GUIDED WAVE PROPAGATION IN PLATE HAVING TRUSSED STRUCTURES

LEE BOON SHING

Universiti Teknologi Malaysia

GUIDED WAVE PROPAGATION IN PLATE HAVING TRUSSED STRUCTURES

LEE BOON SHING

A project report submitted in partial fulfillment
of the requirements for the award of the degree of
Master of Engineering (Mechanical)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

January 2013

To my beloved family and friends,

ACKNOWLEDGEMENT

I would like to express my gratitude to my project supervisor, Dr. -Ing. Zair Asrar, who has been guided me throughout this project, for his constant and unconditional support, advice and encouragement during my difficulties in getting results and completion of this project.

Besides, special thanks to my friends, Chew Lai Yen and Lim Fei Min, for their morale support and shared my problem patiently. They had given me some inspiration in finishing this project with full courage.

Last but not least, I feel grateful to my family members that had supported me and their encouraging, making me to finish this academic with full of effort.

ABSTRACT

Guided wave method is one of the methods in Non-Destructive Testing (NDT) for crack detection. The Lamb wave is the common guided wave that is used for NDT. In this RESEARCH, the determination of the dispersion curves of plate having trussed structures could help to reduce the computational time for simulating solid plate. Hence, here the connections of the solid plate to the plate having trussed structures are studied and the possibilities of simplification of the solid plate using the plate having trussed structures are looked into. The Finite Element Method (FEM) is used to simulate the structures proposed and by using Matlab, the space time domain displacement data are transformed into wave number-frequency domain, which is the dispersion curve, by using 2-Dimensional Fast Fourier Transform (2D FFT). The finite element software package used is ABAQUS. The results obtained are compared to the analytical solution of an isotropic plate. It is found that the geometries that could best approximated an isotropic plate is the cross geometry. However, only the anti-symmetric mode curves for the cross geometry has a good correlation with the analytical solution. By simplifying the solid plate as plate having trussed structures, the simulation time can be reduced.

ABSTRAK

Kaedah gelombang berpandu merupakan salah satu kaedah yang digunakan dalam NDT untuk mengesan keretakan dalam suatu bahan. Gelombang Lamb merupakan salah satu jenis gelombang yang paling biasa digunakan dalam NDT. Dalam penyelidikan ini, lengkung serakan bagi plat yang mempunyai geometri yang berbeza dan struktur begini boleh membantu dalam mengurangkan masa simulasi untuk plat biasa. Oleh itu, gelombang serakan yang diperoleh dapat digunakan untuk mengkaji persamaan antara plat isotop dengan plat yang mempunyai geometri yang berbeza dan dapat menentukan sama ada plat yang mempunyai geometri yang berbeza boleh disamakan dengan plat isotop. Kaedah FEM digunakan untuk simulasi struktur yang dicadangkan, kemudian data yang diperoleh daripada ABAQUS akan ditukarkan kepada lengkung serakan dengan menggunakan 2D FFT. Keputusan yang diperoleh akan dibandingkan dengan kaedah penyelesaian secara analisis bagi plat isotop. Daripada keputusan yang diperoleh, didapati bahawa geometri yang boleh dihampirkan dengan plat isotop ialah geometri silang. Akan tetapi, hanya mod anti-simmetri sahaja yang mempunyai lengkung serakan yang paling hampir dengan lengkung serakan yang diperoleh secara penyelesaian secara analisis. Melalui simplifikasi bagi plat isotop dengan menggunakan plat yang mempunyai geometri yang berbeza, masa simulasi dapat dikurangkan.

CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

λ	-	Wavelength
A	-	Amplitude
v	-	Velocity
f	-	Frequency
ø	-	Angle
v_L	-	Incident wave's velocity
v_P	-	Desired Lamb waves phase velocity
h	-	Thickness of plate
k	-	Wave number
ω	-	Angular frequency
C_L	-	Velocity of longitudinal modes
C_T	-	Velocity of transverse/shear modes
E	-	Young's Modulus of medium
C_p	-	Phase velocity
C_g	-	Group velocity
A_i	-	Anti-symmetric mode (i=0,1,2,…)
S_i	-	Symmetric mode (i=0,1,2,…)
FEM	-	Finite Element Method
FFT	-	Fast Fourier Transform
u	-	Displacement of guided wave
n	-	number of cycles

LIST OF APPENDIX

UNIVERSITI TEKNOLOGI MALAYSIA

DECLARATION OF THESIS / UNDERGRADUATE PROJECT PAPER AND COPYRIGHT

Author's full name : **LEE BOON SHING**

Date of birth : **25 JANUARY 1988**

Title : **GUIDED WAVE PROPAGATION IN PLATE HAVING TRUSSED STRUCTURES**

Academic Session : **2010/2011**

I declare that this thesis is classified as :

☐	**CONFIDENTIAL**	(Contains confidential information under the Official Secret Act 1972)*
☐	**RESTRICTED**	(Contains restricted information as specified by the organization where research was done)*
✓	**OPEN ACCESS**	I agree that my thesis to be published as online open access (full text)

I acknowledged that Universiti Teknologi Malaysia reserves the right as follows :

1. The thesis is the property of Universiti Teknologi Malaysia.
2. The Library of Universiti Teknologi Malaysia has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by :

SIGNATURE	SIGNATURE OF SUPERVISOR
880125-09-5188	**DR. ING ZAIR ASRAR**
(NEW IC NO. /~~PASSPORT NO~~.)	NAME OF SUPERVISOR
Date :	Date :

NOTES : * If this thesis is CONFIDENTIAL or RESTRICTED ,please attach with the letter from the organization with period and reasons for confidentiality or restriction.

CHAPTER I

INTRODUCTION

1.1 Background of Study

There are several methods that can be used in non-destructive testing (NDT) for the detection of crack inside a material, such as eddy current distribution, magnetic particle method, optical method, and guided wave method. Each of these methods has their own strengths and weaknesses. In the guided wave method, an ultrasonic wave is used as source to generate waves that propagate along the material in a long distance.

Nowadays, many methods have been developed to monitor the behaviour of guided waves inside thin plates. The behaviour of the guided wave is referred to the modes that propagated through the entire plate. The analytical solution and the numerical solution for the behaviour of the guided wave inside the isotropic material can be obtained easily by referring to the publications. From the behaviour of guided waves in the plate, the results can be transformed into frequency domain by using Fast Fourier Transform (FFT) to obtain the dispersion curves. Many methods can be used to determine the dispersion curves of the plates, such as Finite Element Method (FEM), Semi-Analytical Finite Element (SAFE) [1], Scaled Boundary Finite Element Method [2], and others numerical simulation methods.

In the study of properties and behaviour of waves in isotropic plates, the most common wave used is the Lamb wave. Lamb waves are useful for detection of cracks in thin sheet materials and tabular products as they are sensitive to damage due to the high frequency oscillations. However, Lamb wave is highly dispersive.

1.2 Statement of Problem

Most of the research done concentrated on the isotropic plates. Different methods to obtain the dispersion curve either using analytical and numerical solutions. However, the guided wave in plate having trussed structure has not been looked into. Thus in this study, the numerical method is used to obtain and monitor the behaviour of the guided waves in plate having trussed structures, as they are difficult to analyzed analytically.

1.3 Objectives of Study

There are three objectives of this study, which are:-

i. To determine the dispersion curves of plate having the trussed structures.
ii. To study the connection to the solid plate by comparing the dispersion curves of isotropic plates with the plate having proposed trussed structure proposed.
iii. To find if there are any possibilities for simplification of solid plate using plate having trussed structure.

1.4 Scope of Study

The limitations in this study includes:-

i. The determination of the dispersion curve for isotropic plates having the trussed structure in two dimensional (2D).

ii. Three dimensional plate having trussed structure such as honeycomb plate is not considered.
iii. Only thin plate is considered.
iv. The finite element method is applied using the commercial package, ABAQUS.

1.5 Significance of Study

Most commonly plate having trussed structure is referred to honeycomb sandwich plate. Some research has also been done on the bridge structure which is made from trussed geometry. However, there are lacks of research on the plate with trussed structures. The numerical method has been used to study these structures but the dispersion curve of plates having trussed structure is not yet available.

In this project, the determination of the dispersion curves for plates having trussed structures by numerical method is made. From this study, the dispersion curve of plates having trussed structure can be obtained and compare with the dispersion curve of isotropic plates. This comparison can be used to identify if a plate having trussed structure could be used to approximate an isotropic plate. Thus, the simplification of the analysis of solid plate using plate having trussed structure could be made.

REFERENCES

1. Lin, Z., Akira Kasai, and Yoshito Itoh, *Dispersion Curves Computation for Waveguides Buried in Infinite Space by Semi-Analytical Finite Element Method*, Procedia Engineering 10, 1615-1620, Elsevier, 2011.
2. Hauke Gravenkamp, Song, C, Jens Prager, *A Numerical Approach for the Computation of Dispersion Relations for Plate Structures Using the Scaled Boundary Finite Element Method*, Jounal of Sound and Vibration 331, 2543-2557, Elsevier, 2012.
3. Blitz. J., *Ultrasonics: Methods and Applications,* London: Butterworths, 1971.
4. Thomas K., *Acoustic Surface and Acousto-optic Devises*, New York: Original from University of Michigan, Optosonic Press, 1971.
5. Su, Z., and Ye, L., *Identification of Damage Using Lamb Waves, From Fundamentals to Applications*, Springer-Verlag Berlin Heidelberg, 2009
6. Olson, S.E., Derriso, M.M., DeSimio, M.P., and Thomas, D.T., *Analytical Modelling Of Lamb Waves for Structural Health Monitoring*, Proceedings of the 3rd European Workshop on Structural Health Monitoring, Granada, Spain, 5-7 July, 2006.
7. Stefen S., Nicolae C., Mircea G., Viorel A., *Extraction Of Dispersion Curves For Wave Propagating In Free Complex Waveguides By Standard Finite Element Codes*, University "Politehnica" of Bucharest, Ultrasonic 51, 503-515, Elsevier, 2010.
8. Z.A.B Ahmad, *Numerical Simulations of Lamb Waves in Plates Using a Semi-Analytical Finite Element Method*, VDI Verlag GmbH, 2011.
9. David R., *Finite Element Analysis*, Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, 2001.
10. David N. Alleyne and Peter Cawley, *A 2-Dimensional Fourier Transform Method for the Quantitative Measurement of Lamb Modes*, Ultrasonic Symposium, 1143-1146, IEEE, 1990.
11. Li, J., Liu, S., *The Aplication of Time-Frequency Transform in Mode Identification of Lamb Waves*, 17th World Conference on non-destructive Testing, Shanghai, China, 2008.