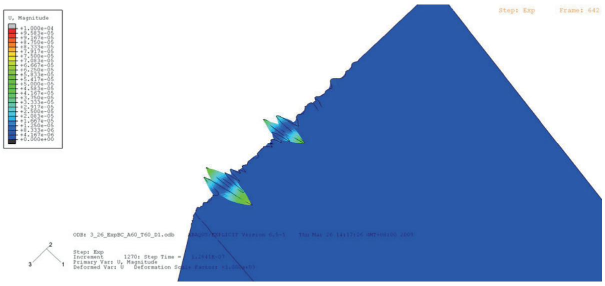

Fig. 3 Result of Transient analysis

## 4. Results

ASF is generated by the pulse laser, and detected by the interferometer. The interferometer laser focus on the front of the defect to detect incident wave (label it for I) and reflection wave (R), and another side to detect transmmision wave (T). According to time domain picture, use peak to peak method to define the the amplitude of the I, R and T signal. RC is the ratio of I to R, and TC is the ratio of I to T.

The 60° wedge allows only one ASF mode to propagate, so there are peaks of $I_{A1}$, $R_{A1}$ and $T_{A1}$ in time domain picture. Its shown in **Fig. 4**. Similarly, **Fig. 5** is FEM analysis result.

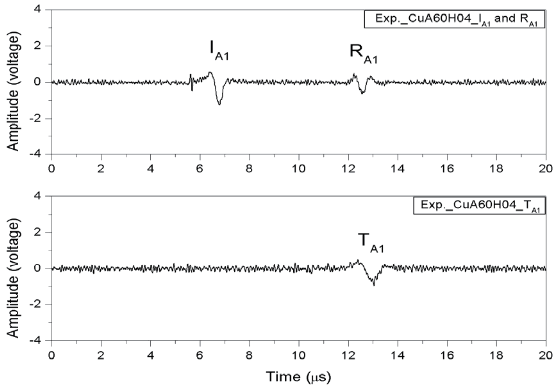

Fig. 4 Time domain signal in experiments

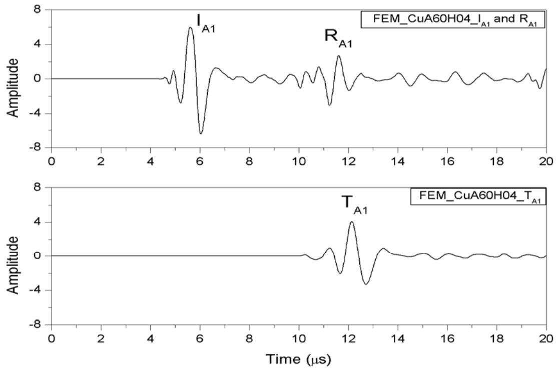

Fig. 5 Time domain signal in FEM

Calculate RC and TC respectively according to the results of experiment and FEM of different defect depths. Its shown in **Tabel II**.

Tabel II. RC and TC of exp. and FEM

| | Experiment | | FEM | |
|---|---|---|---|---|
| Defect depth | RC | TC | RC | TC |
| 1 | 0.72 | 0.18 | 0.76 | 0.13 |
| 0.8 | 0.66 | 0.32 | 0.62 | 0.24 |
| 0.6 | 0.74 | 0.56 | 0.65 | 0.38 |
| 0.4 | 0.63 | 0.83 | 0.48 | 0.63 |
| 0.2 | 0.39 | 0.95 | 0.13 | 0.85 |

Draw the results of experiment and FEM into RT curves as shown in **Fig. 6**. Can observe RC and TC curves cross from RT picture. Prove that RC direct proportional to defect depth, and TC inverse proportion to defect depth.

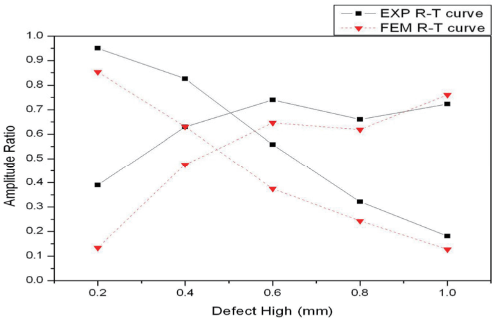

Fig. 6 Reflection and transmission coefficients as a function of defect depth

## 5. Conclusions

Propagation behaviors of ASF modes propagating along wedge tips with various depths of defects are successfully characterized with the laser ultrasound measurements and finite element simulations as well. It is found out that the reflection coefficient decreases as the depth of the defect increases, and vice versa for the transmission coefficient. Results of the current research are potentially useful while condition health monitoring are desired for wedge-like structure such as edge of cutters in automatic machining devices.

## References

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