Identification of the Mechanical Properties of Particle Boards and Stochastic Simulation of the Behavior of Furniture

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In furniture industry, the European committee for standardization suggests to manufacture a prototype which undergoes a series of mechanical validation tests to ensure its strength and durability. Furniture are then designed and optimized from the experimental test results. The development of simulation tools adapted to the furniture industry would help analysts and designers to carry out upstream validation studies in order to accelerate the design process and reduce the costs incurred by experimental tests. The present work aims at (i) characterizing the material properties of particle boards and (ii) developing numerical tools for the simulation of the mechanical response of furniture to external loads.

Numerous 3D calculation tools allow to perform such simulations, but the field of furniture presents some specificities. On the one hand, the furniture elements generally have simple geometry and then can be assimilated to an assembly of plates and/or beams. On the other hand, (i) the material properties of particle boards exhibit strong variabilities due to their heterogeneous and anisotropic behaviors, and (ii) the connections between the different furniture parts can be complex and may induce some non-linear local effects that cannot be represented by simplified models based on plate or beam theories.

Figure 1: Test device

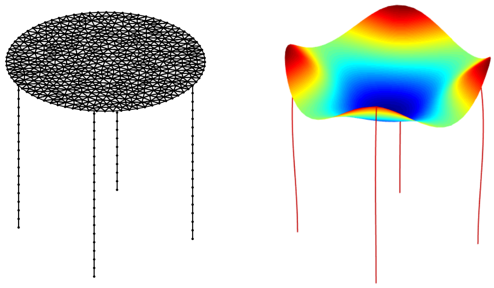

Figure 2: Finite element mesh and associated displacement field

An in-house computer code dedicated to furniture is developed and presents two specific features: (i) a library of link elements is provided to take into account local effects and (ii) the uncertainties in the material properties are modeled by random variables in a parametric probabilistic framework. This work deals with the second point and presents the identification of the elastic properties of wood materials (particleboards) from digital image correlation (DIC) [1]. A finite element plate model is also developed to simulate the furniture response under various load conditions.

Three-point bending tests are performed on samples of particle boards (see Figure 1). The macroscopic material properties (Young's modulus E and shear modulus G) are identified by minimizing the gap between the analytical displacement field for 3-point bending test and the measured displacement field using DIC [2]. A strong dispersion in the mechanical properties is observed between the different samples. The probabilistic model for the uncertain parameters E and G is constructed by using the maximum entropy principle (under the constraints defined by the available information on E and G) and the maximum likelihood method (using the experimental data collected on E and G) [3]. Two different plate models are implemented to simulate the behavior of a table (see Figure 2): (i) the classical thin (Kirchhoff-Love) plate model, which neglects the influence of transverse shear, and (ii) the thick (Reissner-Mindlin) plate model that takes account the transverse shear deformations. Both finite element plate models have been validated by benchmarks. The stochastic boundary value problem (which models the piece of furniture) is solved using a standard Monte Carlo method. Numerical virtual tests are performed to propagate the input uncertainties through the plate models and deduce probabilistic quantities of interest, such as first- and second-order statistical moments (mean and variance of the displacement field), confidence regions... It is then possible to assess the impact of the variabilities in the material parameters on the overall response of the structure.

References

[1] L. Chevalier et al.: Digital image correlation used to analyze the multiaxial behavior of rubber-like materials. *European Journal of Mechanics - A/Solids,* 20(2):169-187, 2001.
[2] H. Makhlouf et al.: A stochastic approach for the evaluation of the reliability of wood furniture in an industrial context: managing virtual standardization tests. *Mechanics & Industry*, 17(5):503, 2016.
[3] C. Soize: Random Matrix Models and Nonparametric Method for Uncertainty Quantification. *Handbook of Uncertainty Quantification*. Springer International Publishing, Cham, 1-69, 2016.