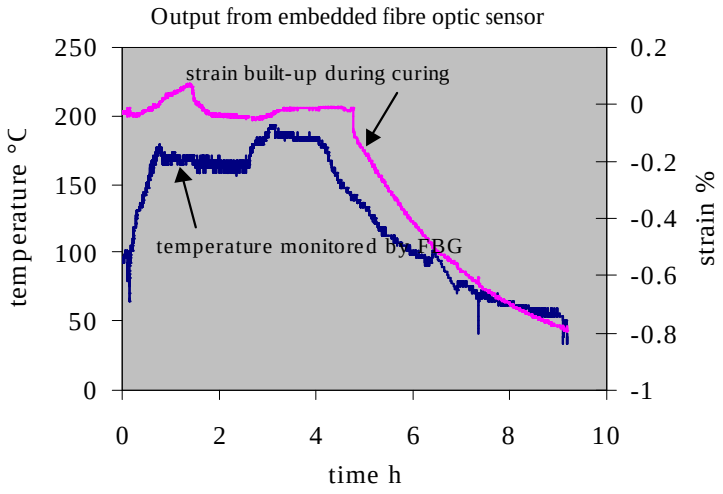
# Composite Manufacturing - Processing Measurements (CPD4B)

The mechanical properties of composite materials are significantly affected by the degree of resin cure. Efforts have been made in the past to understand resin cure mechanisms, chemical structures and resulting physical and mechanical properties. A variety of techniques have been developed to shed light upon resin cure and structure. The extent of thermoset matrix cure can be readily measured in laboratory tests but it is not yet common for 'online' or 'in-tool' techniques to be used in a production environment. AEA Technology carried out the current investigation during 1998, over a six-month period. Two reports were issued and a series of industrial visits were made to discuss some of the implications and arising issues.

| In tool techniques | Post Fabrication Techniques |
|---|---|
| dielectrometry | thermogravimetric analysis (TGA) |
| ultrasonic property measurements | differential scanning calorimetry (DSC) |
| internal temperature measurement with thermocouples | dynamic mechanical analysis (DMA) |
| embedded optical wave guide sensors | torsional pendulum damping |
| electrical resistance | hardness (e.g. Barcol hardness) |
| refractive index measurements | mechanical properties |
| acoustic waveguides | solvent resistance |
| thermal conductivity | dye colour changes |




The changes that occur in thermosetting matrix resins during composite processing can be assessed using a variety of techniques. The literature review focused on those techniques which have the greatest potential for on-line monitoring applications. The principal methods of monitoring resin cure are based on thermal effects, ultrasonics, dielectric/ electrical, optical and mechanical methods. Thermal and mechanical schemes are not applicable to on-line measurements. Many of the remaining schemes require a probe to be placed, and left in place, in the composite and involve complex equipment and information processing. Apart from methods, which assess the level of certain critical chemical groups, all the methods need calibrating, usually by DSC measurements, to relate the signal observed to the degree of cure. Unfortunately the calibration is not absolute and will vary with the type of resin and possibly from batch to batch of the same system. The interpretation of the output signal, to indicate when cure has finished, for example, may be difficult without a lot of experience of the monitoring method and of the behaviour of the resin system.

The review identified available equipment for assessing degree of cure during fabrication. There appear to be many promising techniques but only a few products available commercially. The instrumentation and sensors suitable for real time use in composite manufacturing are based on micro-dielectrometry, acoustics and electrical measurement. Sensors have been designed for use either in the tool or integrate within the composite component. Other techniques, such as those based on fibre optics, are in development. One of the more promising techniques is based on in-core fibre Bragg grating arrays. An added advantage of these systems is that they can also be used for subsequent component health and lifetime monitoring. No one technique is able to give all the required state of cure information. Most techniques rely on the measurement of a secondary property such as viscosity, speed of sound or electrical conductance from which the degree of cure / state of matrix resin chemistry is deduced. There is a requirement for low cost instrumentation and sensors that can be used to monitor aspects of the curing process. In the short term the equipment commercially available will have severe limitations and the development focus will probably remain in the more traditional area of process control. Any cure monitoring method adopted must be selected with the materials, process and end use of the composite in mind, to achieve optimum and economic results. Unfortunately, there is still no simple and inexpensive go/no go device available yet on the market.

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