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Multiphysics of Wooden Artwork

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Extended Abstract

Wooden artwork exhibits a complex structural response to multi-physical loads. Stresses due to dead weight, changes in climatic conditions and constraints due to the structural composition are permanently changing loads and lead to damage. Numerical methods play an important role in damage prevention, as numerical analyses do not harm the valuable cultural artefacts and yet provide information about their (damage) behaviour.

Therefore, a comprehensive material modelling of wood is required. Recent progress in this area is presented e.g. in [1]. Wood is modelled as an anisotropic material, showing elastic behaviour for lower load levels. Damage and failure occur depending on the type of loading as ductile behaviour, modelled as multi-surface plasticity, or brittle failure, modelled by various approaches such as cohesive zones, the phase field approach [2] or the eigen-fracture method. In addition to this short-term features, also time-dependent response such as creep is considered as visco-elastic and visco-plastic behaviour and creep failure.

As a hygroscopic material, wood responds sensitively to climatic influences. Due to anisotropy in the material properties, hygro-expansion leads to internal stresses. A hygro-mechanical coupled analysis is required, taking into account moisture transport for water vapour and bound water as well as the dependence of mechanical properties on the wood moisture content. In some cases, heat transfer and thermo-hygro-mechanical analysis are also required [3]. For a realistic analysis of wooden artwork, non-wood materials such as bond lines and paint layers are also described. Furthermore, the heterogeneous and diverse nature of wood properties must be taken into account through uncertainty quantification.

This presentation shows recent progress in material formulations with a focus on multi-physical modelling and extension of mechanical models for multiple failure mechanisms and long-term behaviour. An application is presented that analyses panel paintings at climatic loading for restoration tasks. The numerical modelling presented is an important contribution to the future vision of a digital twin for historical artwork.

References

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3. J. Stöcklein, M. Kaliske, *Thermo-hygro-mechanically coupled modelling of wood including two-phase moisture diffusion for transient simulation of wooden structures at mechanical and climatic load*, Heat and Mass Transfer, **59** (2023), 67-79.