



61996 Cure monitoring of carbon fiber reinforced polymers using a specific impedancemetry method

Huikangyue BAO¹, Philippe Marguerès², Philippe Olivier³.

¹Institut Clément Ader (Toulouse, FR).

During the manufacturing of airframe structures made of CFRP, a protocol of cure monitoring is essential to ensure production security and product quality. In this work, a cure monitoring method based on electrical impedance (Z) measurements is presented.

The correlation between rheological and electrical properties of thermoset polymer during polymerization enable us to characterize the behaviour of CFRP by measuring impedance. Based on this approach, a reliable and reproducible protocol has been developed [1]. The impedancemetry method enables us not only to monitor the degree of cure, but also to detect any faults at different stages of manufacturing of composite laminate [2]. According to impedance reference signatures, curing processes could be controlled, resulting in cost savings and quality improvements of composites for aeronautics.

A home-made low-cost multi-channels bench has been developed to measure bulk or surface impedance changes of CFRP laminate in real time. Copper mesh fabric is used as electrodes (Figure 1-a). Depending on different directions of measurement (Figure 1-b), 2-wires or 4-wires configuration could be selected to match different measurement ranges. The electrical analysis is based on impedance changes in terms of the magnitude $|Z|$ and the phase θ_z to highlight resistive and capacitive evolution of composite during curing. The result of differential scanning calorimetry technique (DSC) is used as a reference of critical points such as liquefaction, gelation, and vitrification of the matrix (Figure 1-c). These critical points could also be identified by impedancemetry (Figure 1-d).

An improved electrical-mechanical modelling would be developed in further studies to describe the virtual material to address composite impedance change during mechanical testing. Therefore, the impedancemetry method could be applied in SHM of airframe structures.

The proposed approach does not require a dedicated sensor because the composite is used as a sensor of its own state. Combination of embedded instruments and self-sensing materials could be of great interest for smart materials development.

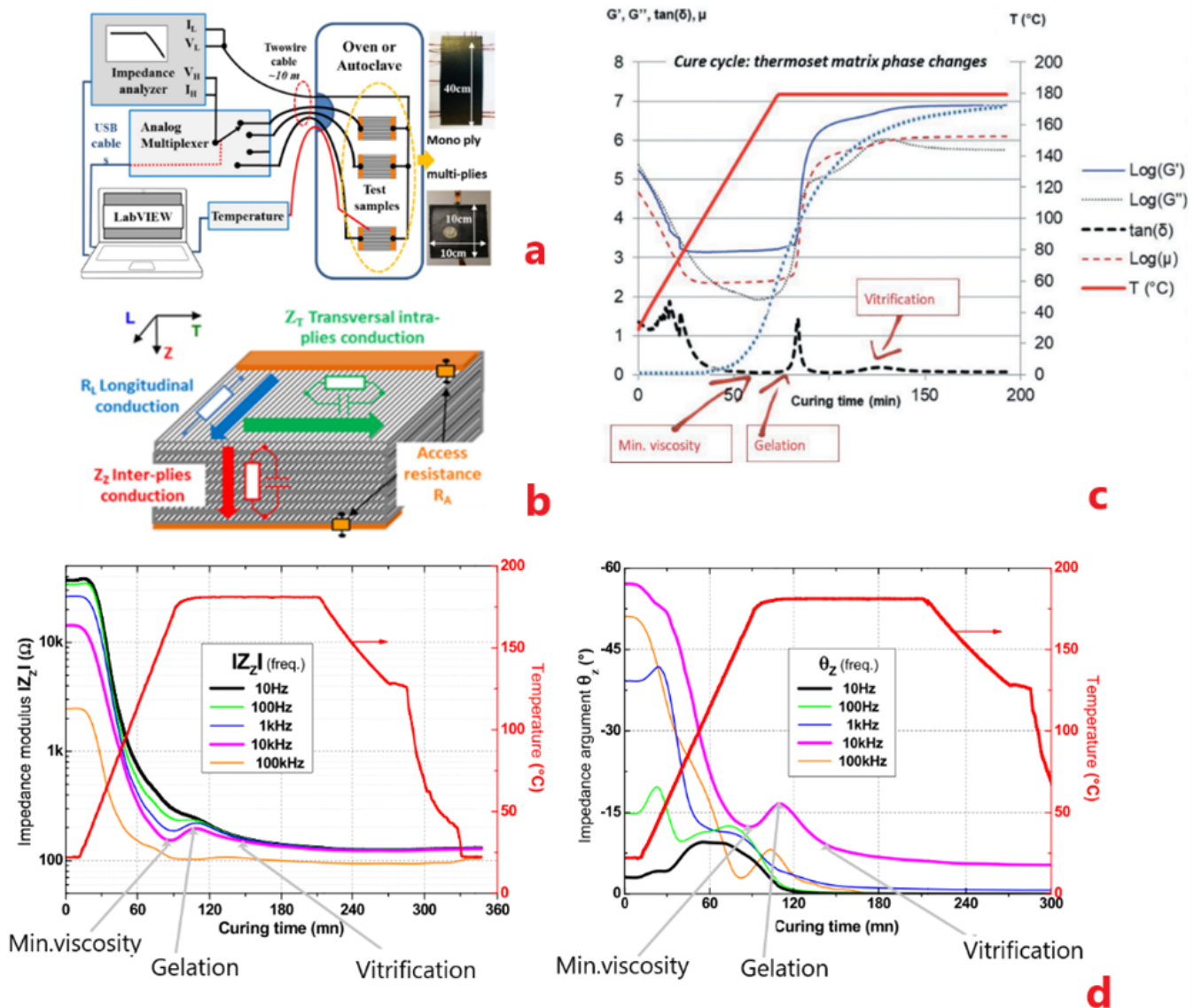


Figure 1 :a) Connection between the impedancemetry bench and laminate; b) CFRP laminate with diagonal electrodes; c) Rheological critical points of matrix M21 during curing; d) Through thickness impedance Z_z changes (magnitude and phase) of laminate T700/M21.

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[2] M. Mounkaila et al., "Modelling the electrical behaviour of carbon/epoxy composites and monitoring changes in their microstructure during oven and autoclave curing using electrical impedancemetry," *Smart Materials and Structures*, vol. 27, no. 8, 2018.

[3] M. Mahamadou, "Analyse impédancemétrique pour le suivi de cuisson ou de santé des structures composites carbone/époxyde : Vers des matériaux intelligents pour le PHM des structures composites," *Thèse, Université Toulouse III Paul Sabatier*, 2016.

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