Investigation on Sensor Fault Effects of Piezoelectric Transducers on Wave Propagation and Impedance Measurements

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Abstract

Introduction
The employment of a large number of embedded sensors in advanced monitoring systems becomes more common, enabling in-service detection, localization and assessment of defects in mechanical, civil and aerospace structures (Figure 1). The automated monitoring with permanently attached sensor systems is referred to as Structural Health Monitoring (SHM). One popular sensor type for active monitoring technologies is the piezoelectric wafer active sensor (PWAS), due to its multi-purpose application as actuator and sensor and its low cost. It is used to generate a wave field, which interacts with the structure and is recorded by a second set of PWASs. This method is called acousto ultrasonics (Figure 2). Generally the use of sensors requires that those are functioning correctly. This is especially important when long term monitoring (e.g. several years) is performed, because the sensor might be the weakest part of the monitoring system. A variety of damages can influence the sensor performance, e.g. degradation of the piezoelectric material or the adhesive bonding layer, debonding of the element from the structure or breakage of the element. All these damages have a different effect on the wave propagation generated by the PWAS. Also the electro-mechanical impedance (EMI) spectrum, as a tool to detect these effects efficiently, including mechanical and electrical impacts, is interesting in this context.

Use of COMSOL Multiphysics®
To be able to understand, how the wave field is changed by the afore mentioned transducer damages, within this paper the multiphysics interaction of the undamaged or damaged PWAS and the structure is modelled in time and frequency domain. This way the effects on the electro-mechanical impedance and on the generated wave field are investigated. The physics-based model consists of a circular piezoelectric element bonded by an adhesive layer on an isotropic structure. In the time domain a typical signal, deployed in acousto ultrasonics is used as actuating voltage signal and the displacement field generated by the PWAS is analysed. Moreover the motion of the piezoelectric transducer itself is investigated (Figure 3). In the frequency domain the electro-mechanical interaction within a certain frequency range is examined by applying a sine signal with different frequencies within this range to the transducer. The electric flux is used to calculate the EMI.

Results
All studied damage scenarios have some impact on the generated wave field and the EMI. The modelling with COMSOL Multiphysics® makes it possible to show, how different effects, which can be seen in the measurable quantities, can be explained. Additionally the effects extracted from the FE calculation are, as far as possible, compared to experimental results gained from PWAS attached to aluminium coupons, showing the quality of the COMSOL Multiphysics® model.

Conclusion
The investigation shows, how important it is to check that employed sensors are intact, as sensor faults have a big effect on the generated wave field, which is used in the Structural Health Monitoring process of acousto ultrasonics. By explaining the reason for effects in the wave propagation the presented COMSOL Multiphysics® model increases knowledge about processes that are caused by sensor faults.

Reference

Source for Figure 1:
Randy Montoya, share.sandia.gov

Figures used in the abstract

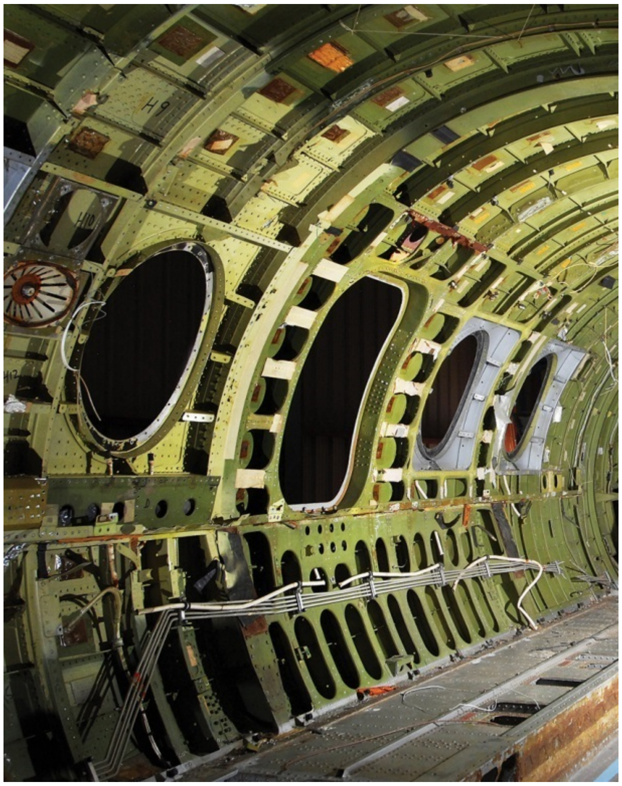

Figure 1: Fuselage of an airplane under investigation (©Randy Montoya, share.sandia.gov)

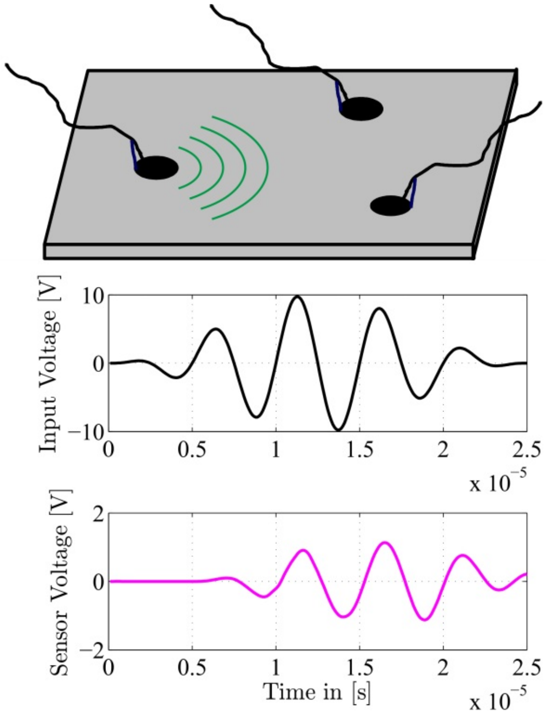

Figure 2: Acousto Ultrasonic Setup with Input and Sensor Signal

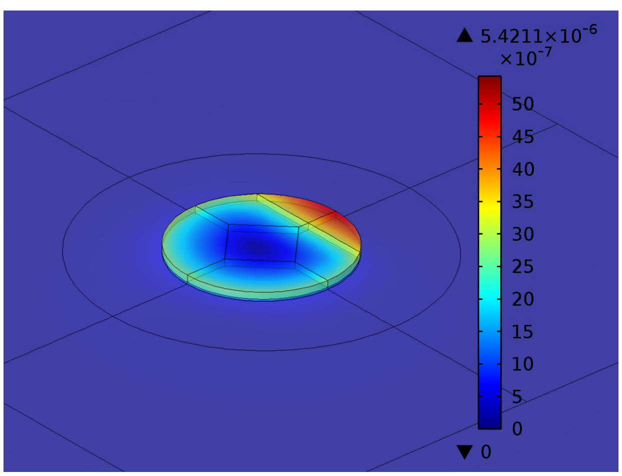

Figure 3: In-plane displacement [mm] of a debonded piezoelectric transducer