HIGHLY SENSITIVE MAGNETOSTRICTIVE CURE MONITORING (MCM) SENSOR

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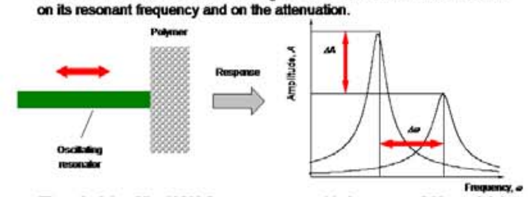
APPROACH

- In general the MCM Sensor consists of a magnetostrictive rod, which performs longitudinal vibrations due to a changing magnetic field. The field is created by an electric solenoid.
- The rod is in mechanical contact with a polymer. This creates a boundary condition which changes during the curing process. Therefore the mechanical behavior of the rod changes, in fact the resin has an influence on its resonant frequency and on the attenuation.



- The principle of the MCM Sensor was proved to be successful in a miniature version, developed by A. Dominauskas and R. Bansevicius.
- The current idea is to implement such a sensor in a mold, and adapt and optimize the design to different needs.

ACKNOWLEDGEMENTS

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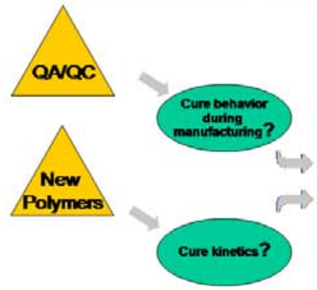
PROJECT RELEVANCE



Need for:

- Robust sensors
- Inexpensive sensors
- Maintenance free operation
- Fail-safe operation
- Online measurement

Advantages compared to existing cure-monitoring systems

- Accurate cure measurement and characterization
- S/N Ratio of 40dB already achieved
- Calibration for different resin systems not required to achieve mechanical properties
- Sensor works during full curing process
- Can be used for flow measurement

Disadvantages

- Local point measurement with direct contact

THEORETICAL MODEL

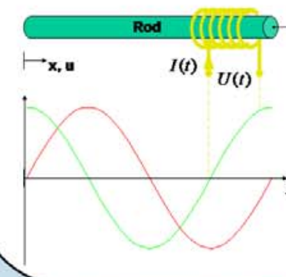
Relations between magnetic field and displacement:

$$\sigma(x,t) = E^B \cdot \varepsilon(x,t) - \lambda \cdot B(t)$$

$$H(x,t) = -\lambda \cdot \varepsilon + \frac{1}{\mu^\varepsilon} \cdot B(t)$$

with:

λ	magnetostrictive constant	x	coordinate over rod
$B(t)$	magnetic flux density	$u(x,t)$	displacement
μ^ε	permeability at constant strain	t	time
E^B	Young's modulus at constant B	$\sigma(x,t)$	stress in rod
		$\varepsilon(x,t)$	strain in rod

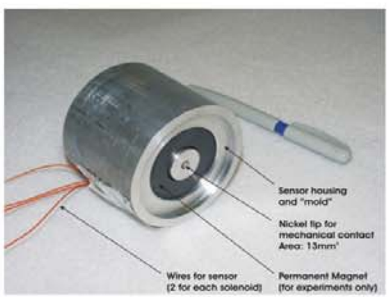


$$U(t) \sim B(t) \neq f(x)$$

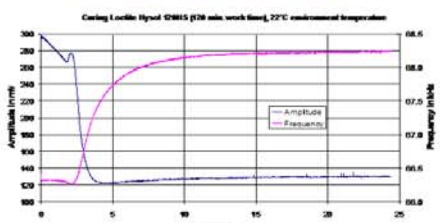
$$I(t) \sim \overline{H}(t) = \sim \int_{Coil} \varepsilon(x,t)dx$$

$$\varepsilon(x,t) = \frac{\partial u(x,t)}{\partial x}$$

EXPERIMENTAL SETUP



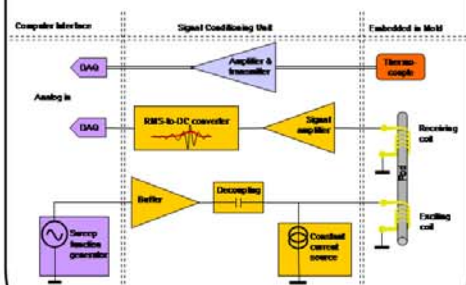
TYPICAL MEASUREMENT



Observations:

- The first local maximum of the amplitude curve is related to rising temperature (in this case 95°C)
- The significant amplitude drop is related to increasing viscosity
- The increasing frequency is related to increasing shear-modulus

SIGNAL CONDITIONING AND INTERFACE



CONCLUSIONS

- Sensor is highly sensitive to mechanical properties of many types of polymers
- Robustness of sensor still has to be proved
- Theoretical model not yet able to determine mechanical properties at the beginning of the curing process
- The most potential "competitors" to MCM sensors are ultrasonic cure monitoring sensors, but MCM sensors have several advantages
- High S/N ratio possible

FUTURE WORK

- Exact determination of all sensor properties to get reliable data
- Optimization of the sensor design with the help of the theoretical model
- Building an experimental station for characterization of polymers