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Guided waves propagating on the wedge tips with a notch

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Abstract

In this study, the propagation behaviors of acoustic waves propagating along the wedge tips is investigated. Using laser ultrasound technique (LUT) and finite element method (FEM) to characterize the anti-symmetrical flexural (ASF) modes propagation along wedge tips with a small notch. The mode conversion (MC) will emerge when ASF wave encounting a defect on the wedge tip. Reflection coefficients (RC) and transmission coefficients (TC) are obtained and calculated from the simulation and measurement results with different defect depths on the wedge tip.

1. Introduction

Wedge waves are guided acoustic waves propagating along the wedge tip [1,2]. Antisymmetric flexural mode (ASF) are wedge waves with their particle motion antisymmetric about mid-plane of the wedge. The wave energy concentrates on the wedge tip around one wavelength. In the prvious research about wedge waves, different wedge geometry [3] or with different coating [4] are already investigated. In this research, the behavior of wedge waves propagate on the defect is need to be investigated for defect diagnosis on the wedge tip.

Using ultrasonic system to generate and detect ASF signals and simulate the phenomenon by FEM with different defect depth. The energy definition for evaluating the RC and TC, the incident, reflection, and transmission waves are calculated from the amplitude of the center frequency of the signals.

2. Specimen

According to the phenomenon [1, 2], wave velocities of ASF mode can be expresses as $V = V_R \sin(n\theta)$ where V is ASF wave velocity, V_R is Rayleigh wave velocity, θ is apex angle, and n is the order of ASF mode. In this research, the apex angles are 40° and 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 experimental parameters are shown in **Table I**.

Table I. Experiment parameters

Material	Apex angle	Defect depth	Defect width
Brass	40°, 60°	0.2mm, 0.4mm, 0.6mm, 0.8mm, 1mm	1mm

3. Experiment setup

This research applies LUT to carry on the experiments, use transducer 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**

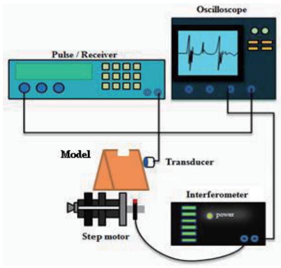

Fig. 1 Experiment setup

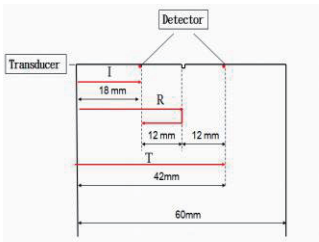

Fig. 2 Position of transducer and detector

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 to the formula that Kawashima[5] derives as follows:

$$h/\lambda < 0.06 \qquad (1)$$

Where 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 displacements. And then carry on transient simulate.

5. Results

ASF is generated by the transducer, and detected by the interferometer. The interferometer laser focus on the front of the defect to detect incident waveand reflection wave (R), and another side to detect transmission wave (T). According to time domain picture, we calculate the peak value to define 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

and 40° wedge allows two ASF modes to propagate, so there are peaks of I, R and T in time domain picture. It's shown in **Fig. 3**. Similarly, **Fig. 4** is FEM analysis result.

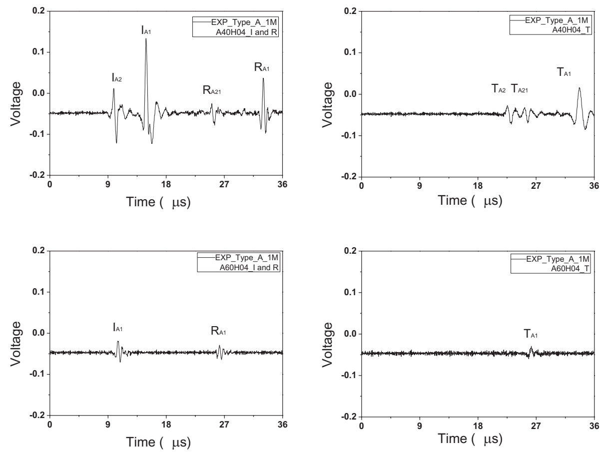

Fig. 3 Time domain signal in experiments

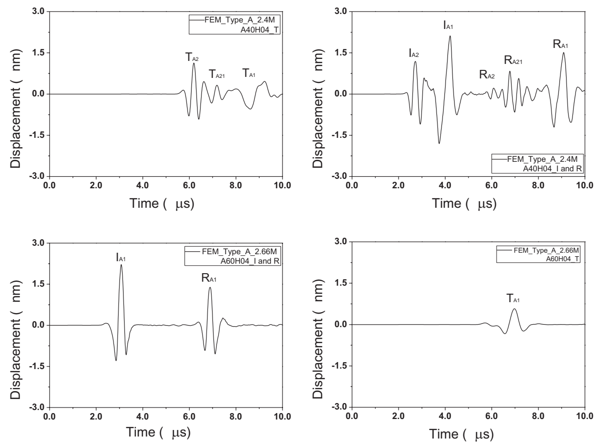

Fig. 4 Time domain signal in FEM

Calculate RC and TC respectively according to the results of experiment and FEM of different defect depths. It's shown in **Table II and Table III**.

Table II. RC and TC of exp. and FEM in 60°

	Defect depth	1	0.8	0.6	0.4	0.2
Experiment	RC	0.024	0.671	0.733	0.693	0.775
	TC	0.969	0.31	0.126	0.393	0.07
FEM	RC	0.27	0.766	0.755	0.675	0.668
	TC	0.74	0.217	0.019	0.02	0.015

Table III. RC and TC of exp. and FEM in 40°

	Defect depth	1	0.8	0.6	0.4	0.2
Experiment	RC	0.103	0.227	0.829	0.778	0.505
	TC	0.747	0.488	0.065	0.095	0.08
FEM	RC	0.264	0.862	0.988	0.879	0.9
	TC	0.758	0.2	0.054	0.02	0.014

Draw the results of experiment and FEM into RT curves as shown in **Fig. 5**. 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.

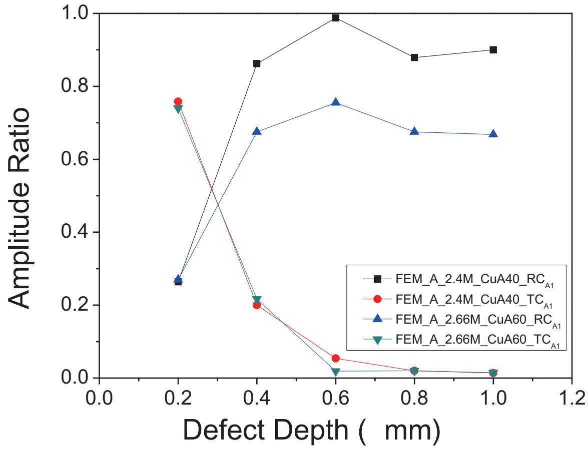

Fig. 5 Reflection and transmission coefficients as a function of defect depth

6. Conclusions

In this research, the behavior of ASF modes propagating along wedge tips with various defect depths are successfully characterized by the ultrasound system and finite element simulation. The phenomenon of mode conversion is investigated from 40° wedge while ASF propagate on the defect on the wedge tip. The A_2 mode will generate the A_1 mode after transmitting or reflecting from the defect. Furthermore, the reflection coefficient will decrease as the increase of defect depth. Contrarily, the transmission coefficient will decrease as the increase of defect depth. 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.

7. References

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