COMPUTATIONAL MECHANICS 2011
27th conference with international participation
Pilsen
November 7 - 9, 2011

# Lamb wave interaction with simulated defects, finite element modeling

P. Hora, O. Červená

*Institute of Thermomechanics of the ASCR, v.v.i., Veleslavínova 11, 301 14 Plzeň, Czech Republic*

The possibility to proof the structural integrity without removing its individual components has become an important technology challenge. The most commonly used nondestructive testing methods are visual inspection, radiography, ultrasonics, and thermography. The most of those methods is not suitable for implementation into a smart structure. Methods that require scanning of large areas are not available as the basis of self-diagnostic systems. To perform the inspection by those methods, direct human intervention is needed. The built-in sensors would be continuously inspected the structural integrity. Therefore, methods that can operate from fixed locations in the structure while inspecting large areas are key candidates for the structural integrity monitoring system.

The Lamb wave method is attractive technique for the structural integrity monitoring system. The Lamb waves in plates, also termed guided waves, can be used as a potential solution for large-area nondestructive inspection of plate-like objects. They are able to travel relatively long distances. Therefore, the material between transmitter and receiver can be inspected. Hence, a line scan is achieved with each pulse rather than the comparatively slower point-scanning performance of conventional ultrasonic pulse-echo technique. This method involves the analysis of the transmitted and/or reflected wave after interacting with the test part at boundaries or discontinuities. The presence of damage is identified when the response signal of subsequent tests deviates from the reference response of the undamaged configuration taken earlier in the structures life [2].

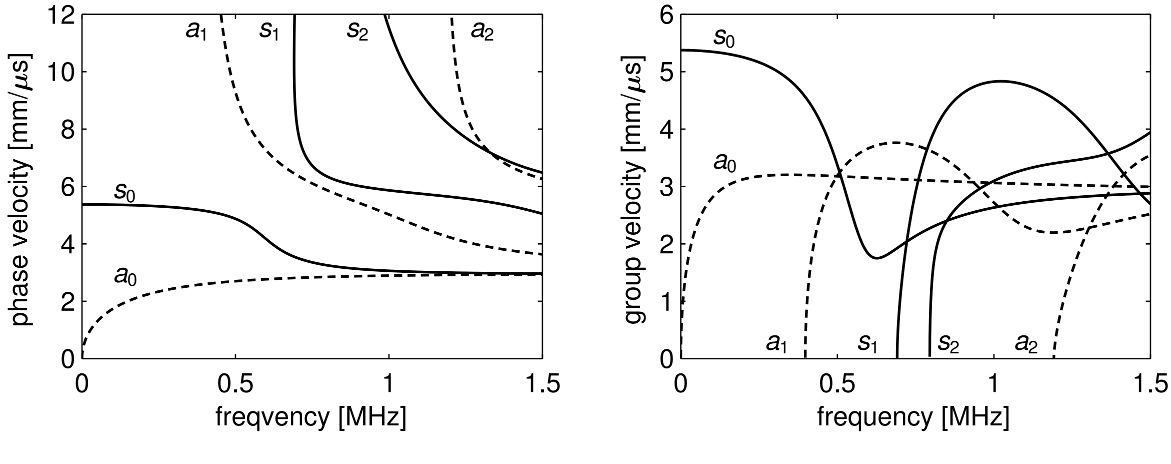


Fig. 1 The velocity dispersion curves for 4 mm thick steel plate; symmetric modes (solid), antisymmetric modes (dashed).

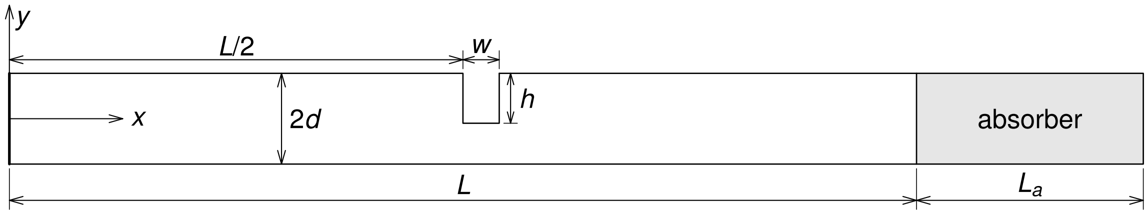


Fig. 2 The plate geometry and the used coordinate system.

Complications encountered in applying Lamb waves include the existence of multiple modes and the dispersive character of the modes. The calculated dispersion curves [4] of 4 mm thick steel plate for phase and group velocities are shown in fig. 1.

Contribution deals with finite element (FE) modeling of Lamb wave interaction with simulated defects. The FE modeling is used to predict the behavior of Lamb waves to idealized defects. In all cases the vertical displacements are obtained since this displacement is measured in experimental tests.

The analyzed steel plate is $2d = 4$ mm thick and $L = 120$ mm long. The $L_a = 20$ mm long absorbing part is appended to main plate [1]. The notch, $h$ depth and $w$ width, is located on the top of the plate at distance $L/2 = 60$ mm. The plate geometry with notch location and the used coordinate system are shown in fig. 2. FE calculations are performed in the commercial environment COMSOL Multiphysics with the Structural Mechanics Module [3]. The plane strain is used as an application mode. The mapped squared mesh with size of elements $0.5 \times 0.5$ mm is created. Elements are the Lagrange–Quadratic type. On the left edge of this plate is set exciting constraint. The exciting pulse is specified by table. The others edges are free. The FE results have been analyzed using the 2D-FT method in MATLAB [5].

The results have shown that sensitivity of individual Lamb waves to particular notches is dependent on the frequency, the plate thickness, the mode type (symmetric or antisymmetric), the mode order, and the geometry of the notch. The sensitivity of the Lamb modes to simulated defects in different frequency regions has been determined as a function of the defect depth and the plate thickness ratio. The results have indicated that the Lamb wave method may be used, when the notch depth to wavelength ratio is about one half. The tests on notches of different widths have indicated that the transmission and reflection amplitudes are insensitive to changes in width. This was caused by the small width of notch in comparison with the wavelength.

## Acknowledgements

The work has been supported by the Institute Research Plan AV0Z20760514 and by the grants GA CR No 101/09/1630.

## References

[1] Castaings, M., Bacon, C., Hosten, B., Finite element predictions for the dynamic response of two thermo–viscoelastic material structures, J. Acoust. Soc. Am. 115 (3) (2004) 1125–1133.

[2] Chimenti, D.E., Guided waves in plates and their use in materials characterization, Appl. Mech Rev. 50 (5) (1997) 247–284.

[3] COMSOL, Inc., http://www.comsol.com

[4] Graff, K.F., Wave motion in elastic solids, Dover, New York, 1991.

[5] The MathWorks, Inc., http://www.mathworks.com