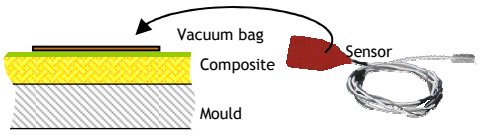
Resin flow front detection, cure monitoring.
Applications: R&D – cycle optimisation, process monitoring (temperatures, infusion and cure).
Domains: Aeronautics, Nautical.

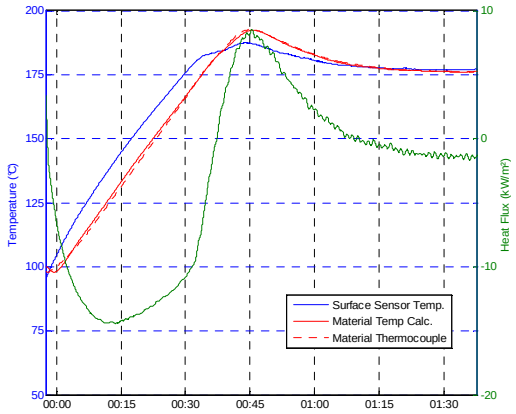
Principle: Resin infusion in reinforcement induces thermal changes which can be detected thanks to the high sensitivity of heat flux sensors. It is therefore possible to monitor material temperature therefore the complete cure cycle from the outside of vacuum layers.

Sensor positioning: Sensors are simply taped on the top of vacuum bag, on the area of interest.



Non intrusive sensors do not disturb the processing cycle since they do not touch the part.

Measured properties: Local heat flux (W/m²) and sensor temperature (°C) which is close to surface temperature of the vacuum bag. In a first approximation, measured heat flux is proportional to temperature difference between the part and the surface through the different absorbing layers.
The knowledge of the proportional coefficient and of surface temperature allows computation of composite temperature at any time (see figure below).

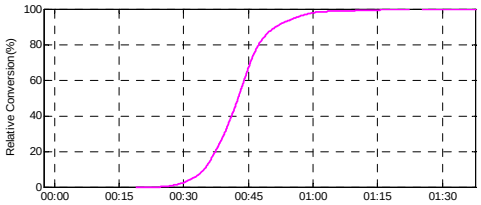


Heat Flux, Measured and Computed Composite Temperature (in red) seen from outside *of vacuum bag.*

Resin flow front detection is possible thanks to the modifications in thermal conductivity between dry and wet reinforcement. However, infusion is often done in isothermal conditions, it is therefore necessary to induce a small temperature gradient (1-2 °C) across the composite in order to improve the sensitivity of the system.

Cure **monitoring** is possible since polymerisation reaction produces heat which is detected by the sensor. It is then possible to detect reaction start, exothermic peak, and return to thermal equilibrium (end of cure). For isothermal reaction, heat flux is directly proportional to reaction rate. Cure cycle often implies temperature changes. In this case, it is necessary to process the signals in order to extract reactive heat flux from global heat transfer which contains mainly heating and cooling induced heat flux.

Kinetic analysis: Similar to DSC (Differential Scanning Calorimetry) once the baseline is known. Reaction rate is then global through all the part's thickness.



Applications: These measurements make possible real savings in development stage, **by seeing** the exact behaviour of resin infusion on real parts. The same quality of measurement can be obtained in production through all the life of the product, and becomes really precious for quality controls.

A post-processing tool for automatic analysis of cycles is available. This software tool extracts data useable for SPC control (flow ability, maximum temperature reached in the part, real heating rate, etc.) for a simple and transparent monitoring of the process.

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