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Multi-Scale Investigation on the Nonlinear Deformation of Flax Fibre Reinforced Composites Based on the Evolution of Microstructures

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ABSTRACT

Plant fibres are emerging as sustainable composite reinforcements. Compared to synthetic fibres, the hierarchical and twisted structure of plant fibres may produce microfibril angle (MFA) reorientation and untwisting time-varying behaviors after loading and consequently decide the mechanical response of plant fibre reinforced composites (PFRCs) in macro-scale. Existing theories, assuming homogeneous fibres, cannot accurately describe the multi-scale coupling nonlinear deformations of PFRCs. Based on this, a multi-scale analysis method on the nonlinear tensile responses of flax fibre reinforced composites (FFRCs) was proposed, focusing on the effect of the evolution of MFA in micro-scale and twist angle in meso-scale on the macroscopic tensile behaviors of FFRCs. Firstly, in micro-scale, a hierarchical constitutive model upon finite transformation was established to elucidate the nonlinear mechanism due to MFA evolution. Then, in meso-scale, a fine numerical model of impregnated flax yarns with twisted structure was applied to obtain the relationship between the twist angle and nonlinear deformation behavior. Finally, the macroscopic tensile performances of FFRCs were predicted by introducing the evolution of MFA and twist angle of flax yarn. The uniform model was employed for comparison. The results showed that the evolution of MFA and twist angle had a distinct influence on the nonlinear tensile behaviors of FFRCs. A significant agreement between the experimental and numerical results was achieved, considering the synergistic effect of the evolution of MFA and twist angle during the tension of FFRCs. The findings in this study provide a parameter foundation for the accurate mechanical prediction of PFRC structures in future.

KEYWORDS

Flax fibre; hierarchical; twist; modelling; mechanical properties

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