4.2.2. APPLICATION OF THE IMPROVED AIR-COUPLED TECHNIQUE FOR DETECTION OF THE BACK-SCATTERED ULTRASONIC GUIDED WAVES OVER DEFECTED REGIONS OF COMPOSITES

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The wide group of modern composite materials, such as fibre metal laminates, honeycombs, glass or carbon fibre reinforced plastics are used as lightweight and high strength materials in component construction of land, air and water transport. Such materials during exploitation under dynamic loads, continuous vibrations, fatigue and harsh environmental conditions have necessity to be periodically tested during the maintenance in order to avoid the dangerous defects, like internal delamination, breakage of fibres, cracks and etc. In other hand, during manufacture, the appropriate quality control of such materials should be performed, also. In the case of non-destructive testing (NDT) of objects having large dimensions and complex geometry structure the access to their surfaces is often possible only from one side.

One of the non-destructive testing techniques which enable to detect the defects both in manufacturing or in-service inspection is based on application of contactless air – coupled ultrasonic guided waves using only single-side access.

The objective of the presented work was to develop the improved air-coupled ultrasonic technique which will be suitable to generate the appropriate modes of guided waves in the composite structure effectively and achieve the sufficient sensitivity in order to detect the weak back-scattered part of the guided waves over defective regions.

From the excitation region the direct mode of guided waves propagates along the structure of test sample. When the internal defect or non-homogeneity occurs in the path of the propagating wave, the reflection of the direct wave backwards simultaneously with the scattering around the edges of the defect and also mode conversion of incident wave occurs. After that the direct wave with reduced energy propagates further. In common cases using the pitch-catch configuration, the defects could be detected in a fast way registering amplitude or delay time variations of the direct wave. However, it is possible to conclude that the detected defect is located somewhere in between of the transmitter and receiver. In order to estimate the size or the geometry of the internal non-homogeneity close to the actual, the distance between ultrasonic transmitter and the receiver should be as short as possible and transducers should have small lateral dimensions. However, in any case the elongated contour of the defect is being obtained. Therefore, the effective solution is to register only the instance of the guided wave interaction with edges of the defect, when the weak back-scattered waves are being generated and leaks into surrounding medium. The amplitude of the back-scattered wave by the defect is significantly smaller in comparison with the direct wave, however it posses useful information about actual size and geometry of the defect. Due to very weak amplitude of the back – scattered wave there are high requirements for sensitivity and low transduction losses of ultrasonic piezoelectric receivers.

The wideband air-coupled ultrasonic transducers, having active diameter up to 12 mm, bandwidth up to 200 kHz, having non-monolithic structure combined with multi-layered matching layers and possessing only 50–60 dB transduction losses have been developed. The air-coupled generation of the appropriate mode of the guided waves and reception of the weak back-scattered waves are very sensitive to positioning of the deflection angle of the both transmitter and the receiver. The appropriate positioning device for simultaneous deflection of the both ultrasonic transducers was developed. In order to improve estimation of the defect geometry close to the real as possible, the advanced signal processing was applied.

The plate-like composite material possessing internal artificial defects have been investigated using the developed air-coupled ultrasonic technique. The defects have been clearly detected using only reception of the back-scattered waves over the edges of the defect. The obtained C-scan image indicates the improvement in the case of the actual size estimation of the internal defects. The obtained results indicate that the developed technique is suitable to register back-scattered leaky waves and the spatial resolution does not depend on the distance between the ultrasonic transducers. In such a case the elongation of the contour of the defect is avoided.

The improved single-side access air-coupled ultrasonic technique, suitable to detect the weak back-scattered part of the guided waves over the defected regions of composite materials in the case of total losses up to –130 dB, has been developed. The wideband air-coupled ultrasonic transducers possessing low transduction losses and high sensitivity to register the back-scattered leaky waves have been also developed. The experimental investigations of the multi-layered composite samples with artificial defects have been performed and the actual size of the internal defect was estimated. The appropriate filtering and signal processing algorithms were implemented. It is possible to conclude that the developed technique after some modifications is suitable to be used for rapid detection of the internal non-homogeneities in the composite constructions at their exploitation places.