

Structural and mechanical characterisation of English Willow: a micro-CT study

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ABSTRACT

This research aims to understand how English Willow (*salix alba* var. *caerulea*) outperforms other wood species as a cricket bat. Wood is a natural composite and porous material, which inspires various designs of engineered advanced materials. As a major material for construction and sports equipment, wood's microstructures has not been studied widely in three dimensions at scales relevant to the cellular structure and fibres. English Willow is traditionally used as a material of choice to make cricket bats due to its lightweight and shock-resistance as well as not being significantly dented nor splintering on the impact of a cricket ball at high speeds.

This study involves in-situ compression tests of wood samples using a tri-axial compression cell (Saadatfar 2012). X-ray Computed Tomography (XCT) is utilised to acquire scans of the samples at multiple axial stress levels. XCT allows wood scientists to investigate the hierarchical and multi-scale structures of different wood species in three dimensions (3D). The 3D datasets of different materials are analysed using parallel 3D image processing tools. The high-resolution XCT images combined with numerical analysis provide us with detailed information on wood's microstructure, cells' shape and volume, inter-connectivity of the cells as well as structural anisotropy of the fibres. We thoroughly examine the mechanical and topological characteristics of inter-species (White Willow and Black Italian Poplar) and intra-species (English Willow and Kashmir Willow) using lab based techniques as well as numerical simulations in all three orientations.

Additionally the internal displacements of the specimens subject to triaxial compression are mapped for each increment of the loading. Each voxel of the 3D dataset can be traced during different steps of loading using a full field implementation of Digital Volume Correlation (DVC) algorithm, where we calculate the displacement to the sub-voxel level by locating displaced pixels based on the correlation coefficients of the surrounding pixels (Bay, 1999). Strain tensors of every pixel are also available to generate a strain field map to study the local deformation. The ultimate objective of the research is to solve the empirical rule of thumb, that why first-class cricket bat shall be made from English Willow with longitudinal-radial section (LRS) direction as the batting surface.

Our results show that both willow and poplar exhibit no specific failure zone beyond yielding strength/strain. The deformation is distributed through over all the fibres and no obvious fracture is found on packed fibres. This distinctive feature of wood, unlike other materials with specific fracture zone, can be investigated, understood and applied to manufacturing of other composite materials or porous materials.

References

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