Climate-induced cracks in wooden art objects

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Introduction

Oak wood has a heterogeneous structure composed of several different cell types such as vessels, tracheids, parenchyma cells and fibres. A good understanding of the failure behaviour of this complex structure is essential for the preservation of historical oak wooden art objects, as visible cracks and dimensional changes in these objects are aesthetically undesired. In recent years, the Furniture Conservation Department of the Rijksmuseum has carried out several challenging treatments on oak cabinets on stands decorated with marquetry. To analyse the damage observed on these cabinets in more detail, the Rijksmuseum organised a masterclass during which 17 pairs of Dutch seventeenth century cabinet doors were investigated [1]. The doors showed shrinkage and shrinkage cracks mainly located at failed joints in the oak substrate.

Research

To further investigate the cause of the damage observed on the art objects, the relation between fluctuations in the ambient climate and the damage resistance of oak wood is analysed. For this purpose, a numerical model is developed that can accurately simulate climate-induced damage development in oak wood. Climate-induced fracture is simulated by surrounding the continuum elements in a finite element model with interface elements equipped with a mixed-mode interface damage model presented in [2]. This approach allows for the description of complex cracking paths in arbitrary directions, including crack bifurcation, branching and coalescence. The moisture and energy transport are described by extended versions of Fick's law of moisture diffusion and Fourier's law of heat conduction. An important phenomenon that significantly affects the moisture content at moderate relative humidity, is moisture hysteresis. The hysteresis model presented in [3] is therefore implemented. Additionally, the formation of cracks reduces the heat and moisture fluxes, which is accounted for in the corresponding constitutive expressions through the damage parameter computed in the damage model.

Results

The numerical model is validated by means of a comparison with a closed-form solution for a one-dimensional steady-state hygral-mechanical coupled problem. In addition, the failure response of oak wood is analysed by considering complex effects of moisture hysteresis. The obtained results will be used to advise museums on future preservation strategies and on the development of sustainable guidelines for indoor climate specifications.

Reference

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