Jurnal Mekanikal
June 2013, No 36, 94-101

GUIDED WAVE PROPAGATION ON LOADED PLATE

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ABSTRACT

During in-situ monitoring, structures are exposed to load changes which may mask the damage-induced signal or produced false alarm unless compensation is performed. Studies on guided wave propagation due to symmetrical load have been done by previous researchers, so this research is concentrated on asymmetrical load applied to infinite, thin aluminium plate with thickness of 1mm using Abaqus done in two-dimensional mesh. There is no analytical solution for loaded plate so dispersion curve provided by semi-analytical finite element (SAFE) method is used for verification purpose. Excitation force is set to 100kHz due to effects of load only occurred at low frequency region. Wave propagation's speed is increased with increases of strain values applied on plate under extensional because stiffness of plate also increased but this condition didn't work for plate under bending. Results of Abaqus in space-time domain able to provide obvious difference between various load applied on plate but not 2D FFT curves. Center frequency of excitation force cannot set lower which is the limitation of this finite element method.

Keywords: *Guided wave propagation, loaded plate, symmetrical, asymmetrical, wave's velocity*

1.0 INTRODUCTION

Guided wave structure health monitoring is a concern due to its difficulty to abstract accurate and reliable response from the complex signal of real structure with complex geometry and boundary conditions. The signal induced by damage can be smaller than the original signal which doubles the difficulty to study the signals. During in-situ monitoring, structures are exposed to load variety which are unavoidable. Besides, load changes may mask the damage-induced signal or produced false alarm unless compensation is performed. Hence, effects of load on guided wave propagation have become the concern in this research [1, 2]. Effects of load only obvious at low frequency region and negligible at high frequency region [3]. Beside, effects of load only obvious at A_0 mode means its effects on others' modes can be neglected [3].

There is no analytical solution for studying the behaviors of wave propagations on loaded plate. Therefore, in this research, finite element method will be used to study the behaviors of guided wave propagations for loaded plates.

The objective of this research is to study, discuss and analyze the behaviors of guided wave propagation under uni-axial load and bending conditions. The second objective is to test for the limitations of this finite element method on study of effects of load on plate. This research studies the effects of (symmetrical and asymmetrical) load on infinite, thin aluminium plate with thickness of 1mm using Abaqus simulation done in two-dimensional mesh. Thin piezoelectric transducer is applied in this research.

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Several researches on effects of load to rod, plate or rail have been done by earlier researchers which only concentrated on axial load. In this research, effects of asymmetrical load to guided wave propagation on plate which is the significant of our study since the load applied to structure is asymmetric in practical application.

2.0 VERIFICATION OF FINITE ELEMENT METHOD

Since there is no analytical solution for loaded plate, dispersion curve provided by SAFE method [4] used to verify procedures in this finite element method. Dispersion curve of wavenumber versus frequency provided by SAFE method [4] using Matlab software is overlaped with 2D FFT curve obtained from Abaqus (FE method) for plate under extensional with 0.1% strain (7e7 Pa). It shown that both curves are intersect perfectly and hence verified the procedures in this finite element method using Abaqus. The finite element analysis will be continued for plate under assymmetrical load.

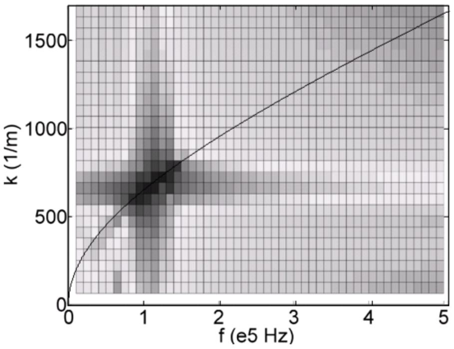


Figure 1 : Overlaping of dispersion curve provided by SAFE method [3] and Abaqus software (straight line represented those from SAFE)

3.0 FINITE ELEMENT METHOD

Finite element method is done using Abaqus. However, result obtained from Abaqus is in space-time domain, cannot be directly to overlap with SAFE solution which is in frequency domain for verification purpose. It required two dimensional Fast Fourier Transform (2D FFT) to convert it into frequency domain. There are several dispersion curves in literature review such as phase velocity-frequency, group velocity-frequency and wavenumber-frequency domain. However, wavenumber-frequency dispersion curve is the easiest dispersion curve to extract from Abaqus space-time domain curve. After the verification of procedures for finite element method, simulations in Abaqus continued for loaded plate in order to study the guided wave propagation in loaded plate. The modeling of loaded plate in Abaqus are shown in Figure 2 to Figure 6. The length of plate modeling under extensional is 250 mm and under bending is 500 mm. The monitored points interval, e is 1mm with 101 monitored points from distance between monitored point and excitation force, d=50 mm to 150 mm. The excitation force set at 100kHz because effects of load only obvious at low frequency region [3]. Only A_0 mode is excited due to effects of load on others' mode are negligible [3]. Finite element analysis of loaded plate consists of static step and explicit step. After simulation of static step, all data measured are exported to explicit step.

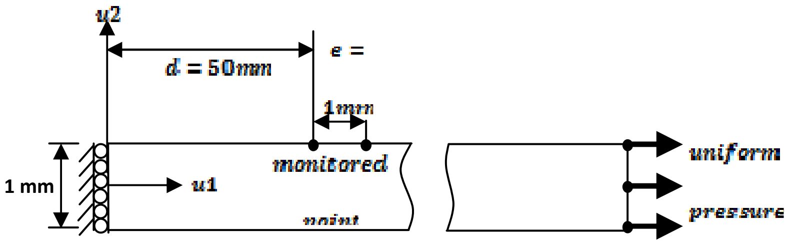


Figure 2: Plate under extensional in Static step with uniform pressure pulling outward.

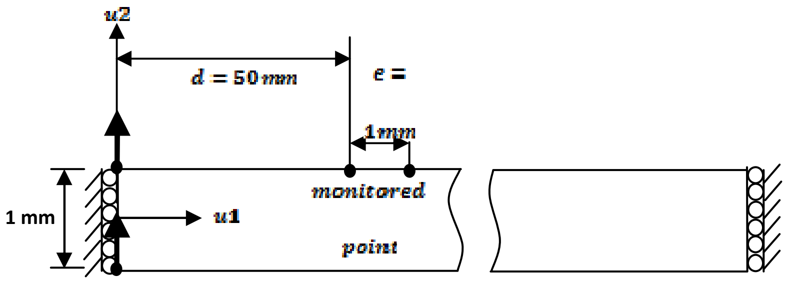


Figure 3: Plate under extensional in Explicit step with Antisymmetrical, A_0 mode as excitation force

Two different bending patterns are tested in this research if the pattern differences would cause any differences in the wave propagation on plate as shown in Figure 4 and Figure 5.

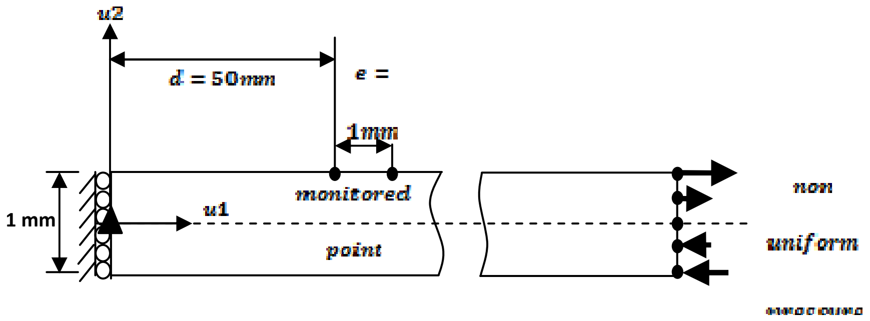


Figure 4: Plate under bending in Static step with asymetrical pressure applied.

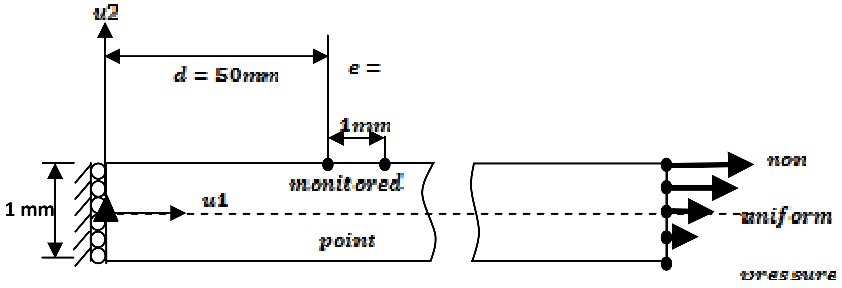


Figure 5: Plate under bending in Static step with asymetrical pressure applied.

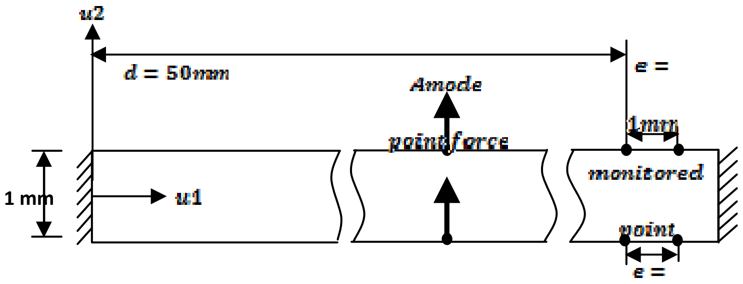


Figure 6: Plate under bending in Explicit step with Antisymmetrical mode, A_0 as excitation force

4.0 RESULTS AND DISCUSSIONS

Results obtained directly from Abaqus is in space-time domain as shown in Figure 7 to Figure 9. Figure 7 provided zoom views at one of the peak of U1 amplitude in time domain for plate under unload and extensional. Travelling of wave is very smooth and in order. Wave propagation's speed increases with strain values applied on plate. The 0.1% strain line (7e7 Pa) always leading all the other lines due to its highest strain value, followed by 0.08% strain (56e6 Pa) line, 0.06% strain (42e6 Pa) line, 0.04% strain (28e6 Pa) line, 0.01% strain line (7e6 Pa) and 0% strain line (unload). Figure 8 shown that wave propagation's speed didn't increase with strain values for plate under bending (pattern in Figure 4) with pressure values of 1e3 Pa (0.00000143% strain), 1e4 Pa (0.0000143% strain), 91e4 Pa (0.0013% strain), 98e4 Pa (0.0014% strain) and 1.08e6 Pa (0.00154% strain).

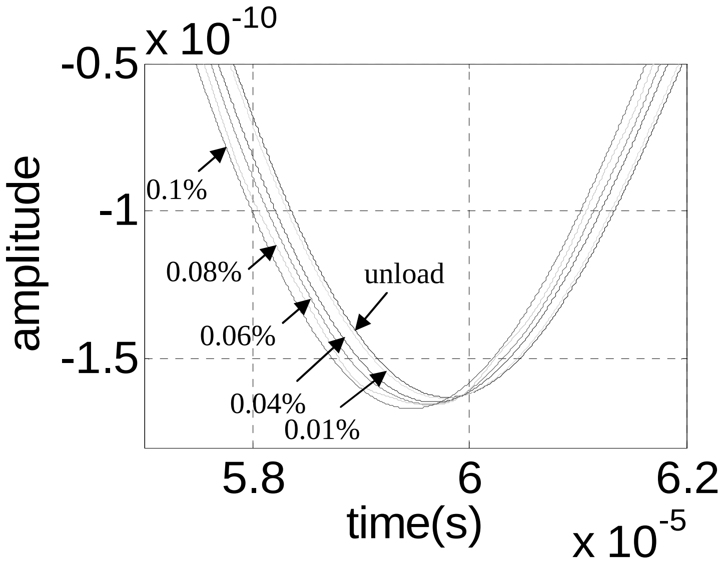


Figure 7: Zoom views of U1 peaks amplitude in time domain for plate under no load and plate under extensional with various strain values at d=50mm

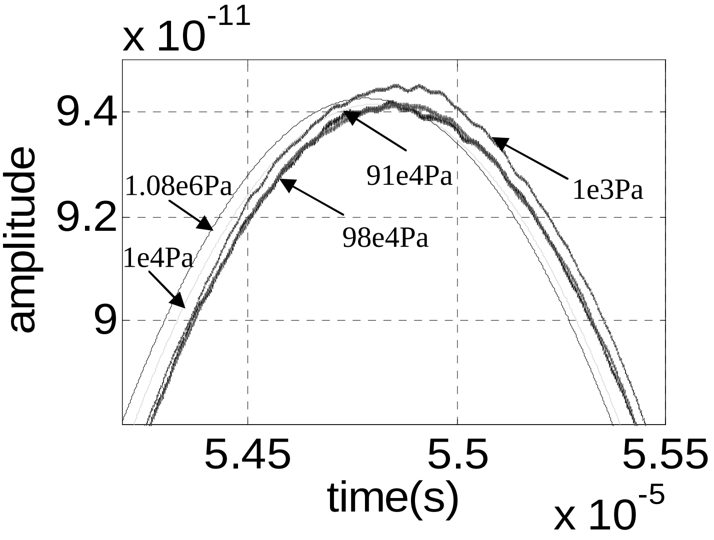


Figure 8: Zoom views of U1 peaks amplitude in time domain for plate under bending (pattern in Figure 4) with various strain values at d=50mm

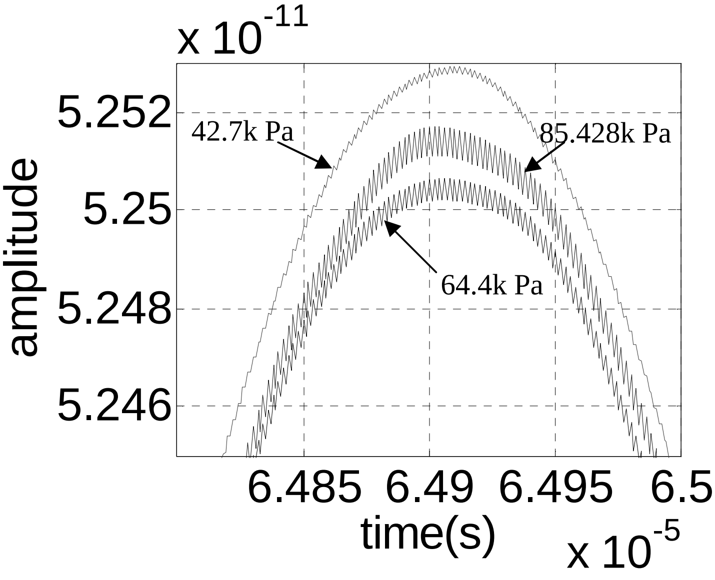


Figure 9: Zoom views of U1 peaks amplitude in time domain for plate under bending (pattern in Figure 5) with various strain values at d=50mm

Figure 9 shown that wave propagation's speed didn't increase with strain values for plate under bending (pattern in Figure 5) with pressure values of 42.7 kPa (0.000061% strain), 64.4 kPa(0.000092% strain) and 85.428 kPa (0.000122% strain). Plate under bending initially contains stress all along the plate and hence caused the signals to have some noise for certain strain.

Results obtained from Abaqus in space-time domain exported to Matlab for 2D FFT which transform data to dispersion curve in wavenumber-frequency domain. Dispersion curves for plate under extensional and bending with various strain values are similar with each other as shown in Figure 10 and Figure 11. The difference between dispersion curves for these strain values are not obvious due to excitation frequency is not low enough as compare to theory. And, FE excitation force frequency cannot be set lower anymore due to the limitation of this finite element method.

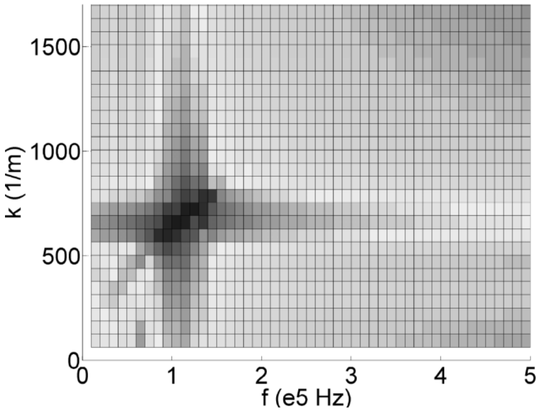
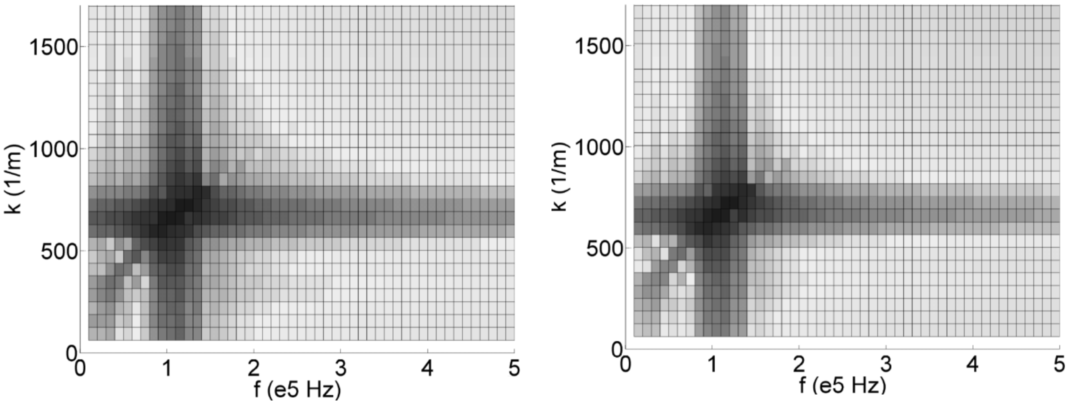


Figure 10: Amode Dispersion curve of wavenumber, k (1/m) versus Frequency, f (Hz) for plate under extensional with 0.1% strain (7e7 Pa)



(a) (b)

Figure 11: Amode Dispersion curve of wavenumber, k (1/m) versus Frequency, f (Hz) for plate under bending (a) pattern in Figure 4 with 1.08e6 Pa (0.00154% strain) and (b) pattern in Fgure 5 with 85.428k Pa (0.000122% strain)

5.0 CONCLUSIONS

Wave propagation’s speed is increased with increases of strain values for plate under extensional. It is because stiffness of the plate increased during strain applied on plate is increased uniformly, and hence increase the wave propagation’s speed. Wave propagation’s speed didn’t increased with increases of strain values for plate under bending. Due to theoretical dispersion curves, effects of load on wave propagation only can observed in low frequency region [4]. Hence, center frequency of excitation force is set at 100kHz in order to observe the load effects on wave propagation. Results of Abaqus in space-time domain able to provide obvious difference for various strain values. However, 2D FFT curves unable to provide differences. Center frequency of excitation force lower than 100kHz cannot be used due to unable to provide any information about the analysis. Hence, this is the limitation of this finite element method. For future research, this finite element procedures could be continued for 3D simple model such as loaded rod and loaded plate. The analysis for loaded rod could be used to compare with analytical solution of beam model. The analysis for loaded plate could be continued for 3D plate under torsion.

ACKNOWLEDGEMENTS

The author, CLY would like to express his sincerest appreciation to his supervisor, Dr Zair Asrar bin Ahmad for the guidance and supports throughout the whole research and thesis writing.

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