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GUIDED WAVE PROPAGATION IN PLATE HAVING TRUSSED STRUCTURES

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ABSTRACT

The guided wave structural monitoring system relies heavily on the known guided wave behaviour in the waveguides. These behaviours are commonly obtained from the dispersion curves. For isotropic plates, analytical expression for the dispersion curves exist. The same dispersion curves can be obtained experimentally or by using finite element method (FEM) with fine meshes. Hence, the FEM simulation approach requires high computation cost. A preliminary study is made in this contribution to simplify the simulation of solid isotropic plate as simulation of plates having trussed structures. By doing so, the computational requirement in the FEM simulation would greatly be reduced. To gauge the effectiveness of the proposed approach, the dispersion curves of plate having trussed structures is obtained from the FEM simulation. The result is then used to find the connection between the solid plate and the plate having trussed structures and the possibilities of simplifying the FEM simulation. The comparison made with analytical result revealed that the best approximation comes from cross geometry truss structure. However, good correlation is observed only for anti-symmetric mode.

Keywords : *guided wave, Lamb wave, plate with trussed structures, dispersion curves.*

1. INTRODUCTION

In the structural health monitoring (SHM) field, guided wave application has gain a lot of interest as it can propagate along the thickness of the plate for relatively long distances compared to traditional non destructive technique i.e ultrasonic technique. In isotropic plates, the in plane guided wave is called Lamb wave while the uncoupled out of plane wave is called the shear/Love wave. As Lamb wave propagates through the whole thickness of the plate, they are useful for detecting cracks, delaminations and other in-plate damages. The detectable damage size depends on the wave frequency. However, the main challenges in applying these waves for SHM are their multi modal and dispersive behaviour [1]. These behaviours are depicted by the dispersion curves. Analytical expression for these curves is available only for isotropic plates. Experimental method can be used to obtain the dispersion cuves although only some of the modes can be detected. On the other hand, numerical methods can be used to determine the dipersion curves for general plates, i.e the matrix methods (i.e global matrix method and transfer matrix method), the finite element method (FEM), the boundary element method and the semi-analytical finite element (SAFE) [2-4]. Since they are no available analytical solution for plate having trussed structure, numerical method is used to obtain and monitor the behaviour of the guided waves in plate having trussed structures. In this study the plate is simulated using finite element method in ABAQUS and the resulting displacements are used to plot the dispersion curves using 2D fast fourier transform [5]. Once the dispersion

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curves of plates having the trussed structure are obtained, the connection with the solid plate is studied by comparing their dispersion curves. Several shapes of truss structure geometry are proposed. Finally, from the dispersion curve comparison, the possibility of replacing the solid isotropic plate with plate having trussed structure is looked into.

2. MODELLING AND SIMULATION

Two dimensional FEM simulation is used to determine the dispersion curves. The geometry of the solid plate and plates having trussed structure are first created in ABAQUS. The material of the plates is set to be Aluminium, with the mass density ρ = 2700kg/m^3, the Young's modulus E = 70GPa , and the Poison's ratio σ = 0.3. The length and thickness of the plate is l = 0.5m and t = 1x10^{-3}m, respectively. The force is applied along the U2-direction and the distance between the symmetric boundary condition and the force is set at 5x10^{-3}m. The distance between the monitoring points is a = 1x10^{-3}m which is equal-distance for each points. The total distance of first monitoring point and last monitoring point must long enough for the observation of the guided wave behaviour. In modelling the solid plate, four node 2D square elements with the size of 1x10^{-4}m x 1x10^{-4}m are used. On the other hand, 2D beam element is used for modelling the truss structure.The model of the plate is shown in Figure 1.

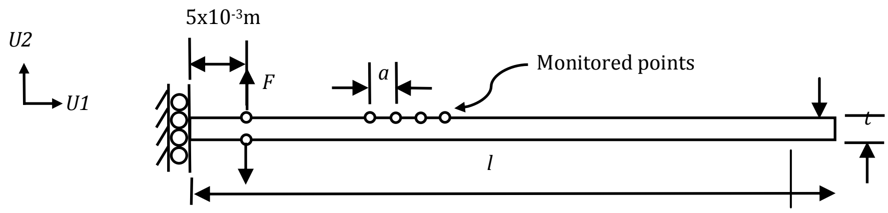

Figure 1: The dimension of the plate. Shown with symmetric point force excitation to induce symmetric modes. Symmetric boundary condition is enforced at the plate end nearest to the applied force.

The analysis of the guided wave propagation behaviour along the structures can be done and monitored at different point. Along the monitored point, the behaviour of the guided wave may be different. Hence, several monitored points can be chosen in order to monitor the behaviour of the guided wave inside the material. The chosen points must not contain the reflection of the wave from the plate end. When the reflection is included in the data, the output will be affected as additional modes due to reflection will be present. The truss structure geometry being proposed in this work is shown in Figure 2. Each truss geometries shown in Figure 2 is excited with both anti-symmetric and symmetric modes through controlling the point forces applied. Anti-symmetric mode is being excited when both point forces act along the same direction while symmetric mode is being excited if the point forces act along the opposite direction. In this work, 200 kHz tone burst in being used for the excitation point force, hence, only the fundamental symmetric mode, S_0 and anti-symmetric mode, A_0 are being excited in the plate. The 2D fast Fourier transform (FFT) is used to convert the monitored point displacement data from the time-space domain into the frequency-wave number domain. In the plot of the 2D FFT curves, the axes are the wave number, the frequency, and the amplitude. Hence, by plotting the top view of the 2D FFT curve, the dispersion curves can be obtained with wave number, k, and frequency, f as its axes.

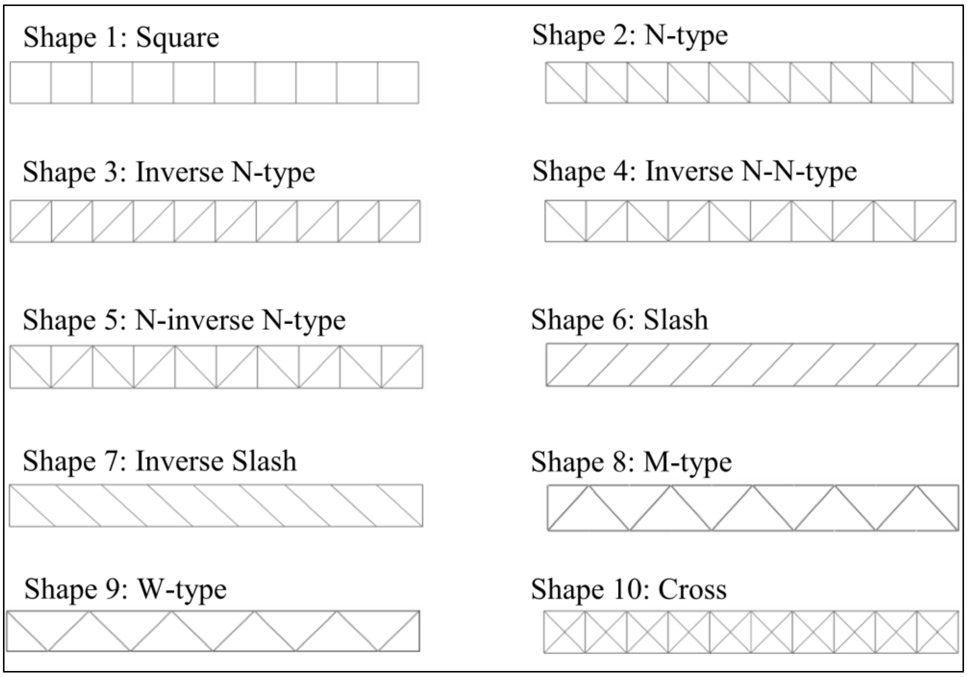

Figure 2: The typical truss geometries being studied in this work.

3. RESULTS AND DISCUSSIONS

There are ten types of typical truss geometries being chosen in this work. From the FEM simulation in ABAQUS, the displacement data in time domain for the monitored points is plotted. From these plots, the monitored points that have no reflection from the plate edge are considered for calculating the dispersion curves. Figure 3 shows an example of the 2D FFT results for the cross geometry truss structure. The displacement at the distance of 60mm away from the plate end is used.

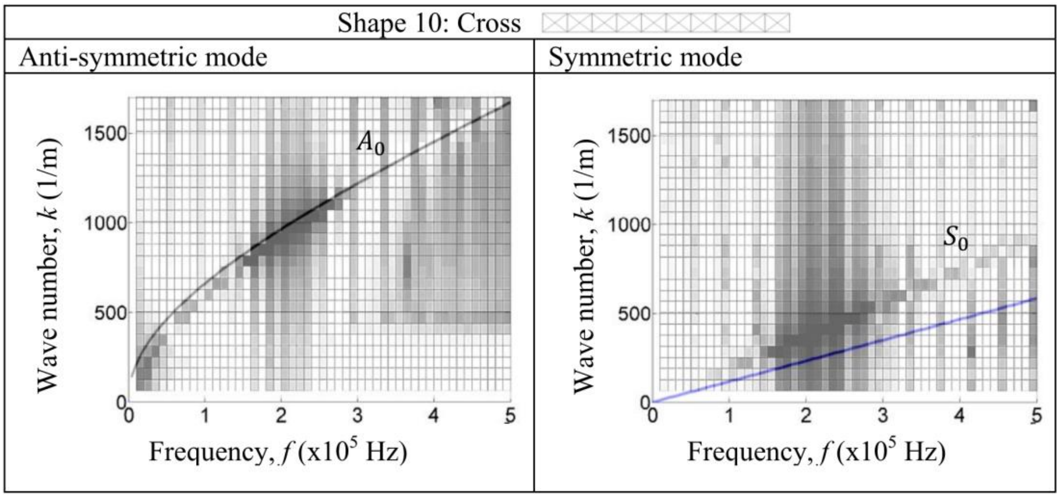

Figure 3: The dispersion curves of plate having trussed structure with cross geometry.

The dispersion curves of plates having trussed structure is compared to the dispersion curves of the solid plate (analytical solution) to check for any similarity on the dispersion curves for both plates. There are some similarities in the dispersion curves for the truss geometry of shape 2 (N-type), shape 3 (inverse N-type), shape 4 (inverse N-N-type), shape 5 (N-inverse N-type), shape 8 (M-type), shape 9 (W-type), and shape 10 (cross) for the anti-symmetric A_0 mode. From these comparison, the shape 10 (cross) has the most similar dispersion curves with the analytical solution of the solid plate. Although shape 8 and shape 9 also have a similar curve lines with the analytical solution, their errors are bigger compared to shape 10. For shapes 2, 3, 4, and 5, their dispersion curves are almost similar only at the frequency of 200 kHz. Based on the dispersion curve results obtained, good approximation to the analytical solution for the plates having trussed structures are coming from the plates with geometry of square type (shape 1), M-type (shape 8), W-type (shape 9), and cross type (shape 10). These four types of truss geometries may be used as a simplification of solid isotropic plate for further numerical analysis. Nevertheless, shape 10 (cross) gives the best approximation for the simplification of solid plate by using plate having trussed structure, as shown in the Figure 3. However the approximation is good only for the anti-symmetric mode. The symmetric mode curve obtained does not correlate well with the analytical solution. The time needed to simulate the plates having trussed structures is much shorter compared to the solid isotropic plate. Therefore the plate having cross geometry trussed structure can be a viable alternative at least to approximate the anti-symmetric mode A_0 dispersion curve of a solid isotropic plate.

4. CONCLUSIONS

From the results, the plates having trussed structures are compared to the solid isotropic plate in order to find the connection between the solid plate to the plates having trussed structures. In this project, there are some similarities of the dispersion curves of plates having trussed structure to the solid isotropic plate. The plates having trussed structures with geometry of square type, M-type, W-type, and cross type can be used to a certain degree to approximate the solid isotropic plate. It shown that the cross geometry trussed structure give the best approximation for the solid isotropic plate dispersion curves, but valid only for anti-symmetric mode. When the solid plate is simplified as a plate having trussed structure, the time taken to obtain the dispersion curves can be shorten considerably.

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