

Evaluation at Nano-Scale of Hot-Water Extracted Ponderosa Pine Chips

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Objective

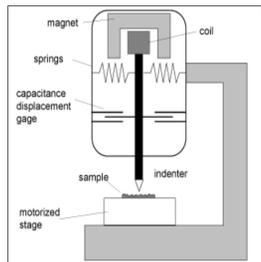
Use nanoindentation to find evidence of alterations to Ponderosa pine cell wall properties due to hot water extraction

Hot-Water Extraction (HWE)

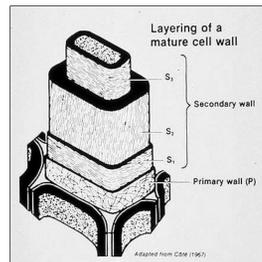
- HWE is a process at high temperature and pressure to extract chemical constituents from wood (e.g. wood chips)
- HWE of ponderosa pine chips is hypothesized to affect hardness and Young's modulus of the cell wall
- It is hypothesized that HWE changes hardness and Young's modulus of wood due to changes in chemical composition of cell walls. The change on chemical composition is mainly due to the removal of hemicelluloses, the redistribution of lignin within the cell structure, and the increased degree of crystallinity of cellulose (Stanzl-Tschegg et al. 2009).
- Mechanical properties before and after HWE can be tested via nanoindentation

Nanoindentation

- The nanoindenter consists of a tip that can indent the sample with various loads in order to determine hardness and Young's modulus on the nanoscale level.
- Nanoindenters use diamond tips to indent small material samples.
- Highly sensitive electronic equipment is used to calculate mechanical data.



A diagram of a nanoindenter.²



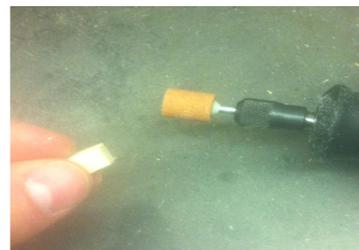
A schematic diagram of a cell wall, showing The S2 layer, which was indented in this study.³

Sample Preparation

To prepare samples from ponderosa pine chips, a series of steps were required. Ponderosa Pine chips were hand selected by thickness (in order to most effectively cut out shapes with little waste).



Step 1: Sand woodchip to a rectangular box shape



Step 2: Grind away corners to produce apex shape



Before and after step 2



Step 3: Shave nanoscale layers from the top of the apex using a microtome



Step 4: Mount the sample onto magnetic disk



A finished treated pine sample, mounted on a 10mm magnetic plate

Calculations

Reduced Young's modulus is the resistance of a body to deformation under stress. During nanoindentation it is given by :

$$E_r = \frac{\text{stress}}{\text{strain}} = \frac{\sqrt{\pi}}{2\sqrt{A(h_c)}} \times S$$

Where A is contact area as a function of depth (h_c), and S is stiffness. Hardness measures the resistance of the wood to indentation, and is given by:

$$H = \frac{P_{\max}}{A(h_c)}$$

P_{\max} is the loading pressure. A depends on nanoindenter tip geometry.

Results

	UP	TP	Variation (%)
Modulus (GPa)	5.68 ± 0.44	4.42 ± 0.86	-22.2
Hardness (GPa)	0.27 ± 0.01	0.21 ± 0.07	-22.2
Contact Depth (nm)	319.1 ± 17.1	409.46 ± 136.7	28.3

Conclusions

Hardness and Modulus have been decreased by approximately 22% as consequence of HWE of ponderosa pine. This result is coherent with previous works that reported a decrease of mechanical properties at the macroscopic level.

References

1. Stanzl-Tschegg, S., Beikircher, W., Loidl, D., Comparison of mechanical properties of thermally modified wood at growth ring and cell wall level by means of instrumented indentation tests, *Holzforschung*, Vol. 63, pp. 443–448, 2009
2. www.nanoindentation.cornell.edu/Machine/commercial_machine.htm
3. www.swst.org/teach/set2/struct1.html

Acknowledgements

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For Further Information

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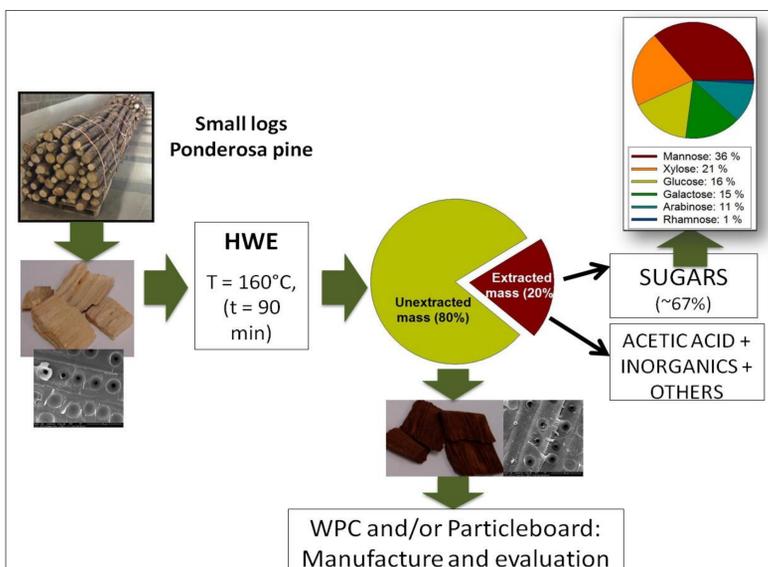


Diagram of the process of HWE of Ponderosa pine

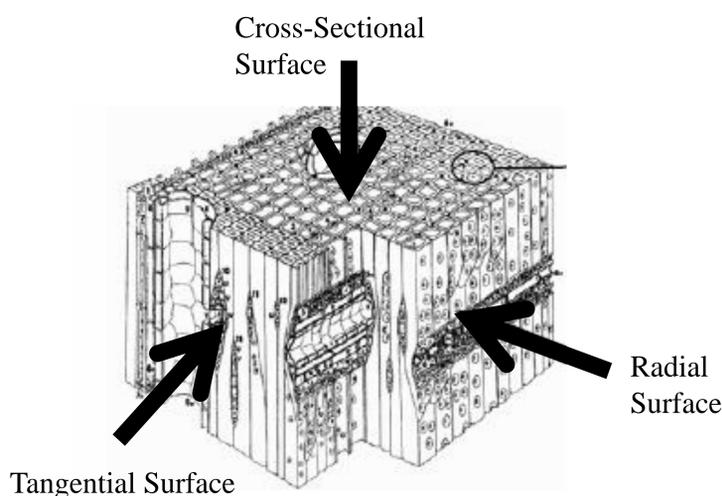


Diagram of the wood grain directions considered in the tests