NUMERICAL SIMULATION OF SWELLING AND SHRINKING BEHAVIOUR OF ROUNDWOOD-TRUNKS

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ABSTRACT: Wood is nature´s versatile building material. It has minimal environmental pollution and a range of excellent technical properties. Therefore it is obvious to use wood for the construction of wind power plants in order to improve their sustainability and profitability.

The idea is to use locally grown roundwood-trunks for the wind tower construction without using long distance transport. In this case the roundwood is exposed to harsh weather with alternating moisture and temperature conditions. To reduce cracks caused by shrinking some manipulations like relief grooves can be applied on the roundwood-trunks. Also the structural connections can be affected due to swelling and shrinking behaviour of roundwood. To develop suitable connections for service class 3 constraints from swelling and shrinking have to be avoided. For this reason a numerical calculation model is set up to estimate the swelling and shrinking behaviour of roundwood and roundwood connections.

This paper presents numerical simulations with the finite element method (FEM) to estimate the stress in roundwood-cross-sections caused by shrinking. First a roundwood-cross-section without machining (reference) is calculated and checked for plausibility. Then three machined roundwood-cross-sections are calculated and compared with the reference.

KEYWORDS: round-wood, swelling, shrinking, finite element method, numerical simulation, relief groove, cracks

1 INTRODUCTION

The International Engineering Office "BERNARD Ingenieure" launched a research project to develop wind power plant towers of round-wood-trunks. The aim is to use the locally grown logs for the wind tower construction without long distance transport. Moreover, wood is a renewable material that offers high strength with low weight and together with short transport distances wood provide an optimal CO_2 balance.

By using wood in outdoor area (service class 3) large differences of moisture can occur. These differences induce stress that often results in cracks.

The focus in this paper will be on the numerical simulation of stresses in the cross-section of round wood caused by alternating moisture contents. Three machined round-wood-cross-sections are calculated and compared with the reference.

2 PROJECT DESCRIPTION

The research project "HOLZWIND" is a Cooperation of the company "BERNARD Ingenieure", the technology

company "Technik Wille", the small wind power plant manufacturer "Silent Future Tech" and the University of Innsbruck. The project is funded by the Austrian Research Promotion Agency (FFG) powered by climate and energy funds.

The project consists of the following three work packages:

- WP1: development of a suitable connection system
- WP2: computational calculations and simulations
- WP3: experimental investigations.

This paper describes the computational simulations of the shrinking behaviour of roundwood which is part of WP2. The development of the connection system and the experimental investigations cannot be shown in this article due to patent rights.

3 NUMERICAL SETUP

To investigate the swelling and shrinking behaviour of round wood, numerical investigations with the FE program "RFEM" are carried out. The analysis is performed on a rotationally symmetric system with 30 cm diameter. The nodes of the FE model are fixed with in plane displaceable supports. The plane strain condition is approximated by setting the Poisson's ratio to zero. The swelling and shrinking behaviour are simulated using a temperature change in the cross section by adapting the temperature expansion coefficient to the differential shrinkage rate. The

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analysis is performed with orthotropic, linear elastic elements, i.e. using the expansion coefficient and elastic modul for radial and tangential direction. To approximate realistic moisture fluctuation a moisture reduction of 4% in the sapwood and 1% in the heartwood is applied.

A total of four numerical investigations are carried out (see Figure 1). First, the roundwood-cross-section is simulated without any machining (reference). Then a relief groove is applied to the centre of the roundwood-cross-section. Next four relief grooves in the sapwood are applied. At last the heartwood is removed totally.
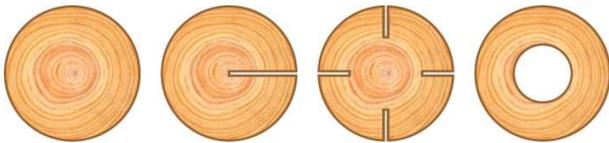

Figure 1: The reference (left) and the three machined logs

4 RESULTS

The pictures bellow shows the stress in tangential direction. The yellow areas are tension stress the blue areas are pressure stress.
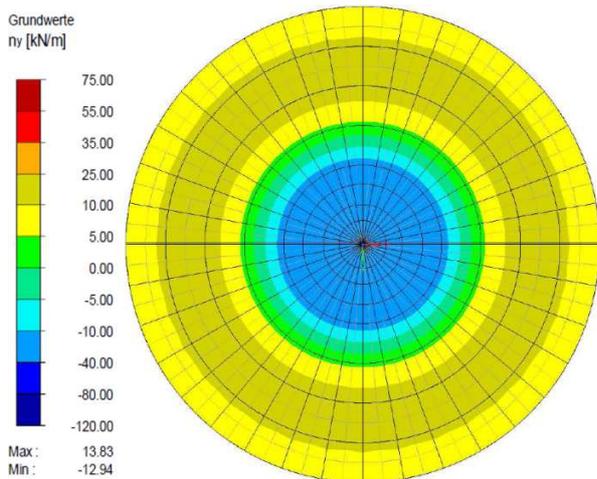

Figure 2: Stress in tangential direction (reference)

In Figure 3 the tensile stress in the outer parts and - to reach equilibrium condition - the compression stress in the inner parts of the roundwood can be seen.
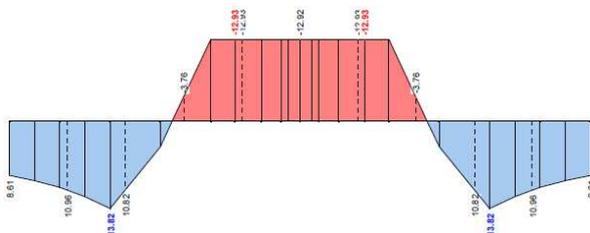

Figure 3: Stress along a centrically cut (reference)

In Figure 4 one relief groove is applied. The stress in the outer parts decreased significantly compared to the reference.
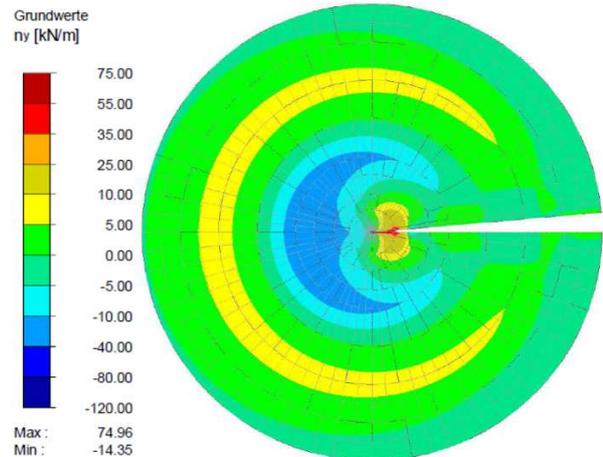

Figure 4: Stress in tangential direction (one relief groove)

In Figure 5 four relief grooves are applied. The results illustrate the reduction of the tensile stress in the outer parts of the cross-section.
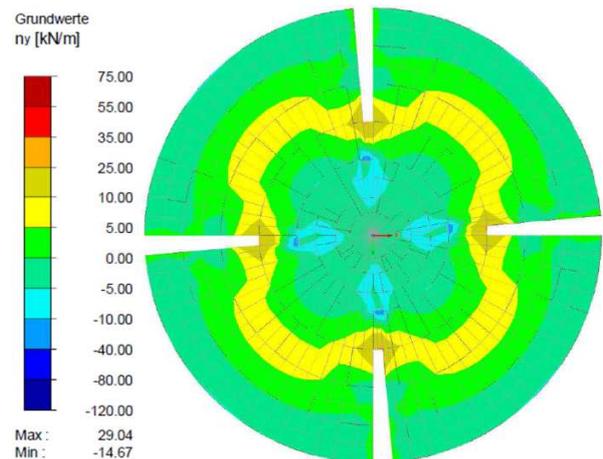

Figure 5: Stress in tangential direction (four relief grooves)

A complete comparison of the three different machined roundwoods with the reference will be made in the final paper.

5 CONCLUSIONS

With appropriate machining of roundwood, the cracking caused by shrinkage tensile stress can be reduced significantly. But not all machining reduce the tensile stress in the same dimensions. More detailed conclusions will be made in the final paper.