Theoretical and experimental investigation of Lamb waves induced by bonded and debonded piezoelectric actuators in a plate with a delamination

Alisa N. Shpak*, Mikhail V. Golub*, Artem Eremin*, Inka Müller♯,

Jens Kathol† and Claus-Peter Fritzen†

* Institute for Mathematics, Mechanics and Informatics, Kuban State University
350040 Krasnodar, Russian Federation
e-mail: alisashpak7@gmail.com; m_golub@inbox.ru; eremin_a_87@mail.ru

♯ Department of Civil and Environmental Engineering, Ruhr-Universität Bochum
44801 Bochum, Germany
e-mail: inka.mueller@ruhr-uni-bochum.de

† Department of Mechanical Engineering and Center of Sensor Systems (ZESS), University of Siegen
57068 Siegen, Germany
e-mail: jens.kathol@uni-siegen.de; claus-peter.fritzen@uni-siegen.de

ABSTRACT

Active ultrasonic Structural Health Monitoring (SHM) systems rely on elastic guided waves (GWs) as a physical principle for structure inspection. Frequently, they employ a distributed network of surface-mounted piezoelectric wafer active sensors (PWAS) for GW excitation and detection. Since GWs are altered by all kinds of structural damages, the corresponding PWAS-recorded signals after certain postprocessing are used for the estimation of the defect presence and might allow its localization and extent evaluation. To enhance these capabilities of SHM systems, preliminary numerical analysis of the corresponding wave phenomena is essential. Here, along with the investigation of single pure GW mode interaction with various defect types, studies of multimode PWAS-induced signal changing are also important. Moreover, the PWAS itself might become a source of imperfections during the structure life-cycle, i.e., its cracking or partial debonding could have a non-negligible effect on the performance of the SHM system. The latter should be also properly addressed in simulations. In the current talk we present the results of theoretical and experimental investigations of PWAS-induced Lamb wave propagation and scattering by a horizontal delamination in a layered elastic structure. The boundary integral equation method is used to simulate wave propagation and diffraction by the specified obstacle type. It is coupled with the frequency domain spectral element method, which is employed to model dynamic behaviour of the PWAS considering possible degradation of the contact between the transducer and the waveguide. The combination of these two methods allows for the detailed parametric analysis of the wave phenomena in the layered structure due to partially debonded PWAS [1] and in the presence of delamination.

Experimental investigations of the debonded PWAS dynamic interaction with the layered plate, containing a horizontal delamination, have been conducted for several damage scenarios. They include various mutual locations between the PWAS and the defect, increasing severity of PWAS debonding and its position regarding the contact area, etc. A good agreement between experimental and theoretical results is demonstrated. Electro-mechanical impedance was measured in order to reveal eigenfrequencies of the transducers itself and in contact with a layered plate [2]. The developed mathematical model is employed to analyse various resonance phenomena, which arise due to partial PWAS debonding and the presence of the delamination. The mutual influence of these two factors on complex eigenfrequencies is illustrated and confirmed experimentally.

The work is supported by the Ministry of Science and Education of the Russian Federation (Project № 9.1022.2017).

REFERENCES

[1] M.V. Golub and A.N. Shpak, “Semi-analytical hybrid approach for the simulation of layered waveguide with a partially debonded piezoelectric structure”, *Appl. Math. Model.*, Vol. **65**, pp. 234–255, (2019).

[2] I. Mueller and C.-P. Fritzen, “Inspection of Piezoceramic Transducers Used for Structural Health Monitoring”, *Materials*, Vol. **10(1)**: 71, (2017).