論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	BEM Analysis for Guided Wave Scattering by Layered Plate Debonding
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出典(和文)	学位:博士(学術), 学位授与機関:東京工業大学, 報告番号:甲第12256号, 授与年月日:2022年9月22日, 学位の種別:課程博士, 審査員:廣瀬 壮一,WIJEYEWICKREMA ANIL,佐々木 栄一,岩波 光保,髙橋 章浩
Citation(English)	Degree:Doctor (Academic), Conferring organization: Tokyo Institute of Technology, Report number:甲第12256号, Conferred date:2022/9/22, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	要約
Type(English)	Outline

DISSERTATION OUTLINE

Title

BEM Analysis for Guided Wave Scattering by Layered Plate Debonding

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Abstract

This dissertation entitled "BEM Analysis for Guided Wave Scattering by Layered Plate Debonding", studies the scattering behavior in terms of scattering coefficients of guided Lamb and SH waves in two and three-dimensional layered plates with the debonding. The standard boundary element procedure is employed to solve boundary integral equations together with elastodynamic traction and displacement fundamental solutions in the frequency domain. An artificial boundary is introduced at the location far enough from the debonding for the far-field approximation. The wave field is assumed to be expressed as the superposition of incident wave and possible scattered wave modes, and the scattered waves at far-field are approximated by the superposition of propagating modes of guided waves. With the artificial boundary, the traction boundary condition can be expressed as unknown total displacement fields, which must be solved to obtain the scattering coefficients. The results showed that with the change of material properties, location of debonding, and length of debonding, different scattering behavior can be seen including the mode conversion and the resonance phenomena. The unique characteristics of each configuration can be useful for nondestructive testing of ultrasonic guided waves to detect the debonding of layered plate structures.

Dissertation outline

This dissertation is organized into the following six chapters:

Chapter 1: Introduction

In Chapter 1, described are the background and motivation, and also includes a literature review consisting of the general feature of guided waves in non-destructive testing (NDT), advantages and drawbacks compared to traditional ultrasonic testing (UT), and previous research on the scattering problem of guided waves, numerical methods used in the studied such as finite element method (FEM) and boundary element method (BEM). The research objectives, methodology and research procedure, anticipated outcome and contribution, and outline of this dissertation are stated.

Chapter 2: Basic theories of guided waves and boundary element method

Chapter 2 begins with the basic formulations of the equation of motion. The basic theories of two-dimensional guided waves based on the partial waves technique are shown and the boundary element formulations including elastodynamic traction and displacement fundamental solutions in the frequency domain are summarized.

Chapter 3: Scattering analysis for two-dimensional guided Lamb wave by layered plate debonding

In Chapter 3, the computation technique based on the boundary element method for a single plate is extended to calculate scattering coefficients of guided Lamb waves generated by a debonding of a double-layered plate. The accuracy is verified for various configurations by comparison with previous studies, and the examples of calculation results are discussed to find new scattering phenomena seen in a multi-layered plate. The outcomes demonstrated that changing the material constants, location, and length of the debonding can lead to different scattering behavior. Particularly in the bi-material plate, it was discovered that mode conversion was the cause of fluctuations in reflection and transmission coefficients and that frequency shifts had a close relationship to the length of debonding. The results from this study will be useful as reference information on quantitative NDT to detect inner defects of a layered structure.

Chapter 4: Scattering analysis for two-dimensional guided SH wave by layered plate debonding

In Chapter 4, the BEM is applied to the scattering analysis of guided SH waves in a layered plate with a partially debonded interface. The technical approach is almost the same as in Chapter 3 on the scattering analysis of guided Lamb waves. The numerical results of reflection and transmission coefficients are demonstrated with various configurations such as material constants, mode of the incident wave, and location of the debonding over a frequency range up to 4.5 MHz. Like the Lamb wave, it was shown that the incident mode, materials, location, and length of the debonding affected the scattered coefficients. Moreover, the numerical results also suggest the potential of the suitable wave mode for the debonding detection that the first SH-mode is not suitable for the detection of debonding, while the second one allows observing the scattering phenomena, which are sensitive to the length and the position of the defect.

Chapter 5: Scattering analysis for three-dimensional guided wave by layered plate debonding

In Chapter 5, three-dimensional guided wave scattering problems with BEM are shown. The computational technique is based on a two-dimensional boundary element method used in Chapters 3 and 4. The modal wave functions are based on the three-dimensional membrane carrier wave which is formulated based on a carrier wave and superimposed thickness motion. The accuracy is verified with the scattering of a circular through-plate hole problem, and the examples of results are demonstrated with a circular debonding problem. It was shown that the material difference affected the scattered coefficients with mode conversion phenomena but requires more numbers with a higher order of elements in order to obtain more accurate and convergent results.

Chapter 6: Conclusions and recommendations

In Chapter 6, all finds obtained in this dissertation are summarized, followed by a recommendation for further study.

The outline can be summarized as the following chart.