M.Sc. Wood Technology Master Thesis

Numerical Investigation of a Wooden Spring System

Abstract

The tendency towards the use of renewable materials and customer demand for natural product are constantly growing. In this trend, wood is an interesting material and new applications can be developed. For example, the Swiss bed manufacturer Elite SA is trying to replace the metallic coil springs present in the box-springs by wooden ones. The present study focuses on the development of finite element (FE) models which predict the short and long-term mechanical behaviour of a wooden spring prototype. The validation of the models was achieved by comparing their results to experimental tests carried out on samples presenting various geometrical parameters as well as different wood species (spruce, ash and beech). Experimental work was also performed in order to characterize the appropriate mechanical properties of the material to be used in the developed FE model. The elastic FE model showed accurate results with a discrepancy lower than 10 % in all cases. The viscoelastic FE model presented accurate results for the species that was characerized experimentally. Greater discrepancies were observed for the two other species.

Materials and Methods

A FE model describing the elastic behavior of the spring system was developed in Ansys® using orthotropic material properties retrieved from the literature. In parallel, experimental tests were carried out on specimens of various dimensions and produced out of three wood species: Norway Spruce (*Picea abies*), European Ash (*Fraxinus excelsior*) and European Beech (*Fagus sylvatica*). The stiffness determined with both methods were compared in order to validate the FE model.

A parametric study was performed to assess the influence of two geometrical parameters (namely the length and thickness of the slats) on the mechanical behavior of the spring as well as the influence of the elastic material properties.

In order to predict the long-term mechanical behavior of the spring system, a viscoelastic FE model was created and its results compared with experimental data. Due to the lack of viscoelastic properties available in the literature, the characterization of a wood species (ash), was performed. Tension tests and creep tension tests were carried out at constant relative humidity and temperature on samples of the three anatomical directions. The viscoelastic parameters were determined by fitting the 3 average creep curves on a 5-branches Generalized Maxwell Model.

Results

The elastic FE model, using spruce and a reference geometry, showed a discrepancy of 3.7 % with the average experimental stiffness. For the other species and geometry variants, a maximum discrepancy of about 10 % was observed. The FE model being stiffer in any cases except for beech samples and spruce samples with the longest slats (120 mm).

Concerning the viscoelastic FE simulation of the spring system, in the case of spruce, it was found that the model predicts a higher relative creep deformation but a lower elastic deformation than that obtained with the viscoelastic and elastic experiments. Regarding the viscoelastic simulation of the springs made out of ash, deformations close to the viscoelastic experiment were obtained. The viscoelastic FE model of beech showed qualitatively good results with a relative creep deformation similar to that measured. Unfortunately, a non negligible offset was observed between the results of the experiment and those of the model.

Conclusion

The accuracy of the prediction of around 10 % is deemed perfectly acceptable for wood simulation. Regarding the assessment of the long-term behavior of the spring prototype, it was revealed that an approximation of the actual behavior can be achieved, but it appeared that the absolute deformation could not be predicted accurately. Some improvements could be achieved by determining the mechanical properties of the two other species.

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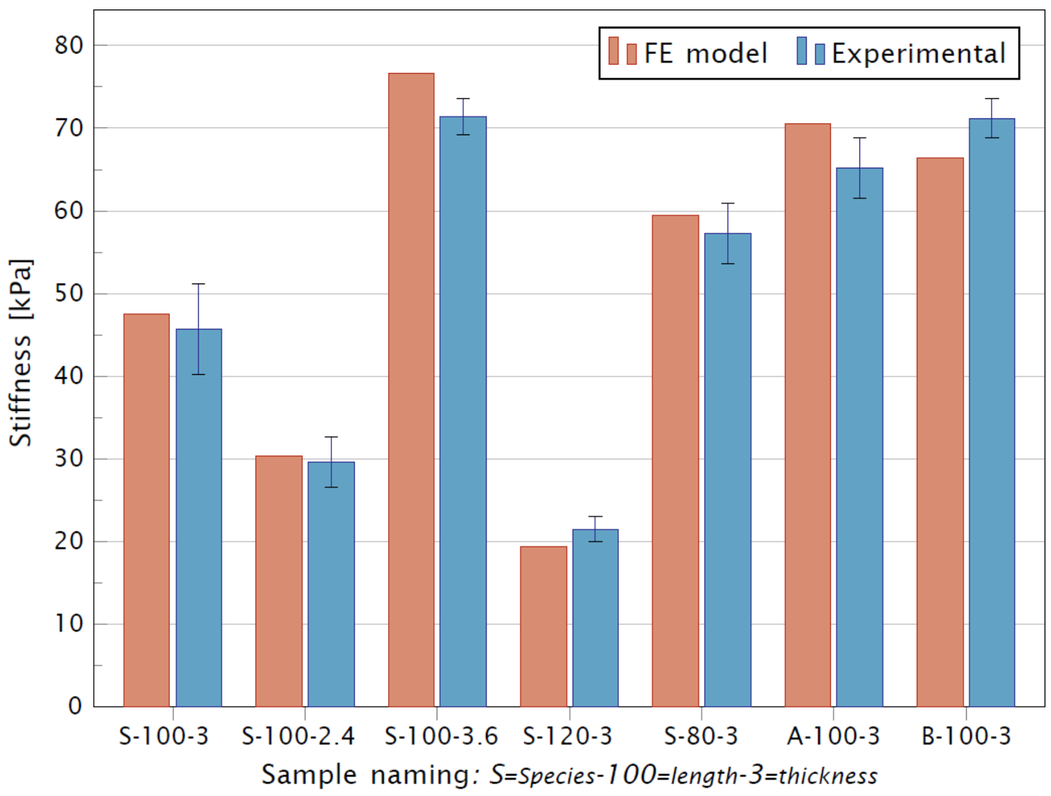

Comparison of the experimental stiffness and the one predicted by the FE elastic model for the different samples.

Picture presenting the experimental samples next to the numerical model in a deformed state.

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