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FEM SIMULATION OF AN INTEGRATED LONGITUDINAL AND TANGENTIAL WAVE PROBE

P. Hora*, **O. Červená****

Abstract: *The aim of contribution is the finite element modeling of integrated longitudinal and shear wave probe. This type of probe was investigated by Cheng-Kuei Jen and Makiko Kobayashi in Jen (2007). Finite element calculations are performed in the commercial environment COMSOL Multiphysics. The ultrasonic transducer excitation was modeled as total force load. The received ultrasonic signal was obtained by integration of velocities at place of ultrasonic transducer. Though these simplifications the resulting ultrasonic signals are in good agreement with results presented by Cheng-Kuei Jen and Makiko Kobayashi.*

Keywords: ***Ultrasonic probe, FEM modeling.***

1. Introduction

Various efforts have been devoted to the development of piezoelectric UTs of large bandwidth and high efficiency and they may be supplied by several companies. However, it is understood that S waves may be advantageous over P waves for NDT and characterization of materials because liquid and gas medium do not support S waves. In addition, for the evaluation of material properties, sometimes it is important to measure shear modulus and viscoelastic properties in which S wave properties are a requisite. Furthermore, a UT setup to generate and receive both P and S waves at the same sensor location would be also of interest.

The P wave UT together with P-S mode conversion caused by the reflection at a solid-air interface can be effectively used as a S wave probe. In this study, a steel with the P wave velocity c_1 = 5770.8 m/s and S wave velocity c_2 = 3138.5 m/s at room temperature was used as the substrate. The maximum energy conversion rate from the P wave to the PS wave is 97.8% at the angle of incidence α = 67.3°, and the reduction of the energy conversion rate is within 1% in the α range between 60.8° and 73.0°. By considering this criterion, $\alpha + \beta$ is required to be 90°, see Fig. 1a). From the Snells law we can obtain α = 61.46°. At this angle, the conversion rate is 97.03% that is only 0.79% smaller than the maximum conversion rate at 67.3°. Therefore, Fig. 1a) shows the schematic design developed for this study. In Fig. 1b) the schematic diagram of an integrated P wave UT probe with the P wave UT is located in a plane parallel to the direction of PP wave where α = 45° is shown. In Jen (2007) is shown, how to generate and receive both P and S waves at the same time. The S wave probe shown in Fig. 1a) can be modified to achieve such a purpose. In fact, it simply makes a slanted surface with an angle 45° from the intersection of the slanted plane and the line from the center of the P UT as shown in Fig. 1c). The 45° angle plane will reflect the energy of the P wave into the PP_{45} wave normal to the probing end as shown in Fig. 1c). Therefore, in principle, the upper part of the P wave, generated from P UT, can be used to produce the PS wave and the lower part to produce the PP_{45} wave.

2. FEM modeling

FEM modeling was performed for all three cases of probes depicted in Fig. 1. FE time dependent calculations are performed in the commercial environment COMSOL Multiphysics with the Structural Mechanics Module, COMSOL (2012). The plane strain was used as an application mode.

*Doc. Ing. Petr Hora, CSc.: Institute of Thermomechanics AS CR, v. v. i., Dolejškova 1402/5; 182 00, Prague; CZ, e-mail: hora@cdm.it.cas.cz

**RNDr. Olga Červená: Institute of Thermomechanics AS CR, v. v. i., Dolejškova 1402/5; 182 00, Prague; CZ, e-mail: cervena@cdm.it.cas.cz

The probe width was 16 mm and middle of P UT was located at 20 mm from probe end for each cases. The P UT size was 6 mm. The steel with Young's modulus 200 GPa, Poisson's ratio 0.29 and density 7870 kg/m^3 was chosen as the substrate material of probe. The quadrilateral mapped mesh with maximal element edge 0.2 mm is created. Elements are the Lagrange–Quadratic type. Number of elements for case a) and c) was 9760, for case b) was 11200. Number of degrees of freedom for case a) and c) was 78890, for case b) 90482. The P UT was modeled as total force load in x-direction. The others edges were free. Calculations were done in time interval from 0 to 30 μs with time step 0.01 μs. Relative tolerance of solution was 1×10^{-4}, absolute tolerance 1×10^{-8}. Method BDF with maximum BDF order equals to 2 was used for this time analysis. The received ultrasonic signal was obtained by integration of velocities at place of ultrasonic transducer.

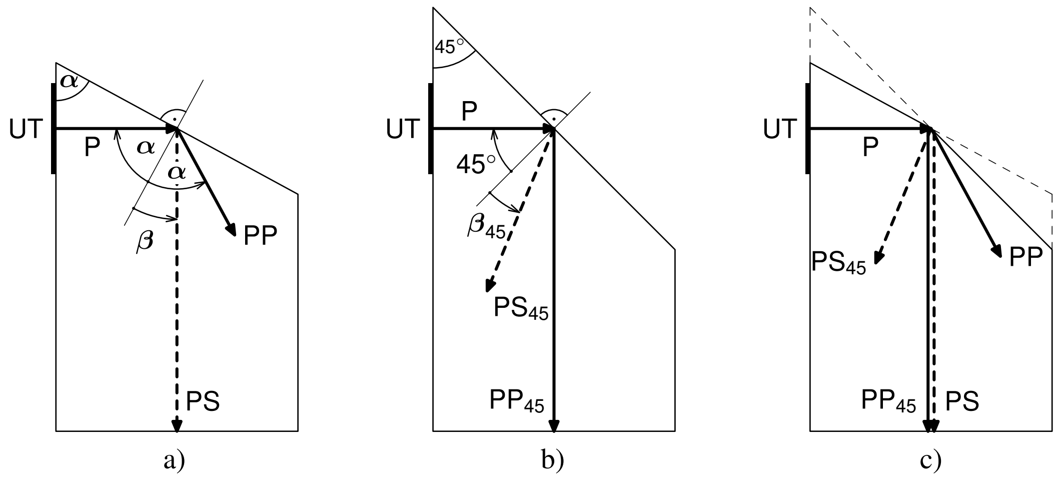

Fig. 1: Cases of the studied ultrasonic probes.

3. Conclusions

The contribution deals with the finite element modeling of integrated longitudinal and shear wave probe that was described by Cheng-Kuei Jen and Makiko Kobayashi. Finite element calculations were performed for three cases of probes: the first one used the reflected S wave, the second one the reflected P wave and the third one used both S wave and P wave. The ultrasonic transducer excitation was modeled as total force load. The integration of velocities at place of ultrasonic transducer was used as the received ultrasonic signal.

The effect of the reflected PP wave for cases a) and c) is negligible due to the low value of the energy reflection coefficient $R_{PP} \approx 3\%$ for given angle of incidence α = 61.46°. The influence of the reflected PS_{45} wave for cases b) and c) is insignificant because of the dimension of the substrate has been chosen so that the reflected PS_{45} wave from the probing end does not enter into the aperture of the P UT. Though some simplifications the results are in good agreement with work of Cheng-Kuei Jen and Makiko Kobayashi. The analyze of the P UT size and location will be our further aim. The area of the P UT will be adjusted so that the amplitudes of the reflected PS and PP_{45} waves will be nearly the same.

Acknowledgments

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