Effects of cell wall ultrastructure on the transverse anisotropy of wood shrinkage

Wiesław OLEK\textsuperscript{1)}, Girma KIFETEW\textsuperscript{2)}, Jan T. BONARSKI\textsuperscript{3)}, Erik MARKLUND\textsuperscript{4)}

\textsuperscript{1)} Faculty of Wood Technology, Poznań University of Life Sciences, Poland
\textsuperscript{2)} School of Engineering, Linnaeus University, Växjö, Sweden
\textsuperscript{3)} Institute of Metallurgy and Materials Science, Polish Academy of Sciences Kraków, Poland
\textsuperscript{4)} Division of Materials Science, Luleå University of Technology, Sweden
Introduction

The transverse anisotropy of wood shrinkage is not explained by existing theories:

- effects of ray cells alignment,
- interaction between earlywood and latewood,
- differences of MFA in tangential and radial walls,
- middle lamella theory,
- geometrical distribution of cell wall tissues.

The spatial distribution of cell wall polymers was not yet applied for explaining the mechanism of the anisotropy.
Introduction

Hemicelluloses - the most hygroscopic component of wood with the highest contribution in wood hygroexpansion.

The ultrastructural organization of hemicelluloses can reveal different character in the radial and tangential cell walls.

The ultrastructural organization of wood polymers can be investigated using the 3D crystallographic texture function (here Orientation Distribution Function).
Objective

To verify the hypothesis on differences in cell walls polymers distribution as a mechanism governing the transverse anisotropic shrinkage behavior of wood.
Experimental

Material:

- Scots pine wood (*Pinus sylvestris* L.),
- 60 years old tree harvested in Sweden,
- Samples from:
  - sapwood (mature wood from the 42nd growth ring)
  - heartwood (mature wood from the 18th growth ring)
  - heartwood (juvenile wood from the 9th growth ring)
- Samples – rectangular prisms 5·15·20 mm (radial, tangential and longitudinal directions respectively),
- Earlywood was subjected to X-ray diffraction.
Experimental

Texture experiment:

- X-ray diffraction technique,
- texture goniometer, filtered CoK\(\alpha\) radiation,
- Schulz back-reflection method,
- set of incomplete pole figures registered for (101), (002) and (040) lattice planes.
Experimental

Texture experiment:

Pole figures measured in the range of $\alpha = 0-75^\circ$ and $\beta = 0-360^\circ$, 642 diffraction spectra were registered during a single experiment.

642 positions of a sample during a measurement = area of incomplete pole figure

unmeasurable area
Experimental pole figures – input data

Heartwood (mature wood from the 18th growth ring)
Experimental pole figures

Orientation Distribution Function (ODF)

- Complete pole figures
- Inverse pole figures
- Additional (non-measurable) pole figures
- Volume fraction of texture components
Results

Complete pole figures

Heartwood (mature wood from the 18th growth ring)
Results

"An inverse pole figure is an angular distribution of a chosen specimen direction with respect to the crystal coordinate system."

Results

Heartwood (juvenile wood from the 9th growth ring)
Results

Heartwood (mature wood from the 18th growth ring)
Results

Sapwood (mature wood from the 42nd growth ring)
Results

The maximum values of Inverse Pole Figures identified for:
- tangential direction (radial cell wall) \( \text{IPF}(T)_{\text{max}} \)
- radial direction (tangential cell wall) \( \text{IPF}(R)_{\text{max}} \)

The ratio of the maxima calculated as \( \frac{\text{IPF}(R)_{\text{max}}}{\text{IPF}(T)_{\text{max}}} \)

The ratio reflects the anisotropy of the spatial arrangement of the ordered areas.
## Results

<table>
<thead>
<tr>
<th></th>
<th>IPF(T)$_{\text{max}}$</th>
<th>IPF(R)$_{\text{max}}$</th>
<th>IPF(R)$<em>{\text{max}}$/IPF(T)$</em>{\text{max}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heartwood - juvenile wood 9th growth ring</td>
<td>2.2</td>
<td>4.9</td>
<td>2.23</td>
</tr>
<tr>
<td>Heartwood - mature wood 18th growth ring</td>
<td>3.5</td>
<td>6.6</td>
<td>1.88</td>
</tr>
<tr>
<td>Sapwood - mature wood 42nd growth ring</td>
<td>2.6</td>
<td>3.9</td>
<td>1.50</td>
</tr>
</tbody>
</table>
Concluding remarks

1. The significant differences in cell wall polymers distribution were found.

2. The differences were evident when comparing the Inverse Pole Figures of the tangential and radial directions.

3. The simplest quantification of the differences was made by calculating the ratio of maximum values of the corresponding Inverse Pole Figures.

4. The ratio was proportional to the shrinkage anisotropy.

5. Future work: identification of the crystallographic orientations, quantification of changes of the orientations related to the T and R directions.