PREDICTING THE MECHANICAL BEHAVIOUR OF A NATURAL COMPOSITE: THE FLAX FIBRE

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Plant fibres and especially flax can be distinguished from most synthetic fibres by their intricate shape and intrinsic porosity called lumen, which is usually assumed to be tubular. However, the real shape appears more complex and might influence the fibre performance [1]. This work proposes a new vision of flax fibre lumen and an interpretation of its effect on fibre tensile properties based on high-resolution X-ray microtomography (µ-CT, voxel size of 150 nm and fibre clamping length of 140 µm) combined with a finite element analysis (FEA). Experimental results highlight the difficulty to draw a single geometric reference for the lumen, with variations observed along the fibres investigated, and mean porosity contents varying from 0 to 7.2%. The effects of such intricate fibre shapes on the mechanical properties were investigated by FEA with a model based on 3D fibres from X-ray µ-CT and tensile testing performed in the elastic domain. Numerical results demonstrate the decrease of elastic modulus as an effect of porosity and the development of stress heterogeneity, with a mixture of various deformation mechanisms including tension and shearing and triggered by geometrical considerations. Moreover, stress concentrations induced by surface roughness and complex lumen shape were observed [2], highlighting their possible implication in the failure mechanisms. The model was further refined by taking into account the cellulose microfibrils initial orientations and realignment upon tensile testing observed experimentally on flax fibres with contrasted defect density. The investigations were performed on SWING beamline at synchrotron SOLEIL, thanks to *in situ* X-ray diffraction. The results highlight a microfibril angle (MFA) decrease from 3 to 24% depending on the fibre, with initial MFA ranging from 4.7° to 7.4°. Moreover, the heterogeneous MFA along flax fibres and reorientation is evidenced by stepwise tensile testing. Finally, the results were again implemented in the FEA, which showed the influence of the microfibril realignment on the resulting apparent modulus, with a stiffening only partly explaining the non-linearities observed experimentally. Prospects include taking into account viscoelasticity and plasticity in the FEA, as well as damage mechanisms leading to fibre failure.

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