Enhancing the mechanical properties of pine wood through a densification process for eco-friendly adhesively bonded joints

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Introduction

Wood is a versatile and renewable material, valued for its durability, resistance to environmental factors, mechanical strength, and lightweight nature [1]. However, its complex and heterogeneous nature, influenced by factors such as species, growth conditions, and defects, presents challenges for its use. Densified wood has been proposed as a solution to improve predictability and enhance mechanical properties [2]. This study examines the strength and fracture properties of natural and densified pine wood, exploring their viability as sustainable alternatives for composites in high-performance industries.

Experimental methodology

Densification procedure

The densification process consisted of two main steps:

- Chemical bath using a solution of 2.5 M NaOH and 0.4 M Na_2SO_3, boiled for seven hours. This allowed the chemical catalyst to penetrate the cell walls, increasing cell volume.
- Boiled in deionized water for an hour to remove the catalyst. The final step involved a thermo-mechanical procedure.

Wood blocks were placed in a hot-press with a steel mold for 24 hours at 3 MPa and 100°C, compressing and deforming the cell walls without damaging the fibers. This led to increased wood density and strength.

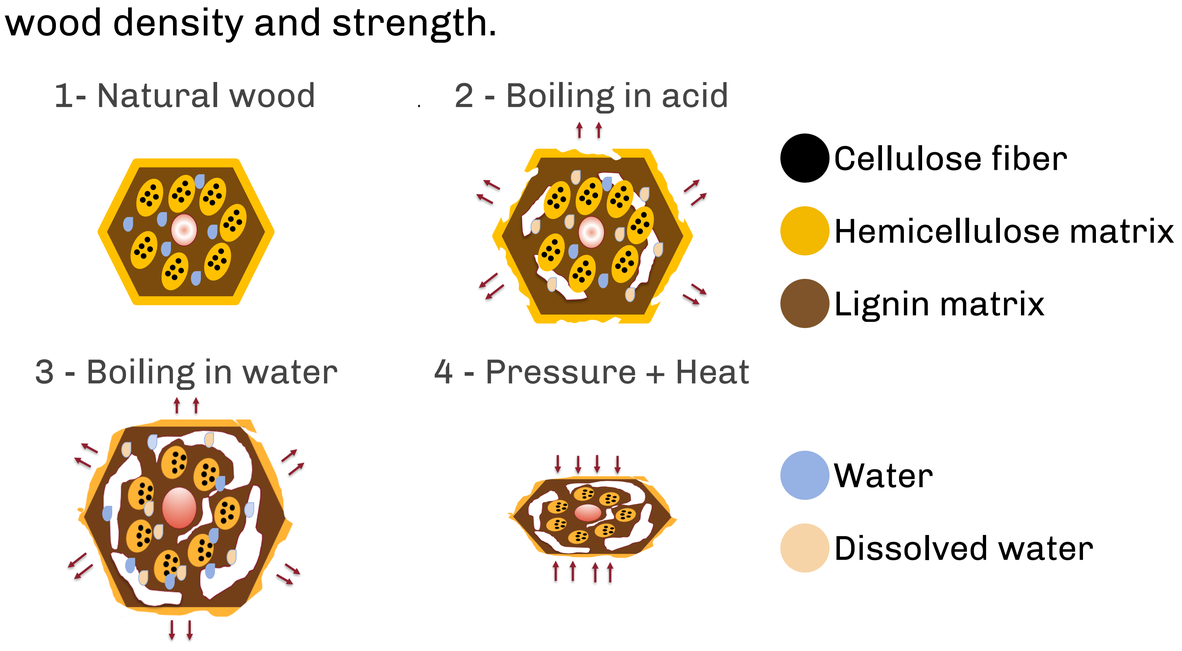

Figure 1 – Scheme of the wood behavior during the densification procedure.

Testing methods

To fully understand the elastic properties of the wood, dogbone shape samples were utilized in the fiber direction, while butt joints were employed for the transverse direction.

Results and Discussion

The stress strain curves obtained in the fiber and transverse directions are depicted in Figure 2a and Figure 2b, respectively.

When changing from natural wood to densified wood:

- **Fiber direction:** increase in Young's modulus of 90% and strength of 85%.
- **Transverse direction:** modulus decreased by approximately 75%, while the strength decreased by about 44%

The densification process can have a negative impact on the transverse mechanical properties of wood due to the destruction of lignin and the wood matrix, which provide good adhesion between wood fibers.

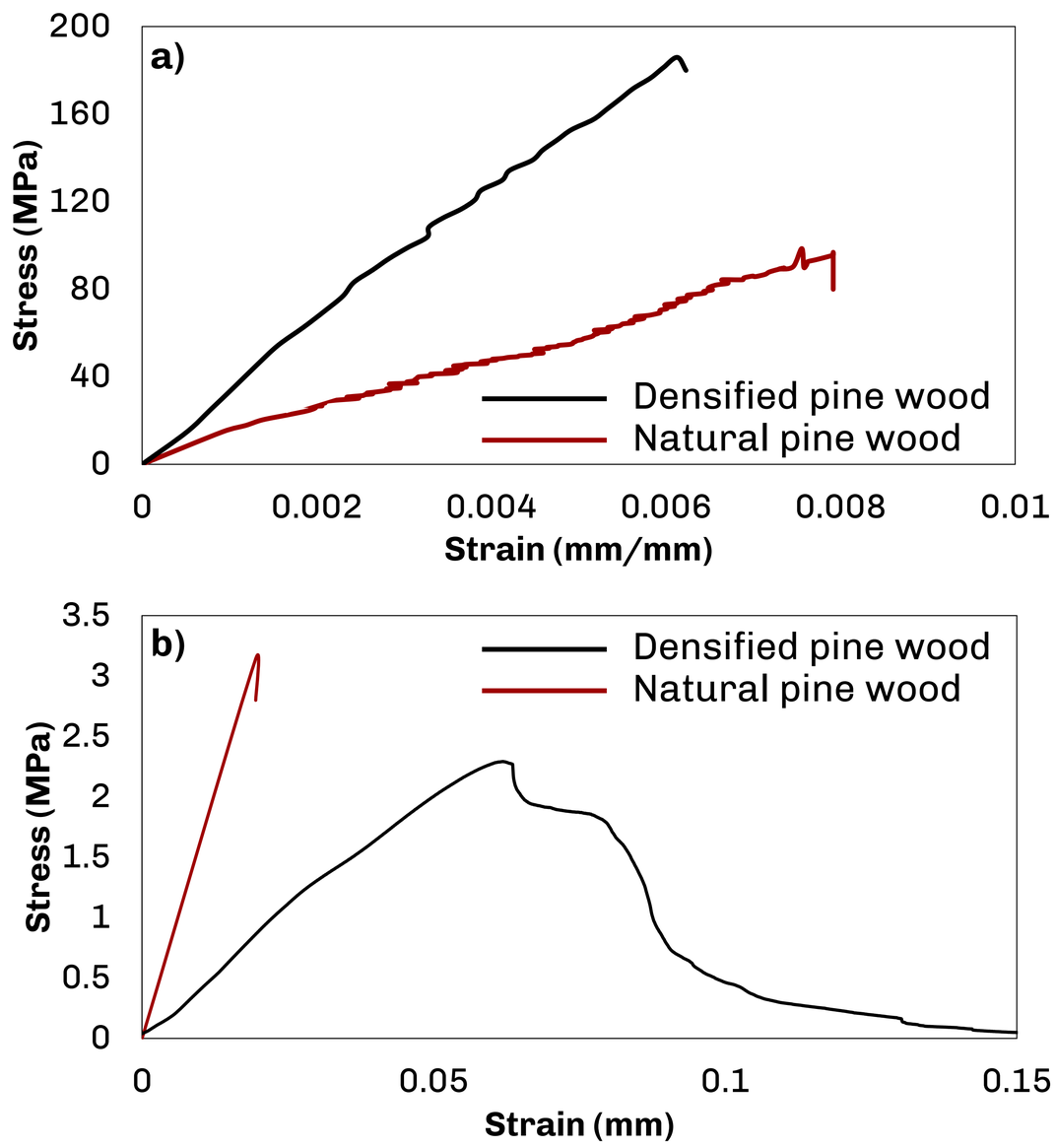

Figure 2 – Representative tensile stress-strain curve of natural and densified wood in the fiber a) and transverse b) directions.

Conclusions

The densification process greatly enhances the mechanical properties of wood in the fiber direction, since it leads to a higher fiber volume fraction and increased material stiffness and strength. The improved density also contributes to better dimensional stability, making it suitable for use in challenging environments. Furthermore, the densification process promotes the alignment of fibers, resulting in improved structural integrity and resistance to deformation. While the densification process significantly improves the tensile properties of wood in the fiber direction, it can have a negative impact on the transverse direction, due to the degradation of the matrix of wood, lignin and hemicellulose.

References

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[2] Corte-Real LM, Jalali S, Borges CSP, Marques EAS, Carbas RJC, da Silva LFM. Development and Characterization of Joints with Novel Densified and Wood/Cork Composite Substrates. Materials. 2022 Oct 14;15(20):7163.

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