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Abstract

Toward Material-Integrated Wireless Electronics for SHM in Fiber Metal Laminates †

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Abstract: A self-sufficient wireless electronic sensor node for the acquisition of guided ultrasonic waves (GUW) is introduced. The system presents a step toward a structural health monitoring (SHM) system fully integrated into fiber metal laminates. It removes the need for complex wiring to transfer energy and data and reduces electromagnetic actuator excitation interference observable in wired GUW measurements. The functionality of the integrated system, e.g., to monitor the structural health of FMLs, is tested with the help of magnets used as pseudo defects.

Keywords: structural health monitoring (SHM); fiber metal laminates (FML); embedded sensor node; RFID; lamb waves

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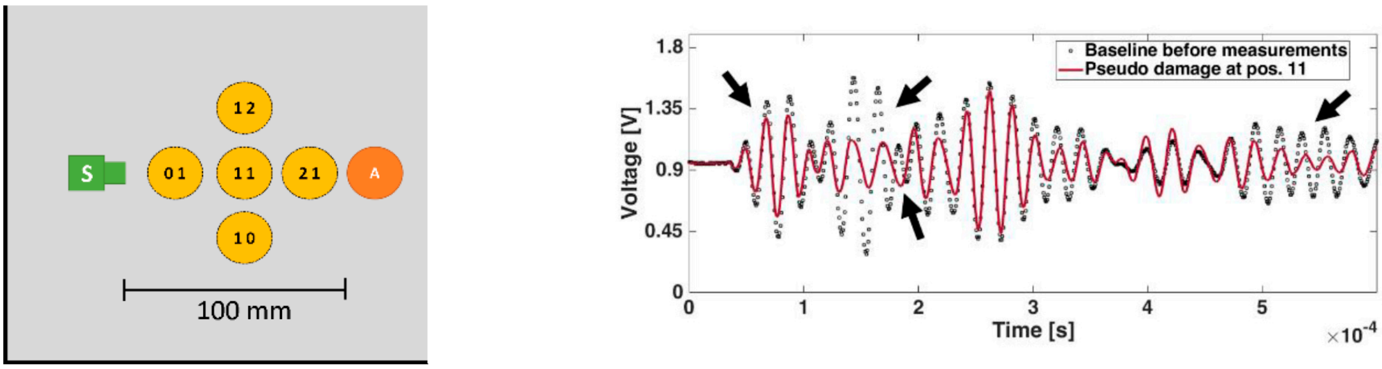
1. Introduction

The unique properties of fiber metal laminates (FMLs) make them an attractive material choice for modern aircraft. Embedded SHM sensors are usually wired [1]. Although few attempts have been made to connect to sensors embedded in fiber composites wirelessly [2], no such system has been reported for FML, where the presence of metal layers and high manufacturing temperatures make the integration of electronics and antennas difficult. Here, we show that the outer metal layer of FMLs, usually seen as an impediment for wireless transmission, can be turned into an advantage by structuring it in a way that it can be used as an antenna. We build upon our previous work [3,4] and present measurement results of the first fully integrated system consisting of sensors and wireless sensor nodes inside an FML.

2. Materials and Methods

The system consists of three parts: an antenna, a sensor node, and a piezoelectric sensor. A non-standard GLARE plate is investigated, into which a digital sensor node is embedded that transmits the sensor data presented here wirelessly to an external reader. For material integration, an epoxy resin coating is applied to provide electrical insulation and mechanical support to soldered components. The node measures $17 \times 17 \times 0.8$ mm^3. To test the efficiency of our sensor for SHM, the setup as shown in Figure 1a is used. A piezoelectric actuator (A) excites GUW in the FML. Magnets with varying positions (yellow, XY coordinates of position) are placed on the FML and represent pseudo defects that change the transmission of the waves to the embedded sensor node (S).



(**a**) (**b**)

Figure 1. (**a**) Pseudo defect positions during experimental investigation; (**b**) Experimental results.

3. Discussion and Conclusions

The system allows for reproducible, material-integrated measurements of GUW. Using a pair of magnets acting as pseudo damage shows significant changes in the measured data. Magnets are applied and removed multiple times on and around the measurement path, while the system amplifies and digitizes the sensor signal for wireless readout using 13.56 MHz radio-frequency identification (RFID). Figure 1b shows two measurements: the dotted line shows the baseline signal without magnets before the measurements with magnets, while the solid line shows the signal with applied magnets at position 11. Several differences to the baseline signal can be identified (arrows). On repetition, comparable results are obtained multiple times, thereby proving that material-integrated measurements of GUW with the presented system can be used to detect reversible pseudo damage. This represents a first step toward material-integrated wireless systems with automated damage detection.

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