

CHARACTERISATION OF SURFACE ACOUSTIC WAVE SENSORS FOR STRAIN MEASUREMENT

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1. Introduction

Strain gauges are applied in a wide industrial range. Sometimes, their application can be very difficult or even impossible due to a lack of space or the requirement of an electronic connection with a processing unit. To avoid these problems, the SAW Components Dresden GmbH has developed a new sensor system for strain measurements. It is capable to transmit the measured signal directly from the sensor to the processing unit without any need of wires. In comparison to the strain gauge technology, the deformation on the components surface is not determined by a change of the sensors electrical resistance. Instead the SAW device measurement principle is based on the propagation of surface acoustic waves between two interdigital electrodes. The resonance frequency of the standing wave can be determined using an interdigital transducer. This resonance frequency is directly related to the tension of the sensor and decreases with increasing strain. The coupling factor between the modification of the resonance frequency and the tension of the component, the sensor is mounted to, can be described by the sensitivity, similar to the gauge factor of strain gauges.

The sensitivity of the SAW sensors is mainly affected by the transmission of strain in the intermediate layer between component and substrate as well as the strain transmission of the piezoelectric crystal itself.

2. Numerical Analysis

The strain transmission of the sensor can be determined using different methods. One of them is the Finite Element Analysis (FEA). In addition to the mounting method, the strain transmission of the SAW sensor also depends on its geometry. Therefore the influence of the length, width and thickness of the carrier substrate has to be analyzed. By varying one of these geometric values, the other two geometric dimensions, the

thickness of the intermediate layer and the sensor structure itself are kept constant, Fig.1. During the FEA the length of the whole sensor varies between 2700 μm and 6000 μm , its width between 630 μm and 2700 μm and its thickness between 100 μm and 500 μm . The sensitivity of the sensor increases with an increasing length and a decreasing thickness of the carrier substrate. The width of the sensor has no significant effect at all.

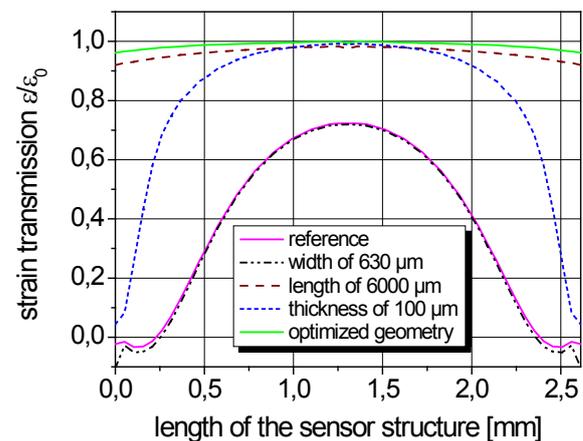


Fig.1: Results of Finite Element Analysis

Based on these results, a sensor twice as long and half as thick as the actual available sensors pass more than 96 % of the components strain to the sensor geometry, which is comparable to the commonly used strain gauges technology [1]. This good strain transmission also leads to a higher sensitivity of the SAW sensor system.

3. Experiment

In addition to the optimization of the sensor geometry, the influence of the different application methods has to be characterized as well. Among other methods, the SAW sensor can be affixed like a strain gauge using a plane bond. This paper is focused on mounting the SAW sensor analogues to strain gauges without (a) and with steel bands (b), Fig.2.

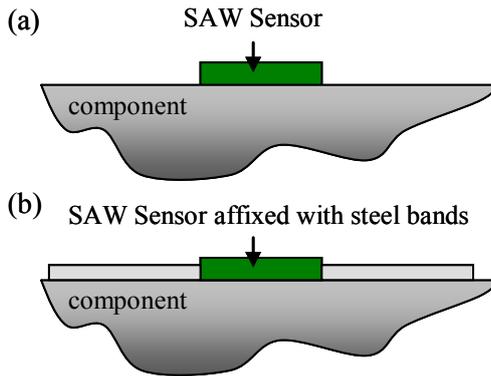


Fig.2: Mounting methods of the SAW sensor

According to the literature different experimental setups are available. Due to the advantages of pure bending, four point bending is a suitable experimental approach to determine the sensitivity [2] of the SAW sensors. Therefore a strain gauge and a SAW sensor are applied to a steel beam, Fig.3.

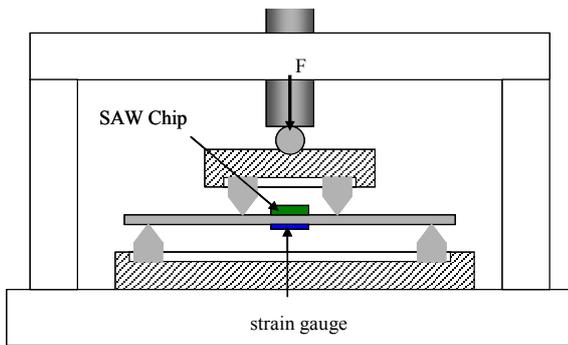


Fig.3: Experimental setup

The strain gauge is used as reference and measures the strain in the outer fiber of the steel beam. Comparing the measurement results of the SAW sensor and the strain gauge against each other, the sensitivity can be estimated using

$$S = \frac{\Delta f}{f_0} \cdot \frac{1}{\varepsilon_{strain_gauge}}$$

4. Results

Referring to the experimental results, the sensitivities of the currently available SAW sensors are much smaller than for commonly used foil type strain gauges. While the sensitivity does not depend on the mounting method and loading

of the sensor, these two parameters mainly affect the applicability of the sensor system. In comparison to fixing the sensor in an analogous manner to strain gauges, mounting the sensor with steel bands has one significant advantage. For compressions up to 2000 $\mu\text{m}/\text{m}$, its sensitivity is almost constant, Fig 4.

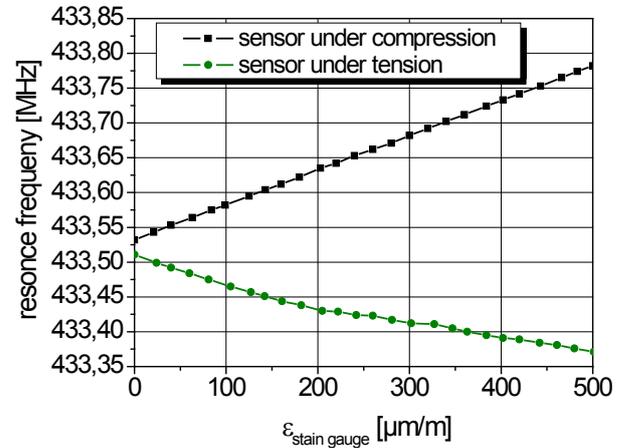


Fig.4: SAW sensor mounted with steel bands under various loading

The sensitivity rapidly decreases under tension for both mounting methods, because the bond between the sensor and the component as well as the bond between the sensor and the steel bands fails.

5. Outlook

Current research is focused on a new application method, where of the sensor is pre-loaded by an additional centre key and embedded in a cavity. First analyses are quite budding, because the sensitivity of the whole sensor system can be increased to about three, which is also high compared to foil strain gauges.

References

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- [2] VDI/VDE/GESA 2635: Experimental structure analysis, Metallic bonded resistance strain gages, Characteristics and test conditions