DESCRIPTION FOR THE GENERAL PUBLIC

Engineering structures undergo gradual destruction in the course of time as a result of static and dynamic loading, temperature changes, humidity, wind or corrosive factors. Degradation of mechanical properties of structural elements of buildings, installations, machines, vehicles or aircrafts under the influence of different types of service loads may lead to catastrophic failure of a whole structure, which is associated with the risk to human health or life and to the environment. To ensure the safety and the reliability of engineering structures, early detection and localization of potential damage is necessary. Therefore assessment of the condition state of structures becomes a very important subject of research. Connections of structural elements are places of particular importance. Due to the abrupt changes in stiffness, stress concentration, difficulties in performing or susceptibility to corrosion, joints are places that are the most vulnerable to damage and they are the most common cause of failure. Evaluation of health condition of connections of structural elements is very important in the context of the reliability and durability of a whole structure.

The advance in experimental methods, measuring equipment as well as digital signal processing technology allows the development of systems for accurate diagnosis and monitoring of structural elements. One of the methods for non-destructive testing of structures is a technique utilizing the phenomenon of elastic wave propagation. Traditional diagnostic methods utilizing guided Lamb waves are effective for structures in which open cracks occur and a distinct boundary for reflection of waves appears. The actual process of damage development under service loads has a multi-step character. First, the initiation and formation of micro-defects occurs and then connection of micro-cracks follows until creation of an open crack. A limitation of existing methods based on linear wave propagation is their low sensitivity to micro-material damage in the early stage of the degradation process. An alternative technique exhibiting much more sensitivity to damage of micro-structure is nonlinear ultrasonics which is the subject of this research project. The major aim of the project is to recognize and to acquire new knowledge concerning the phenomenon of guided wave propagation in adhesive and bolted connections subjected to gradual mechanical degradation that occurs under monotonic and cyclic loadings.

Within the framework of the research project, a comprehensive program of strength tests and measurements of Lamb wave propagation in adhesive and bolted connections will be carried out. All experiments will be performed on laboratory scale models in two stages. During the first stage Lamb wave propagation measurements for each type of connections at unloaded state as well as strength tests of connections will be made independently of each other. The wave leakage between jointed elements will be analysed and in preloaded bolted joints the influence of the level of the bolt torque and fastener clamping force on the energy of the recorded signals will be also analysed. Then the connections will be loaded with the use of the testing machine. In the second stage of experimental tests, investigations on nonlinear propagation of Lamb waves by the connection subjected to mechanical degradation under monotonic and cyclic loading will be carried out. Piezoelectric transducers distributed at selected points of the connection will be used to excite and sense ultrasonic waves. Ultrasonic measurements will be taken in monitoring mode, i.e. at the specified time intervals, depending on the speed of applying a load, excitation and registration of wave signals will be performed, without interrupting the process of degradation. In addition, the measurement of wave propagation over the entire surface of the connection using the laser scanning vibrometer in selected states of the mechanical degradation of the connection will be executed. The scope of analyses of measured wave propagation signals involves the analysis of signals in time and frequency domains and the time-frequency analysis using wavelet transforms. Correlations between the degree of degradation of the connection and the measurable characteristics of the propagating wave will be formulated. Progressive damage of a connection will be described using indicators of nonlinear Lamb wave propagation.

Knowledge of the relationship between the state of connection and characteristics of the propagated wave is of primary importance for the development of non-destructive diagnostic methods. In a broader perspective, the results of the project will have a significant impact on the increase of the safety of engineering structures. Reliable assessment of the degree of degradation of structural components will enable their rational maintenance as well as will extend the structure service life.