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In-situ X-ray tomography reveals 3D higher order fibre buckling in composite prepregs

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Abstract

Draping of carbon fibre prepregs is widely used to create the desired form of composite parts with complex geometries. Imperfections introduced during this process are subsequently frozen into the structure during curing and often play a dominant role in determining stiffness, strength and durability. Despite their importance, the three-dimensional deformation mechanisms that develop in uncured prepregs during draping are still not well characterised, as most experimental studies rely on surface inspection or two-dimensional measurements. Using in-situ X-ray tomographic observations, we investigate the formation of fibre waviness in uncured carbon fibre prepregs subjected to imposed bending deformations that simulate draping operations. The measurements reveal a previously unreported three-dimensional higher-order buckling mode in nominally zero-degree plies, in which fibres buckle out of the bending plane. This deformation mode is not accessible through surface-based observations or conventional two-dimensional imaging and therefore remains hidden in standard experimental characterisation. The dependence of the buckling wavelength and morphology on consolidation pressure, ply lay-up sequence and fibre type is investigated systematically. The results show that both processing conditions and laminate architecture strongly influence the onset and spatial characteristics of this instability. To support the experimental observations, a laminate-scale model is developed that captures the essential features of the observed buckling mode and provides a mechanistic understanding of the development of higher-order fibre buckling during draping operations. These findings highlight the importance of three-dimensional characterisation for understanding forming-induced instabilities in composite materials and provide new insight into the origin of fibre waviness that may later control the structural performance of cured composite parts.

Keywords:

Composite manufacturing Carbon fibre prepregs Fibre waviness In-situ mechanics Uncured composites