CHARACTERISATION OF NEW EMBEDDED EMBROIDERED SENSORS FOR STRAIN MEASUREMENTS IN COMPOSITE MATERIALS

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1. Introduction

The structural integration of new embedded embroidered sensors (EES) in fibre reinforced plastics (FRP) has some advantages by comparison to other measurement solutions like normal strain gauges or fibre bragg gratings (FBG). The ability to produce them in mass production and the less expansive data acquisition systems lead to lower costs by contrast with FBG. In comparison to strain gauges there is no weakening of the FRP after integrating the sensor.

For the use of new embedded embroidered sensors (fig. 1) knowledge about their characteristics is very important. Therefore some theoretical considerations and practical test were realised.

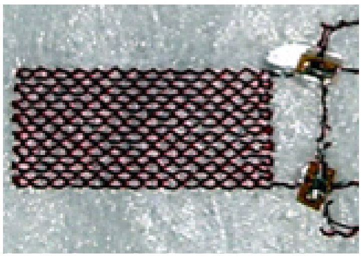

Fig. 1: New embedded embroidered sensor

2. Design of the Sensor and the Test Specimen

For the experiments the sensors were integrated into different laminates (tab. 1) made of glass fibre reinforced plastics (GFRP). They were placed in the middle of the laminates (Fig. 2). Furthermore there were three sensors in each specimen, one along the force direction, one transeverse and one in 45° (Fig. 3).

The position for the contact wires was placed outside the measurement area. The connection between the sensors and the contacts were made of copper wires. These wires are stretched in the experiments, but their influence on the signal can be neglected.

Tab. 1: Different types of test specimen

type	design	number
Unidirectional (UD)	0/0/0/0/s/0/0/0/0	8
Bidirectional (BD)	0/90/0/90/s/90/0/90/0	5
Quasi isotropic (QI)	0/45/-45/90/s/ 90/-45/45/0	5
Antisymmetric (AS)	30/30/30/30/s/ -30/-30/-30/-30	5
General (GL)	0/0/30/30/s/60/60/90/90	5

Fig. 2: Integration of EES in GFRP

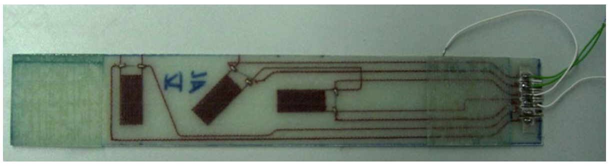

Fig. 3: Specimen with three sensors

3. Experimental Setup and Results

To characterise the new embedded embroidered sensor, the specimen were tensioned and the reproducibility of the signal was investigated. Furthermore longitudinal strain of the samples was 1%. The results showed that the reproducibility of the sensors was very good. The standard deviation of the signal was ±1,74%.

4. Transverse Sensitivity

The investigations were focused on the transverse sensitivity. Although the experimental setup is not appropriate to get transverse sensitivity of the embroidered sensor the results can show its dimension. Concerning Wei-ming [1] the transverse sensitivity

q = 0,0375 ±30% is determined by

$$q = \frac{\nu_{mes} - \nu_{12\_lam}}{\nu_{mes} \cdot \nu_{12\_lam} - 1} \qquad (1)$$

with

$$\nu_{mes} = \frac{\varepsilon_{mes\_transverse}}{\varepsilon_{mes\_lengthwise}} . \qquad (2)$$

The index *mes* indicates a measured value. The value of the Poisson´s ratio ν_{12_lam} was calculated with the theoretical material constants of the single layers.

To get an overview about influences through the transverse sensitivity some theoretical considerations were made. Concerning Keil [2] the systematic error caused by the transverse sensitivity can be calculated with

$$f = \frac{q(\nu_0 + m)}{1 - q\nu_0}, \qquad (3)$$

where ν_0 is the Poisson´s ratio of the reference material (used for determination of the gauge factor) and *m* is the relation between transverse and longitudinal strain. In case of uniaxial tension this relation is the Poisson´s ratio, but relating on the sensor coordinate system it has to be transformed (fig. 4).

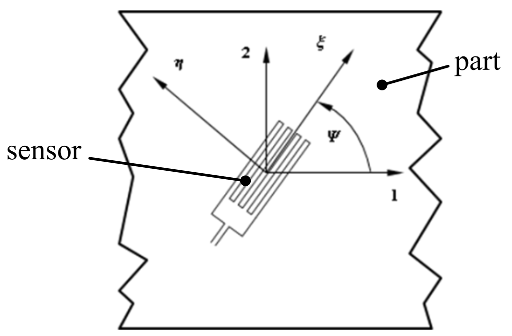

Fig. 4: Coordinates systems of the part and the sensor

The polar diagram (fig. 5) shows the measurement error depending on the sensor-stress-orientation for three different laminates. The measurement errors for UD- and QI-laminates are up to 15% and for BD-laminates up to 40%. The results of AS- and GL-laminates are similar.

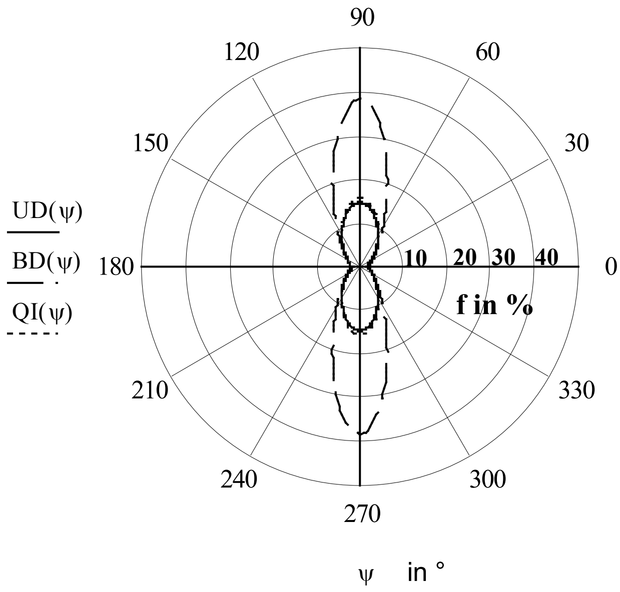

Fig 5: Measurement error depending on the sensor-stress-orientation

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References

[1] Wei-ming, G., A Simplified Method for Eliminating Error of Transverse Sensitivity of Strain Gage, Experimental Mechanics, Volume 22, Issue 1, pages 16-18, January 1982

[2] Keil, S., Beanspruchungsermittlung mit Dehnungsmessstreifen, CUNEUS Verlag Zwingenberg a. d. Bergstr., 1995