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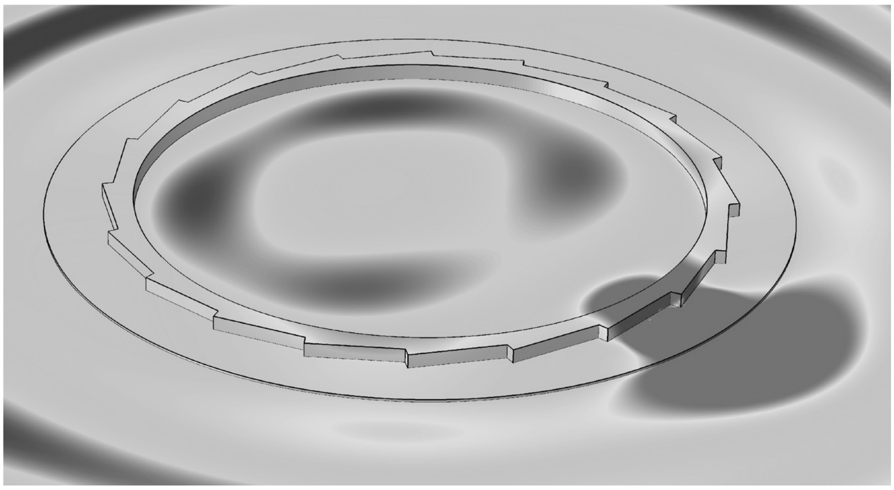

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Proceedings of the 25th Nordic Seminar on Computational Mechanics
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Numerical modelling and optimization of all plywood sandwich panels with rib-stiffened cores

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Summary. The current paper deals with numerical modelling of all plywood sandwich panels with rib-stiffened core. Commercially available finite elements code ANSYS has been implemented to simulate mechanical behaviour of sandwich panels in bending, according to the EN 789 standard. It has been confirmed that in order to simulate plywood a multilayered panel model with shell type elements could adequately represent the mechanical behaviour of such a structure sufficiently well. Developed parametrical model has been initially validated with experimental results showing less than 10 % scatter among finite element model and physical model. Following this a validated numerical model has been implemented for structural parameter optimization resulting in significant improvement of initial panel design.

Key words: plywood, sandwich panels, ANSYS

Introduction

All plywood sandwich panels with hollow core structure could offer significant weight reduction comparing with conventional plywood boards for applications where the lightweight design could provide cost saving benefits in long term perspective, like freight cargo transport. However in order to develop effective therefore functional product some research effort is required to design a reliable methodology with sole ability to predict mechanical behaviour of such item.
The finite element method (FEM) analysis is well accepted design methodology by all sectors of industry and for sure scientific institutions. For example, numerical modelling of wood based sandwich panels are extensively studied and described in several recent papers [1,2] where good correlations between experimental and numerical results were found.
All plywood sandwich panels with rib-stiffened and corrugated plywood core has been experimentally studied earlier by Zudrags [3] with aim to increase plywood specific stiffness. Kalnins [4] described theoretically optimal cross–sections configurations for sandwich panels with rib-stiffened cores.
The aim of current research is to extend and to improve the numerical model`s accuracy for design of sandwich panels with multi angular stiffener orientations: longitudinal, transverse and diagonal direction along panel length. Moreover numerical models are validated with

experimental tests in four point bending mode. Once numerical models has been validated and the convergence approved an optimization procedure with aim to increase stiffness/weight ratio of sandwich panels has been realised.

Materials and methods

Numerical model has been built using 4-node SHELL181 elements with multilayered structure (1.3 mm thin layers) implementing the birch mechanical properties. Panel's geometrical tolerance and loading conditions are kept as close as possible to the experimental set up. Numerical model is made parametrical to be suitable for further optimizations tasks. The FE mesh step of 10 mm has been assigned to sandwich plate (Figure 1). Both deflection at the panel mid-span as well as strains and stresses at various plies have been extracted and applied as constraint for optimisation task.

Four point bending test on static load frame INSTRON 8802 (Figure 1) has been performed according to EN 789 [5] for several types of sandwich panels (Table 1) in order to verify if developed numerical models appropriately represent the mechanical behaviour. The distance between supports is 1000 mm and between loading points 200 mm. The bending deflection of the panels have been measured with LVDT deflectometer at the bottom of the panel`s midspan. All sandwich panels were tested in elastic range up to 22 mm (about 1/50 of the span length) to deliver stiffness properties of such structure without reaching the ultimate load. Moreover in structural engineering applications deflection extending 1/150 of the span is restricted by legislation thus experimental results are within the range of good engineering practice

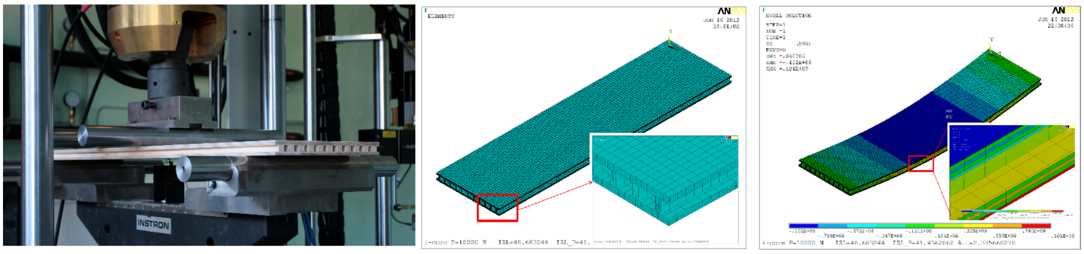

Figure 1. Experimental test set-up in line with level of detail of numerical model of rib-stiffened panel and a stress plot in each ply.

Table 1. Specification of tested panels

Series number	Direction of stiffeners	Average thickness, [mm]	Thickness of stiffener, [mm]	Distance between stiffeners, [mm]	Surface thickness, [mm]	Surface plies orientation
Nr. 1	Diagonal	28.21	14.4	22.0	9.0	/-/-/-/
Nr. 2	Transverse	27.65	14.4	27.0	9.0	-/-/-/-
Nr. 3	Longitudinal	28.42	14.4	22.0	9.0	/-/-/-/

/ fibres direction parallel to panel's longitudinal direction

fibres direction perpendicular to panel's longitudinal direction

Design parameters considered for the sandwich panel cross-section optimizations are following: the panel height, the thicknesses of separate components – the face sheets and stiffeners, all expressed in odd number of layers. Metamodelling technique has been employed to acquire sensitivity of each parameter and mechanical responses of plywood sandwich panel. The sequential experimental design based on Mean Square Error (MSE) space filling criteria has been elaborated in order to sample the design variables within the domain of interest. The optimization function is to maximise the stiffness/weight ratio.

Results and discussion

In order to compare the experimental and numerical results, the load/deflection and load/strain curves have been compared with numerical results obtained from ANSYS. It is obvious that sandwich structure has fully elastic mechanical behaviour within tested deflection range and linear numerical model describes structure behaviour sufficiently well. The difference between average experimentally obtained deflection at 5 kN load magnitude and one obtained numerical not exceeding 10 % for panels with diagonal, transverse(Figure 2) and longitudinal (Figure 3) orientation of stiffeners

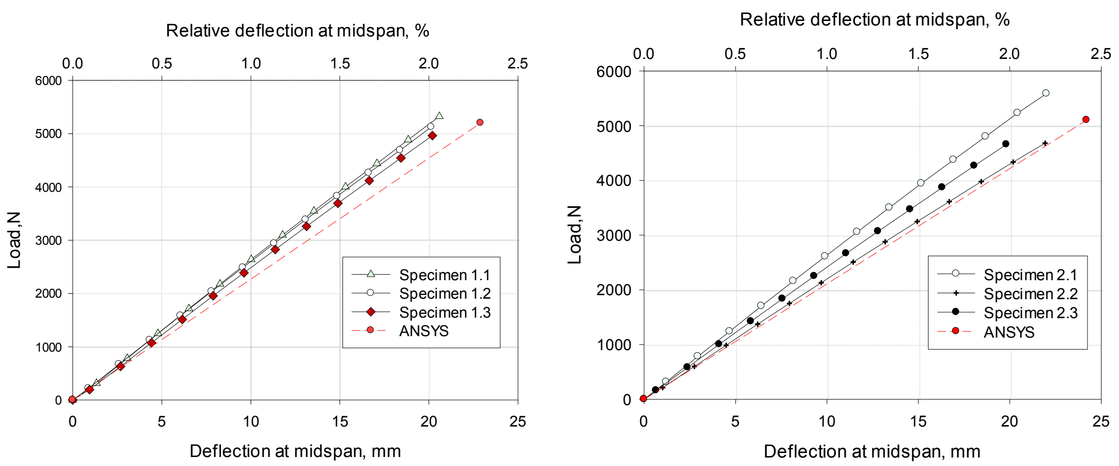

Figure 2. Load/deflection curves for panels with diagonal and transverse orientation of stiffeners

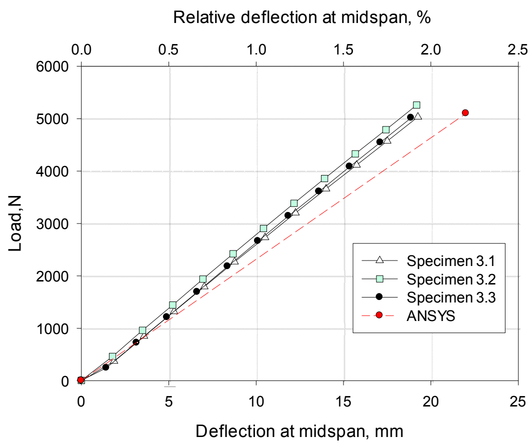

Figure 3. Load/deflection curves for panels with longitudinal orientation of stiffeners

Taking into the consideration a natural wood material property scatter, obtained accuracy of numerical model could be considered as adequate for employing it in further optimisation tasks. An overall efficiency of all plywood sandwich panels have been demonstrated by formulating Pareto optimization problem (Figure 3) where maximization of relative stiffness ΔK is done simultaneously by minimizing the relative volume ΔV of the panel.

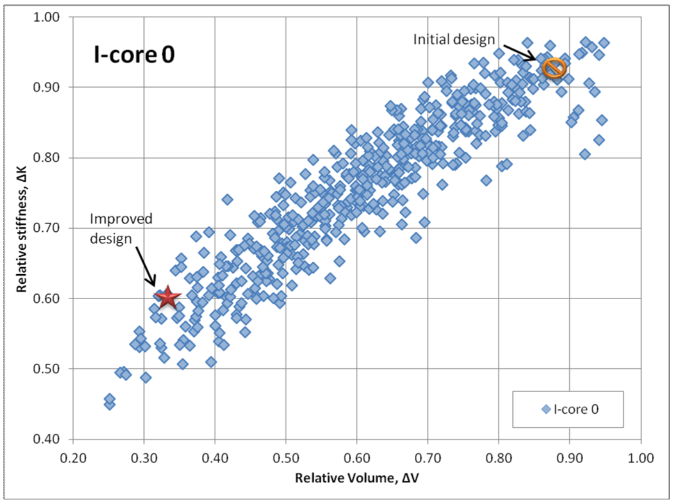

Figure 3. Pareto optimality plot for panels with longitudinal stiffeners direction.

Relative stiffness is acquired dividing numerically calculated conventional plywood board deflection with calculated deflection of sandwich panel with same length and thickness, under the same loading conditions. Relative volume is acquired by dividing sandwich panel volume with full plywood panel volume. Using these plots is possible to select beneficial combination of variables as well as improve initial design of prototype panels. It has been concluded that numerical optimisation task has generated improved design scenarios with up to 80% weight efficiency. A further prototyping will be carried out in order to validate the optimisation results.

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