

INVESTIGATION IN DEVELOPMENT OF EMBROIDERED STRAIN MEASUREMENT SENSORS

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1. Introduction

The integration of electronic units, sensors and actuators into complex function-oriented systems is one key point in development of intelligent lightweight composites and lightweight structures. A wide range of materials are available for that purpose and can be used to create active structures with selective properties. Often, these complex systems are manually integrated into smart structures with prefabricated and individually designed layer materials. But, automated production is difficult.

Therefore, main aim of Department of Lightweight Structures and Polymer Technology (SLK) in cooperation with Competence Centre for Lightweight Structures (SLB) and the Lightweight Structures Engineering GmbH (LSE) is developing application-oriented technical solutions for series production. One result of this network is a technology for the fabrication of embroidered strain measurement sensors. These sensors are capable for a direct integration whilst the manufacturing of active lightweight structures and composites, for example fiber reinforced plastics.

2. Embroidery technology

Embroidering, micro system technology and polymers combined in a closed process chain is quite unusual so far. However the research results showed that there are novel and future orientated fields of applications by embroidery technology. This technology is actually well known in industrial applications like Tailored Fiber Placement (TFP) for selective reinforcement of high duty plastic systems.

In both ways, the TFP and embroidery method, fibers or wires can be placed in individual patterns on flexible base materials. Furthermore, this

technique is known for producing micro system structures in the field of flexible materials

Thin metallic wires (e.g. constantan® or isaohm®) or conductive coated or rather conductive yarn are used as sensor materials. Embroider techniques are used to attach the sensor material on a non-woven [1]. Figure 1 shows a larger scale image of that. The wire shown in this picture is positioned by Tailored Fiber Placement technologies and fixed with clearly visible purple yarn on a non-woven polymer. In principle the shape and dimension can be designed individually. At the moment the achievable resolution is about 0.8 mm.

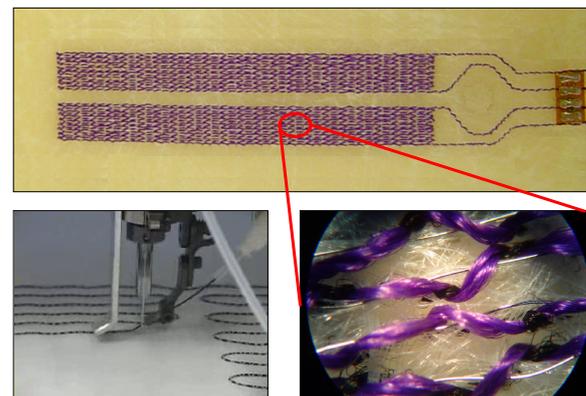


Fig. 8: Embroidered sensor structures embedded in fiber reinforced plastics (above), production process (bottom left) and enlarged view of a sensor (bottom right)

3. Strain measurement

The total resistance is a very important parameter for strain sensors. Its value is key factor for power consumption by sensor system. Besides, typical resistances of 120 Ω , 350 Ω and 1 k Ω per sensor can be designed for any value between and

around that. Tolerance for series production is about $\pm 10\%$ at the moment. For small scale and laboratory application a tolerance of $\pm 3\%$ is achievable.

The demonstrated strain sensor has less priority in exact measurement of mechanical strains inside a component like common strain gauges. It is rather used to functionalize fiber reinforced structure components. For example it is possible to adapt a part with a sensor that gives information about current status (health monitoring). Hence the sensor is embedded it is protected against environmental influence like humidity. By choosing an appropriate geometry and adjusting resistance the sensor can be freely customized and fitted to almost any component.

A common bridge connection is used to analyze the sensor signal in the same way as for typical strain gauges [2]. If a standard value is chosen for resistance a usual industrial analysis unit can be applied.

4. Experimental setup

The gauge factor of that sensor was determined as well. Therefore the sensor was glued on another beam. That beam was deflected in a four-point bending experiments (see Fig. 5). The test was carried out according to the VDI/VDE GESA 2635 norm (compare [3]).

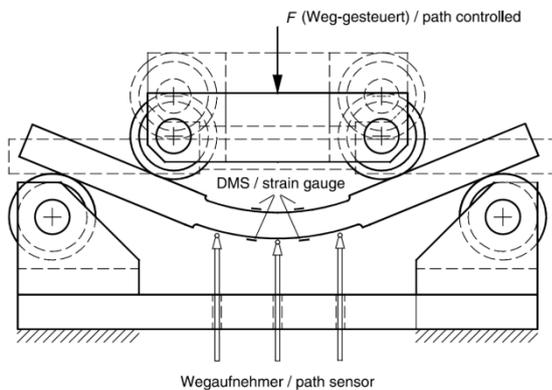


Fig. 9: Experimental setup for the investigation of gauge factor

The gauge factor is the proportion of the elongation of the sensor to its change in resistance. Due to the four-point bending

experiment the deformation at the sensor area is clearly defined. The gauge factor can be calculated as followed:

$$k = \frac{\left| \frac{\Delta R}{R_0} \right|_{\text{pos}} + \left| \frac{\Delta R}{R_0} \right|_{\text{neg}}}{\left| \bar{\epsilon}_{M_{\text{pos}}} \right| + \left| \bar{\epsilon}_{M_{\text{neg}}} \right|}$$

5. Experimental results

The experiment results are shown in Fig. 6. All tested sensors provide a nearly constant gauge factor over a width elongation range.

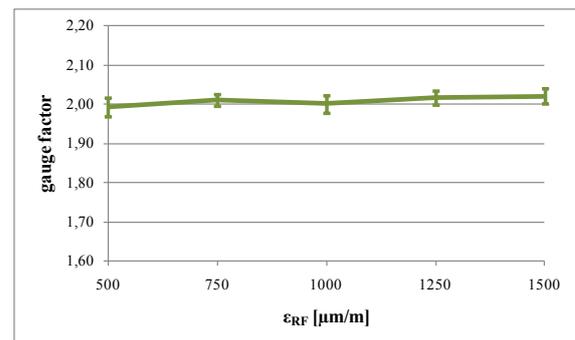


Fig. 10: Measured gauge factor and standard deviation for 10 investigated sensors

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