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Investigating porosity and fibre bundle deformation in thermoplastic composite plates through 2D multi-modal imaging techniques

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Abstract

This experimental study investigates impregnation mechanisms and porosity localization in thermoplastic composite plates using a displacement-controlled thermo-compression technique, representing the impregnation phase as a variant of a CRTM process with through-thickness matrix flow [1]. Plates were manufactured using varied compaction ratios (C_r) [2] of woven glass fibre and polypropylene in two stacking configurations. By controlling press displacement at eight sequential stages, targeted fibre volume fractions (V_f) were achieved as well as different partial impregnation states (Fig. 1). Samples from the central zone of these plates underwent microscopy analyses using fluorescence microscopy (FM) and scanning electron microscopy (SEM) to examine microstructures across full plate thickness at single glass fibre resolution. A novel two-step surface polishing protocol, integrating fluorescent dye and binding epoxy resin, was developed to minimize damage during polishing of the partially impregnated samples, such as fibre breakage and loosening. The correlative imaging workflow merged extended field images from both techniques to create high-fidelity composite images for both qualitative and quantitative porosity analyses (Fig. 3). This approach allowed the assessment of fibre bundle deformation at the meso-scale and porosity area fraction at the micro-scale relative to the macro-scale compaction ratio, aiding in understanding the polymer impregnation mechanisms in fibre bundles at different scales. Using advanced imaging techniques, the study provides insights into the evolution of microstructure in CRTM processes and how compaction ratios affect composite quality, potentially enhancing the understanding and optimisation of fluid-structure interactions in manufacturing processes like CRTM.

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Key-words

Thermoplastic matrix composites, multi-scale, porosity, multi-modal imaging, correlative imaging

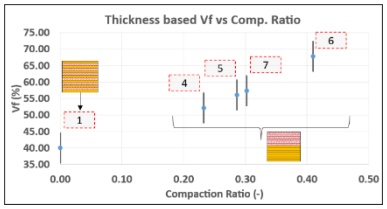

Fig 1: V_f vs C_r of manufactured plates

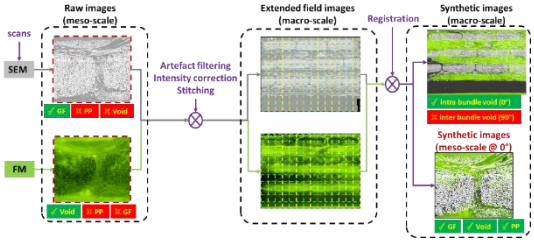

Fig 2: Correlative imaging workflow

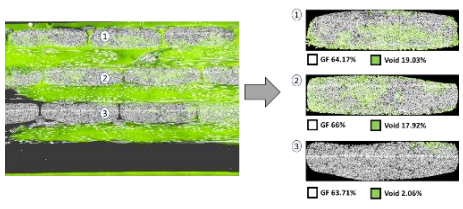

Fig 3: Quantitative analysis

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