INTERNAL STRAIN MEASUREMENT OF COMPOSITE MATERIALS WITH A NOVEL MAGNETIC WIRE SENSOR

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Overview

The mechanical responses of a novel magnetic film coated copper wire sensor were investigated. Small size, high sensitivity, and good compatibility with composite materials make the sensor a potential low-cost sensing tool to determine internal strain in composite structures. Experimental work was carried out to assess the sensor for strain measurement and feasibility of detecting internal strain developed during manufacturing. A linear voltage and strain relation is found in tension tests. The sensor has a very high sensitivity in the range of 0< ε<1000με. However, when the strain is above this threshold level, the sensitivity of the sensor is greatly reduced. Good agreement between a strain gauge and the Magstrain sensor integrated into composite specimens was found for static tension and bending, demonstrating the sensor's ability for internal strain measurements. VARTM manufacturing scenarios, such as neat resin gelation, fiber bundle compaction, nesting, resin injection, and curing, can be observed with the sensor, revealing the micro-mechanisms of the VARTM process and residual strain inside the composite parts.

Acknowledgements

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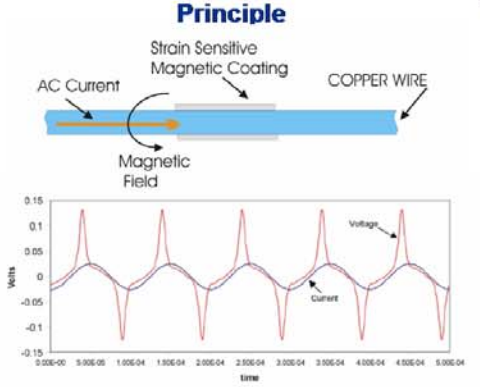
Principle

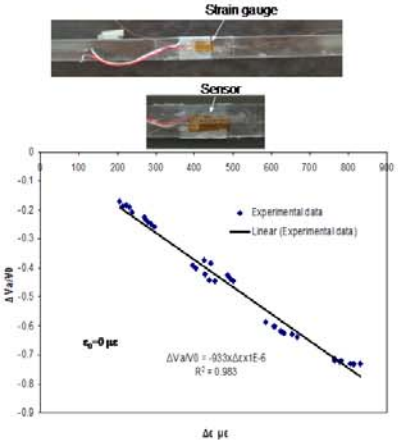


$$V = -\frac{l}{2\pi}\ln\left(1+\frac{t_m}{r}\right)\left(\mu I_a \cos\omega t + \frac{\ln\left(1+\frac{t_m}{r}\right)}{2\pi t_m} I_a^2 \sin\omega t \cos\omega t \frac{d\mu}{dH}\right)\omega$$

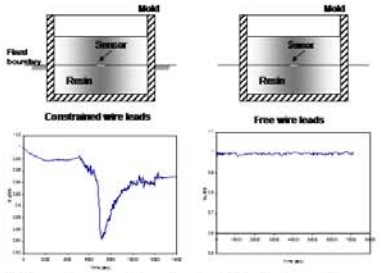
$$0 \le \varepsilon$$

$$\frac{V_a}{V_0} = C - F(\varepsilon + \varepsilon_r) \qquad \frac{\Delta V_a}{V_0} = -F\Delta\varepsilon$$

Sensor Calibration



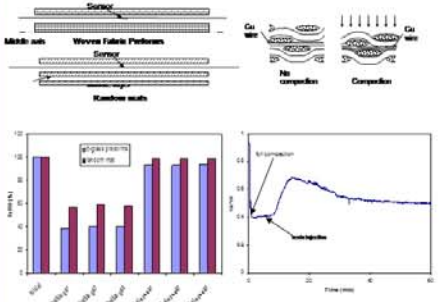
Neat Resin Curing



Voltage drops were found during resin gelation when wire leads were constrained

Free Wire leads result in a constant sensor output during resin curing, indicating the heat generated in chemical reaction has no impact on this wire sensor

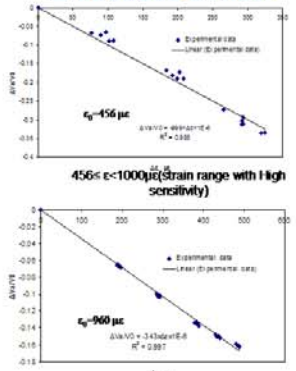
Compaction and Injection



Internal strain and nesting due to preform compaction are detected with the wire sensor

Resin flow redistributes the internal strain inside the preform and impacts the sensor output

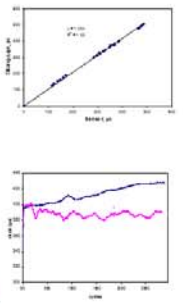
Embedded Sensor



456≤ ε<1000με(strain range with High sensitivity)

960με≤ε<1500 (reduced sensitivity)

Bending and Low Frequency Fatigue



Comparison of strain measurement by embedded sensor and strain gauge

The sensor was tested in two consecutive tensile fatigue blocks, 0.5 Hz for 1000 cycles and 1 Hz for 2000 cycles. The Magstrain sensor shows the tendency to have a relative stable peak value, which is about 400με as measured by strain gauge within initial few hundreds cycles. About 30με increase in strain gauge measurements is observed, which may be due to change in temperature, bonding or local strain variation during cyclic loading.