APPLICATION OF LAMB WAVES AND IMPEDANCE SPECTROSCOPY FOR STRUCTURAL HEALTH MONITORING OF COMPOSITE MATERIALS

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1. Introduction

Structural Health Monitoring (SHM) offers new possibilities for damage prevention of technical structures. SHM implies permanent monitoring of structural integrity as well as damage detection by inherent means [1, 2]. Disadvantages of conventional maintenance concepts (time based with fixed inspection intervals) are overcome by introducing more and more condition based maintenance. Direct damage detection replaces assumptions for damage initiation and progress thus making damage tolerance concepts more effective.

Monitoring and detection demand implementation of sensorial (and actuatorial) functions into the structure. For components made of CFRP (Carbon Fibre Reinforced Polymers) the use of embedded or attached piezo-ceramic elements is an attractive way for designing smart SHM-structures.

Different approaches for SHM- purposes with piezo-ceramics in CFRP-structures are possible:

Impedance spectroscopy is based on the coupling of the structures' mechanical vibration behaviour with measurable electrical properties of the piezo-ceramics [2]. Another way is the evaluation of ultrasonic Lamb-waves [3, 4]. The piezo-ceramic acts in a passive variant as a receiver for Lamb-wave signals, generated by damaging events such as impact damage in fibre reinforced materials. Actuatorial piezo-ceramics produce Lamb-waves that are picked up by distributed sensors in an active alternative, so that distinct subject regions may be observed selectively.

2. Results

In both cases, detailed understanding of the interactions of Lamb-waves with the structure and defects is necessary. In the following, examples of investigations for the use of impedance spectroscopy and Lamb-waves as tools for SHM in CFRP-structures are presented.

Figure 1 shows the principal arrangement for electrical impedance spectroscopy. Due to measuring constraints the admittance was recorded and is depicted as an absolute value Y. The graph at the left side shows the general progress of the admittance with frequency that is controlled by the piezo-ceramic as a capacitance element. Due to coupling of electrical and mechanical properties of the whole structure, resonance peaks become visible which are related to eigenvalues of structural vibrations. In addition to the global admittance behaviour, these resonances offer potential for SHM-purposes e.g. self-monitoring of the piezo-patches or detection of structural changes.

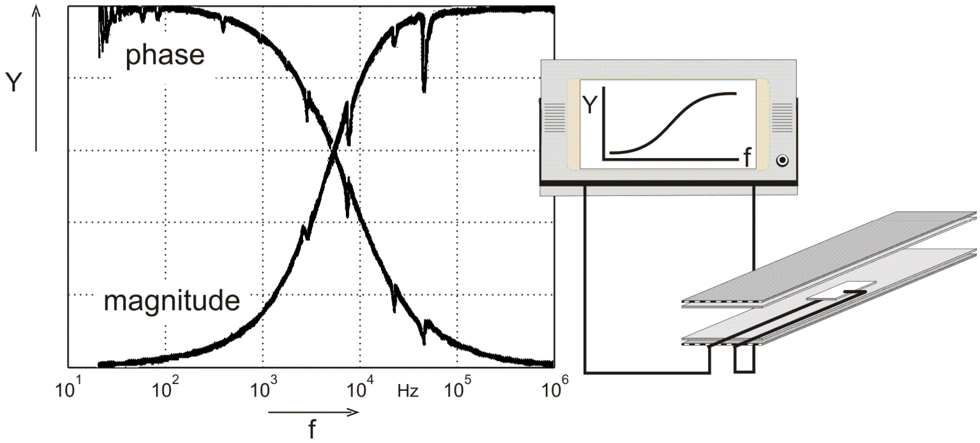

Fig. 1: Principal arrangement for impedance spectroscopy and spectrogram

Examples regarding the estimation of influence factors such as ageing effects of electrical contacts, outer mechanical loads or degradation of the piezo-ceramic, and the detection of impact damage of the CFRP-material are presented.

Figure 2 shows an example of Lamb-wave-signals, generated by an integrated piezo-ceramic patch in a CFRP-stripe. The A-Scan demonstrates the generation of mainly two signals of the fundamental symmetric mode s_0 from the edges of the piezo-ceramic. The B-scan shows the spatial progress of the waves, making the direct and reflected signals clearly visible. Examples of Lamb-waves recorded with Scanning Laser Vibrometer and ultrasonic testing devices are given. Typical properties of the wave modes and their potential for SHM are discussed and examples for damage detection in CFRP are presented.

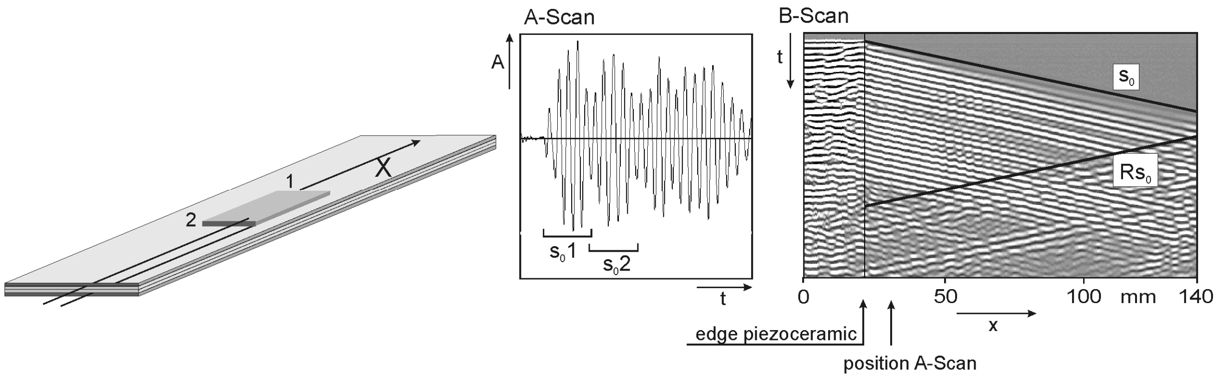

Fig. 2: Lamb-waves generated by integrated piezo-patch: arrangement, A-scan, B-scan

3. Conclusion

Impedance spectroscopy is attractive for self monitoring of piezo-ceramic sensors or actuators to detect changes in coupling, connections or environmental factors. A detection of defects in the surrounding areas is possible, the action range strongly depending on geometry and material properties. Lamb waves offer a high potential for monitoring large areas, but further investigations regarding interaction with defects and solving the inverse problem of damage prediction from Lamb-wave-data are necessary.

4. References

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