SIMULATION AND EXPERIMENTAL VERIFCATION OF DAMAGE DETECTION USING ULTRASONIC LAMB WAVES

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Today there is a rapid development of structural health monitoring (SHM) which is based on the evaluation of various structural parameters using embedded sensor system. The registered data after digital processing can provide useful information about the presence of damages, material degradation, etc. Recent papers show the increasing interest to ultrasonic guided waves for SHM. But in order to design robust SHM systems sophisticated algorithms of damage detection are to be developed. One of the powerful methods of data processing is using of artificial neural networks which should be trained for exact structural application. For extensive training one should perform large amount of experimental testing with different location, type and severity of damages that is very time consuming and expensive. These experiments can be replaced with simulation using computer models. But in order to provide reliable data the models should be carefully tuned and verified. The paper present the results of finite element method simulation of Lamb wave testing of aluminum panel.

The aluminum panel with a size of 500x500 mm and 3 mm thick was simulated using ABAQUS software and explicit solver. The maximum size of the element was 1 mm resulting in the formation of the mesh with 3-elements through thickness. The network of actuator-sensor system consisted of 4×4 transducers which are modeled as a set of elements on the surface of the panel. Each set can be used either an actuator or a sensor resulting in 132 actuator-sensor pairs obtained for the 4×4 network. Hanning window-modulated 5-cycle sine wave was used as a testing signal; there were 3 frequencies: 50, 100 and 200 kHz. The sensor response was measured as a plot of ε_{zz} stress component by time. After the simulation of the pristine aluminum panel the damaged one was simulated as well. The damages were 1 mm wide cracks with the length of 5, 15 and 25 mm. Then the obtained signals were analyzed using previously developed software based on the analysis of attenuation of ultrasonic waves due to emergence of damage. In order to assess the state of tested object one should compare registered signals for initial (baseline) and damaged states for each actuator-sensor pair using following parameters: *dA* – difference of envelopes and *dP* – difference of Fourier spectrum energy.

Baseline and damaged states are compared in the software to calculate location and severity of damage. For each actuator-sensor pair *dA* and *dP* are calculated and sorted in ascending order thus the pairs with the highest decrease of amplitude or energy are in the upper part of the list. Then *N* pairs (paths) are selected from the top of the list and used for damage location procedure. After the paths are chosen the intersection points are found. For each pair of paths there is no more than one intersection point having its weight equal to product of *dA* or *dP* of two paths producing this intersection. Damage location is calculated as mean of the obtained intersection points: $r = \Sigma\, r_i \cdot w_i \,/\, \Sigma\, w_i$, where r_i and w_i are coordinates and weight of *i*-th intersection point. Damage index $DI = \Sigma\, w_i, / n$, where *n* is a number of intersection points, describes the severity of the damage: the higher the index the more the damage is severe.

The results of location of the crack are presented and discussed in terms of accuracy of detection and sensitivity to the damage severity.

Acknowledgements
This work was performed within the frame of the Fundamental Research Program of the State Academies of Sciences for 2013-2020, line of research III.23 and with a partial support of RF President Council Grant for the support of leading research schools NSh-5875.2018.8.