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Numerical Simulation Study on Wedge Elastic Waves Propagating along Sharp Edge

鋭角エッジ先端を伝播するウェッジ波に関する数値シミュレーション

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1. Introduction

There has been an increasing interest in wedge waves propagating along the tip of a sharp elastic wedge because such waves have features that the propagation velocity is slower than the Rayleigh wave velocity and the acoustic energy effectively confines near the tip of the wedge during its propagation [1]. It is also known that the wedge waves are dispersionless for the tip of an ideal infinite elastic wedge and often dispersive for some practical cases such as truncated or modified tips [2]. In addition, there is a number of antisymmetric modes for wedges with wedge angles less than 100 degrees and only one symmetric mode for wedge angle larger than 125 degrees [3]. Wedge waves with such asymmetric modes have large displacement and low energy attenuation when the truncation of the tip is small. Because of such characteristics of wedge waves, it is highly expected to apply wedge waves to measurement devices for nondestructive testing [4, 5]. However, the propagation of wedge waves is not always well understood and the behavior is often unpredictable for practical wedges having various cross-section geometries and materials. To overcome such practical problems, the use of numerical simulation may be much effective because any wedge having arbitrary shape, cross-section and material could be analyzed to examine the propagation behavior of wedge waves. In this work, a three dimensional finite element analysis method (FEM) has been applied to a sharp metal wedge to examine the generation, propagation and characteristics of wedge waves and the feasibility of using the FEM is demonstrated.

2. Method

A three-dimensional voxel-based finite element method (FEM) software commercially available (ComWave™ from ITOCHU Techno-Solution Co.) is used for numerical simulations of wedge wave propagation. **Figure 1** shows a geometrical shape of the wedge model used for the FEM analysis and the detail of the EFM mesh near the tip of the wedge. The length of the waveguide is 75 mm, the wedge angle is 30 degrees and the material is aluminum. Uniform isotropic voxel element is used for the modeling. To ensure successful and accurate wave propagation analysis, the voxel element size is decided to be 50 μm which is less than 1/40 of the shortest wavelength of interest. An *x*-direction displacement in the form of 0.5 MHz raised cosine function (Mexican hat function) is induced to the front surface of the excitation area near the tip of the wedge as shown in Fig. 1 (b) so that wedge waves could be generated and propagate along the tip of the wedge, where the length *L* of the excited area is changed to examine the influence of the *L* on the wedge wave propagation.

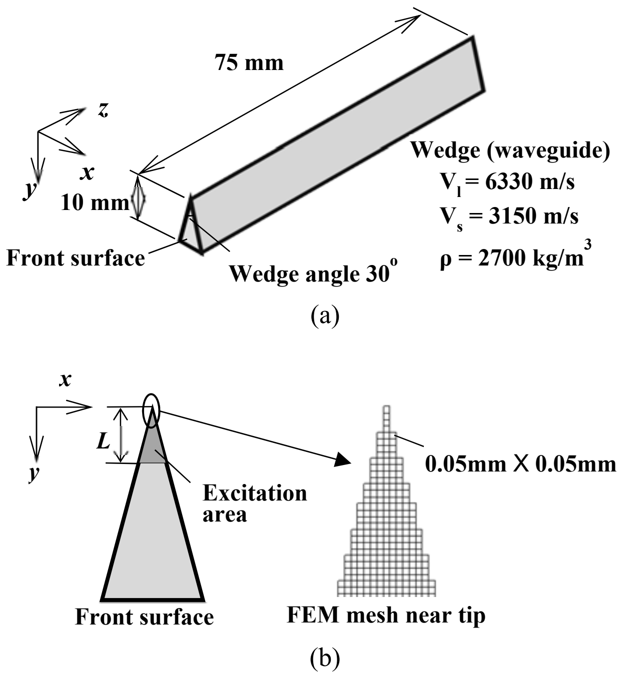

Fig. 1 Wedge model for FEM, (a) Geometrical shape of the wedge and material properties used for the simulation, (b) excitation area of ultrasonic vibration at the front surface and finite element meshes near the tip of the wedge.

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3. Results

A simulation result showing snap shots of displacements in x direction component of ultrasonic waves at 20 μs after the waves are launched is shown in **Figure 2**. As we expected, the displacements effectively confines near the tip of the wedge during its propagation. Thus, wedge waves are successfully generated and propagating along the wedge. In this result, two wedge waves corresponding to mode 1 and mode 2 are clearly observed and a small wave which probably corresponds to the wedge wave of mode 3 is also recognized forward to the mode 2. It should be noted that almost similar results are obtained regardless of the excited length L. **Figure 3** shows progress in the propagating three wedge waves, mode 1, mode 2, and mode 3, as time proceeds. Two distinct wedge waves, mode 1 and 2, are clearly observed. **Figure 4** shows displacement distributions of the wedge waves with normalized distance from the wedge tip, where the displacement is for x direction component and normalized by the maximum, and also the distance is normalized by the wavelength of each mode wave. It has been found that a predominant displacement region of the mode 1 is almost within one wavelength and the predominant region becomes deeper as the mode number increases. It is known that the propagation velocity of wedge waves can approximately be estimated from an empirical formula, the velocity = $v_R \sin(m\theta)$, where v_R is Rayleigh surface wave velocity, m is the mode number, and θ is wedge angle [1]. It has been found that the estimated velocity by the FEM almost agrees with both the estimated value from the empirical equation and measured value, for mode 1. However, there is a discrepancy between them for mode 2.

4. Conclusions

The feasibility of the present FEM analysis to investigate wedge wave propagation has been demonstrated. Although there is a certain discrepancy between the results by experiments and the FEM in quantitative investigations, such numerical simulation could be a useful tool to study of applying wedge waves to nondestructive testing.

Acknowledgment

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References

1. P. E. Lagasse, I. M. Mason, and E. A. Ash: IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-**21**(1973)225.
2. E. S. Sokolova, A. S. Kovalev, R. Timler, and A. P. Mayera: Wave Motion **50** (2013) 233.
3. V. V. Krylov and D. F. Parker: Wave Motion **15** (1992)185.
4. P.-H. Tung, W.-C. Wang, and C.-H. Yang: Proc. Symp. on Ultrasonic Electronics **35**(2014)185.
5. I. Matsuya, T. Yoshimura, Y. Honma, and I. Ihara: to be published in Proc. Symp. on Ultrasonic Electronics **38**(2017).

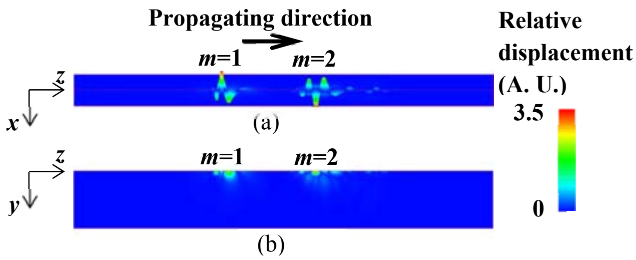

Fig.2 Graphical view in displacement of wedge waves at 20μs after the waves are launched, (a) Top view, (b) Side view.

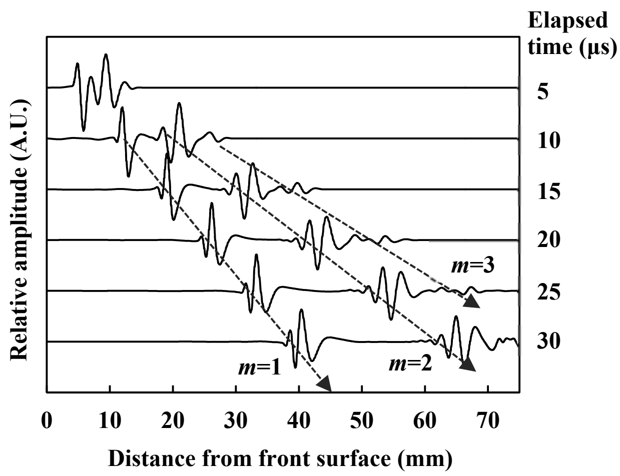

Fig. 3 Propagations of three wedge waves, mode 1, mode 2, and mode 3, as time proceeds.

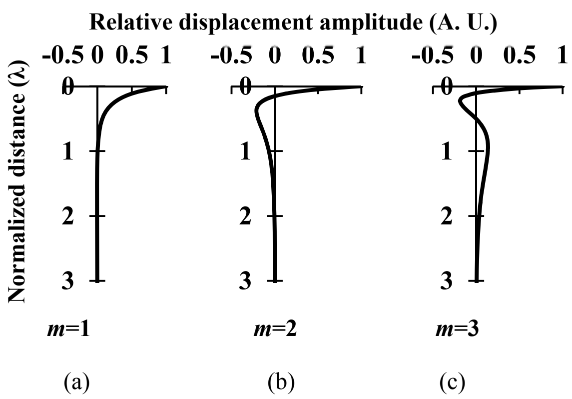

Fig. 4 Displacement distributions of wedge waves with normalized distance for the aluminum wedge, (a) mode 1, (b) mode 2, and (c) mode 3.