Microstructure-stiffness relations of the ancient oak wood from the Oseberg ship

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ABSTRACT

The Oseberg ship is a more than 1,200 years old Viking vessel, one of three displayed at the Viking Ship museum in Oslo. It served as a burial chamber for two Viking women and was covered more than 1,000 years by clay and turf sods, before it was excavated in 1904. The oak wood of the vessel, though fully waterlogged and broken into many pieces, was in a fairly good condition, but had to be treated to be preserved for a longer period of time. For this purpose, a mixture of creosote and linseed oil was applied onto the surfaces of the strakes during air drying. Thereon, the ship was re-assembled nearly completely with the original strakes that were pressed into their original shape under steam. In 1926, the reassembled Oseberg ship was transported to the Viking ship museum [1].

Plans for a new museum made it necessary to asses risks of transportation of the collection, including the ships [2]. To estimate strength of the whole Oseberg ship structure, a Finite Element (FE) model was set up, which however needed mechanical properties of the wooden material as input. In a condition survey, the material was classified into three categories from 0 (good condition) to 3 (very poor condition). Mechanical tests were performed on small-scale specimen, in terms of three-point-bending tests [3] and ultrasonic sound propagation velocity measurements [4]. Moreover, the microstructure of the ships wood was investigated by using chemical analysis [5] and scanning electron microscopy (SEM) [6]. These microstructural characteristics, which have so far not been considered in the assessment, in combination with macroscopic mechanical tests were the motivation to apply micromechanical modeling techniques to represent the microstructural origin of the materials macroscopic 'effective' mechanical behavior. During a Short Time Scientific Mission of one of the authors, some samples were further investigated by measuring the density and by taking images under a light microscopy to study the hardwood-tissue structure.

For the purpose of taking into account microstructural characteristics in estimating the material stiffness and strength, a multiscale micromechanical model [7] that represents the hierarchical microstructure of hardwoods in five representative volume elements (RVEs) [Ia: polymer network – Ib: cellulose fibers – II: cell wall material – III: softwood – IV: hardwood] is applied. Therein, random homogenization theory - namely continuum micromechanics - and periodic homogenization theory – namely the unit cell method – are used in the framework of poromechanics. Model predictions for two samples of category 0 and of category 1, which are both considered as load bearing in the ship structure, are compared to corresponding experimentally observed properties.

Since the microstructure of the Oseberg oak wood is not fully resolved and understood in all detail, only ranges of input parameters of the model could be specified, based on the performed investigations, rather than definite values. In particular, variations in the density and in the microfibril angle (of the S2 layer, which incorporates about 80-90% of the wood fiber cell wall) give model predicted variations in the macroscopic 'effective' stiffness properties of the oak wood that can subsequently be compared to corresponding experimental results.

Model predictions reproduce quite well the ranges of stiffness properties found in corresponding bending and ultrasonic tests. However, for a higher accuracy of the model output, a more detailed look on the microstructure is required. This is currently under way and will constitute future research efforts.

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