VÉRONIQUE MICHAUD-ECOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

CAPILLARY EFFECTS

IN FIBER REINFORCED POLYMER COMPOSITE PROCESSING, A ZOOM ON THE FLOW FRONT

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ABSTRACT

Capillarity plays a major role in many natural and engineered systems, from nutrient delivery in plants, management of humidity in soils, to heat pipes and porous systems for spill recovery. In composite manufacturing, particularly in Liquid Composite Molding processes, capillary effects take place close to the resin/fiber interface forming at the wetting front. They are strongly affected by the flow dynamics of the viscous resin. In addition, the reinforcement phase forms an anisotropic and inhomogeneous pore network scaling from micron sized pores between fibers to millimeter sized pores between fiber bundles that are woven or stitched into the textile preform. The link between the thermodynamic and geometric considerations acting at these length scales is thus not trivial. These phenomena however play a crucial role in producing high quality composites: they have been shown to strongly correlate with void content in the final part. Despite their importance, capillary effects largely remain overlooked in composite processing. Their magnitude is considered a second order effect as compared to hydrodynamics, and it is difficult to characterize them due to a lack of adequate monitoring techniques to capture the time and spatial scale on which they take place. Interest is nonetheless rapidly increasing, due to a gain in process maturity and thus higher demand for high performance, low porosity composites and to recent advances in experimental techniques as well as numerical modeling methods. This presentation will review the main experimental techniques developed to investigate capillary effects in LCM processes, ranging from post-mortem analyses on cured parts, to extrapolation from unsaturated and saturated flow experiments and finally in-situ and fast observation techniques compatible with both translucent and non-translucent reinforcements. Based on our recent work, I will present approaches to quantify and predict capillary effects as a function of the nature and geometry of the reinforcement and the resin phase, with strategies for improving composite quality. Finally, I will highlight some remaining challenges in the analysis of capillary effects and their role in composite manufacturing.

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BIO

Véronique Michaud is currently Associate Professor, head of the Laboratory for Processing of Advanced Composites and Associate Dean of Engineering for Education, at the Ecole Polytechnique Fédérale de Lausanne, in Switzerland. She graduated in 1987 from Ecole des Mines in Paris with an engineering degree, in 1991 from MIT with a PhD in Materials Engineering, and obtained a Research Habilitation from INPG in France in 1994. After a post-doctoral research stay at MIT, she spent 3 years at Ecole Centrale in Paris for teaching and research in the Laboratory for Materials, Structures and Soils Mechanics, before joining EPFL in 1997. Her fields of research address fundamental aspects of composite materials processing, often including economic and environmental aspects to lower the overall product footprint, as well as the development of smart materials and structures including self-healing, shape and vibration control and tailored damping. She is the author of more than 300 publications, out of which about 150 in peer-reviewed journals, and several patents. She is also the co-founder of the start-up CompPair Technologies SA, which was created in 2020.