Mechanical Stress Measurement Using Phased Array Ultrasonic System

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Background, Motivation and Objective

In this paper, a new ultrasonic system is developed to measure the mechanical stresses. The study is part of a larger research project to use the Phased Array Ultrasonic Testing (PAUT) system for the residual stress measurement of high-value manufacturing and safety-critical components, like aerospace, wind turbines and nuclear structures. The stress measurement using the ultrasonic method is explained by the acoustoelastic effect which is based on the sound velocity change in an elastic material subjected to the static stress field.

Statement of Contribution/Methods

Single element transducers are conventionally used for stress measurement using the ultrasonic method while the PAUT system is innovatively used in this paper. The mechanical stresses, tensile and compressive, are applied using a customized tensile test machine and vice clamp system. The ultrasonic arrays are 5 MHz transducers manufactured by IMASONIC (France) and configured in Longitudinal Critically Refracted (LCR) setup (see Fig. 1). The transmitter array generates 8 ultrasonic waves which are received by 8 elements of the receiver array. Therefore, a matrix of 8 × 8 acoustic paths can be generated. This has resulted in higher stress measurement accuracy, compared to the traditional setup in which only one acoustic path can be generated using two single element transducers, through minimization of the Time of Flight (ToF) measurement error, created by transmitter triggering uncertainty, wave speed changes in the transducers/wedge, positioning uncertainty, transducer alignment and material texture effects. Additionally, a higher measurement resolution was achieved because of the lower distance between the elements, array pitch was 0.5 mm compared to the >10 mm transducers distance in the single element setup.

Results/Discussion

The PAUT-LCR system was able to detect variations in ToFs of the sample subjected to the stress changes. Therefore, the mechanical stress was successfully measured using this newly developed PAUT-LCR system. Using the acoustoelasticity law, the novel setup was also used to measure the acoustoelastic coefficient required for future residual stress measurement.

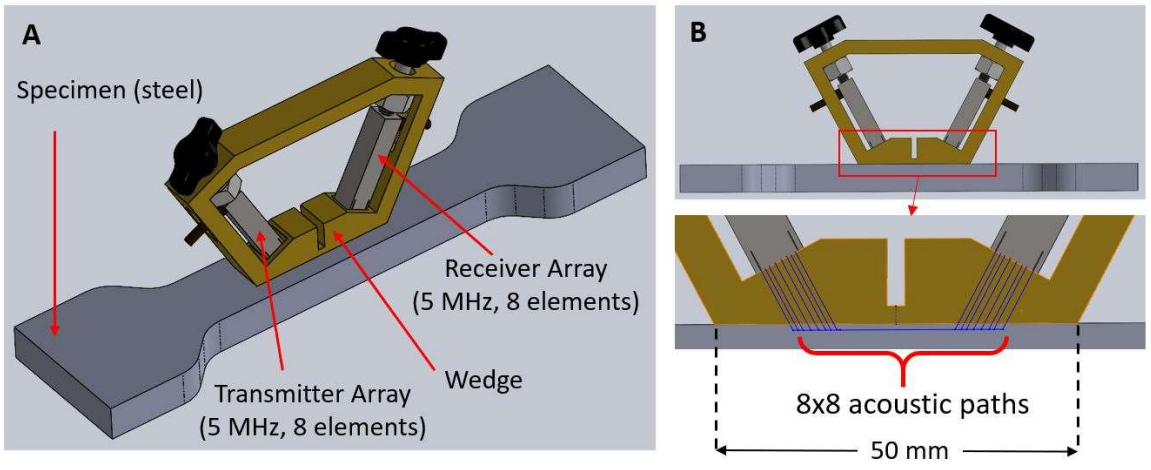

Fig. 1. Mechanical Stress Measurement using the PAUT-LCR System on the Tensile Test Specimen (A) and The Possibility of Producing 8x8 Acoustic Paths (B)