Reduced order models for efficient uncertainty quantification of wooden structures with inhomogeneous material properties

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Simulating natural fiber-based structures is not a trivial task as - in addition to the inherent geometrical complexity - environmental conditions influence the material properties significantly. Especially knots and fiber deviation of wooden components are decisive for the quantification of the material behavior [3]. To achieve better quantification of the material properties, the spatial heterogeneous properties can e.g. be modeled by the theory of random fields within a simulation workflow. However, such detailed and complex FE analysis are computationally costly and impractical for uncertainty studies with multiple analysis iterations. Hence, a low-fidelity model is developed here to enable an efficient multi-query scheme. For nonlinear problems, a widely used approach is the Model Order Reduction (MOR) technique, which combines data-based and physical knowledge. The MOR scheme assumes that the combination of a few basis vectors approximates the system sufficiently well with a reduced number of unknowns. For this study the idea is modified and transferred to applications for wood structures.

In general, the MOR workflow can be divided into an online and an offline phase. The offline phase is a preparation step, where full-order model results, called snapshots, are exploited to derive the main deformation modes. Besides a conventional singular value decomposition of the snapshot matrix, the proposed training of intrusive MOR schemes includes here an additional hyper-reduction step to approximate the nonlinear terms [1, 2]. Moreover, a suitable approach for inhomogeneous material properties is developed to create a low-fidelity model predestined for the uncertainty studies, conducted in the online phase. Within this contribution, an efficient analysis of the anisotropic and heterogeneous material behavior is proposed. The material properties of a natural fiber-based material are modeled by the theory of random fields and a statistical analysis is conducted. Therefore, an intrusive MOR model is created to efficiently evaluate the nonlinear, transient problems within the multi-query analysis.

References

[1] C. Bach. *Data-driven model order reduction for nonlinear crash and impact simulations.* PhD thesis, Technical University of Munich, Munich, Germany, 2020.

[2] C. Farhat, T. Chapman, and P. Avery. Structure-preserving, stability, and accuracy properties of the energy-conserving sampling and weighting method for the hyper reduction of nonlinear finite element dynamic models. *Numer. Methods Eng.*, 102:1077–1110, 2015.

[3] A. Rais, M. Bacher, A. Khaloian-Sarnaghi, M. Zeilhofer, A. Kovryga, F. Fontanini, T. Hilmers, M. Westermayr, M. Jacobs, H. Pretzsch, and J. W. van de Kuilen. Local 3D fibre orientation for tensile strength prediction of European beech timber. *Constr. Build. Mater.*, 279, 2021.