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Densification of *Eucalyptus nitens* and *E. fastigata*

Results of Scion's SSIF funded experiments

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Report information sheet

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Executive summary

The problem

The objective of this study was to increase the surface density and surface hardness of *Eucalyptus nitens* and *E. fastigata* through wood densification. Wood densification is a process of heating wood and compressing it to flatten the wood cells and increase the density and hardness of the wood.

This project

The densification process, and the surface hardness of the densified wood, have been reported previously (Sargent, 2020). In short, the *E. nitens* samples were able to be compressed to a higher degree than the *E. fastigata* without sustaining damage, and consequently the increase in surface hardness of the *E. nitens* boards was significantly higher. Densifying one surface of the *E. nitens* boards gave a lower density increase than densifying the entire board thickness (bulk densification), but for quarter-sawn boards this difference was not significant. In this report, the dimensional stability (set-recovery), and vertical density profiles of the densified wood are reported on.

Key results

One major result of this study is that the densification process generally resulted in a peak density at, or within 1mm of, the surface of the boards. This is a promising result, as it ensures the maximum increase in surface hardness for a given degree of densification.

When soaked in liquid water, or exposed to humid air, densified wood tends to swell irreversibly and regain some of its undensified thickness. For both *E. fastigata* and *E. nitens*, the surface densified boards regained most of their original thickness when soaked in water. For the bulk densified E. fastigata boards, some regained most of their original thickness, but some only regained a proportion (40-50%). The bulk densified *E. nitens* boards regained very little of their original thickness (only 30-40%) when soaked in water. This is a significant improvement over the *E. fastigata* and is much lower than published figures for other wood species.

Implications of results for the client

Both bulk, and surface densification can be used to increase the surface density and hardness of both *E. fastigata* and *E. nitens*. Overall *E. nitens* was more amenable to densification, as it can be compressed to a greater degree without damage, leading to larger increases in surface density and surface hardness compared to *E. fastigata*. Additionally, the bulk densified *E. nitens* swelled very little after contact with liquid water or humid air, which is unusual compared to other species reported in the literature. For an in-service application (e.g. flooring), reducing the tendency of the wood to swell when it gets wet would be a key performance requirement, so this is a positive result.

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Table of contents

Introduction

Wood densification is a process where wood is heated and compressed, with the aim of giving the wood a hard, dense surface. *Eucalyptus nitens* and *E. fastigata* have previously been densified to increase the surface hardness (Sargent, 2020). This showed that the surface hardness of both *E. nitens* and *E. fastigata* were significantly improved by densification, and that the hardness of *E. nitens* approximately doubled following bulk densification, and the *E. fastigata* boards increased by nearly 40%. Here the density profiles of the densified wood are presented, plus the long-term stability behaviour of densified wood when it is exposed to liquid water or humid air.

Materials and methods

The source of the test material and the densification process are described in Sargent (2020). Briefly: 20mm thick boards of *E. fastigata* and *E. nitens* left over from previous sawing studies were used. For each species both flat-sawn and quarter-sawn boards were densified to three levels:

- Undensified control
- Surface (partial) densification
- Bulk (complete) densification

Different levels of compression were used for each species. For *E. nitens* the surface densified boards were compressed to 16mm (20% compression) and bulk densified boards were compressed to 10mm (50% compression). The *E. fastigata* boards became damaged with such high levels of compression, so they were densified to a much smaller degree than the *E. nitens*: 17mm (15% compression) for the surface densified boards, and 16mm (20% compression) for the bulk densified boards.

Density profiles

Following densification, 25mm long samples were cut from each board and these were equilibrated at 25°C, 65% RH before being scanned in the Scion Discbot to produce a two-dimensional density map of each sample. These density maps were averaged across the board width to give a one-dimensional density profile through the board thickness. The average density of each sample was also calculated. To compare density profiles between boards, the variation in board thickness, and initial board density needed to be taken into account. The board thickness was normalised to the target compression thickness for that species and densification level, and the density values were normalised to the average density of the unmodified control boards of the same species.

Dimensional stability

Two 20x20mm cubes were cut from each board for dimensional stability measurement. Two methods of measuring dimensional stability were used, a water soaking test and humidity cycling test. One cube from each board was included in each test.

For the water soaking test the samples were oven dried, soaked in water for two days, then oven dried again. This was repeated four times to give a total of 5 water soaking cycles. The thickness of each sample was measured after each oven drying step. Results are presented as '% set-recovery' which is the proportion of the initial (undensified) board thickness that is regained during soaking – a set-recovery of 100% indicates that the board has swelled back to its undensified thickness, and a set-recovery of 0% indicates that the board has not swelled at all.

For the RH cycling test the samples were equilibrated sequentially at the following conditions

- 25°C 65% RH
- 25°C 90% RH
- 25°C 65% RH
- 25°C 30% RH

This sequence of conditions was then repeated a further 4 times to give a total of 5 humidity cycles. Once the samples had equilibrated at each condition, the thickness of each sample was measured. Results are presented in the same way as the water soaking test, as a % set-recovery.

Results and discussion

Density Profiles

Average density profiles for each sawing orientation and densification level for *E. nitens* are shown in Figure 1. Not surprisingly the control boards have a very even density profile, with minimal differences between flat sawn and quarter sawn boards. For the surface densified boards, the density peaks at, or near the densified surface, and reduces to the same density as the undensified boards at the other surface. The quarter sawn boards have a peak density right at the board surface, but the flat sawn boards have a peak density a few millimetres below the surface. The bulk densified boards have a high density throughout the board thickness with a density peak occurring at each surface.

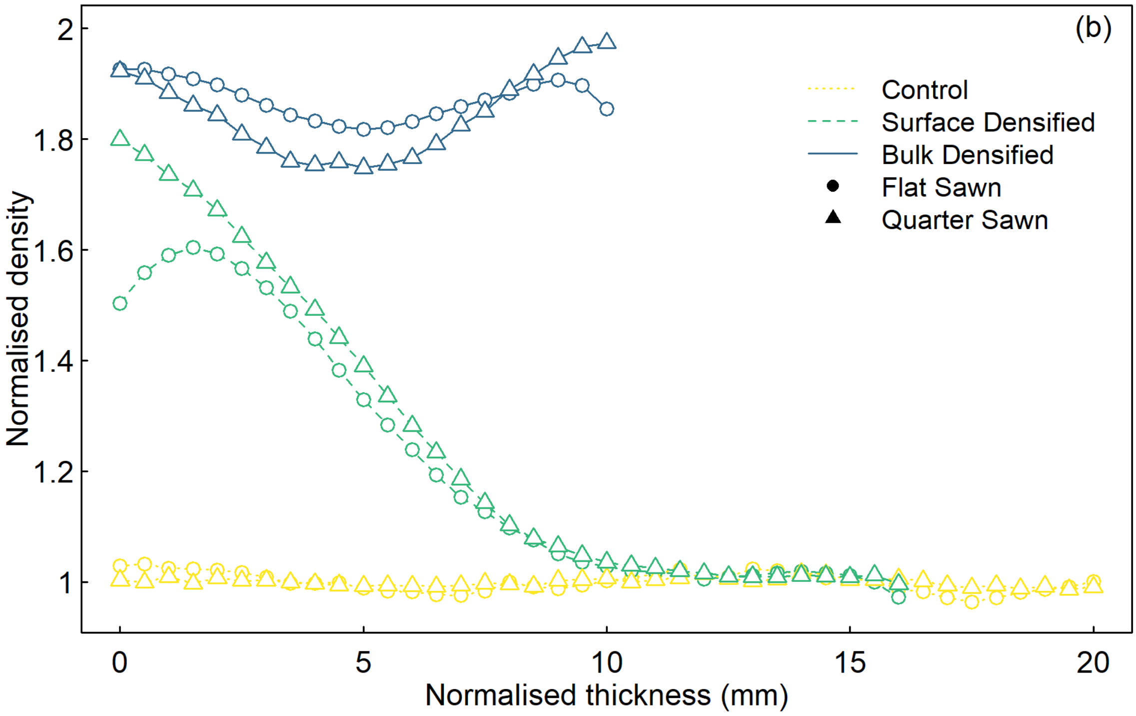

Figure 1: *E. nitens* average density profiles for different sawing orientations and different levels of densification (density normalised to the average density of the control samples, and thickness normalised to the target thickness of the densification).

The density profiles for *E. fastigata* boards are shown in Figure 2. Because these boards were compressed to a lesser extent than the *E. nitens* boards, it follows that the densified boards do not show the large density increases of the *E. nitens* boards. For the surface densified boards, the differences between flat and quarter sawn boards were much smaller than for the *E. nitens* boards. The profiles for the bulk densified boards were similar to the *E. nitens* boards, but with a much smaller density increase than the *E. nitens*.

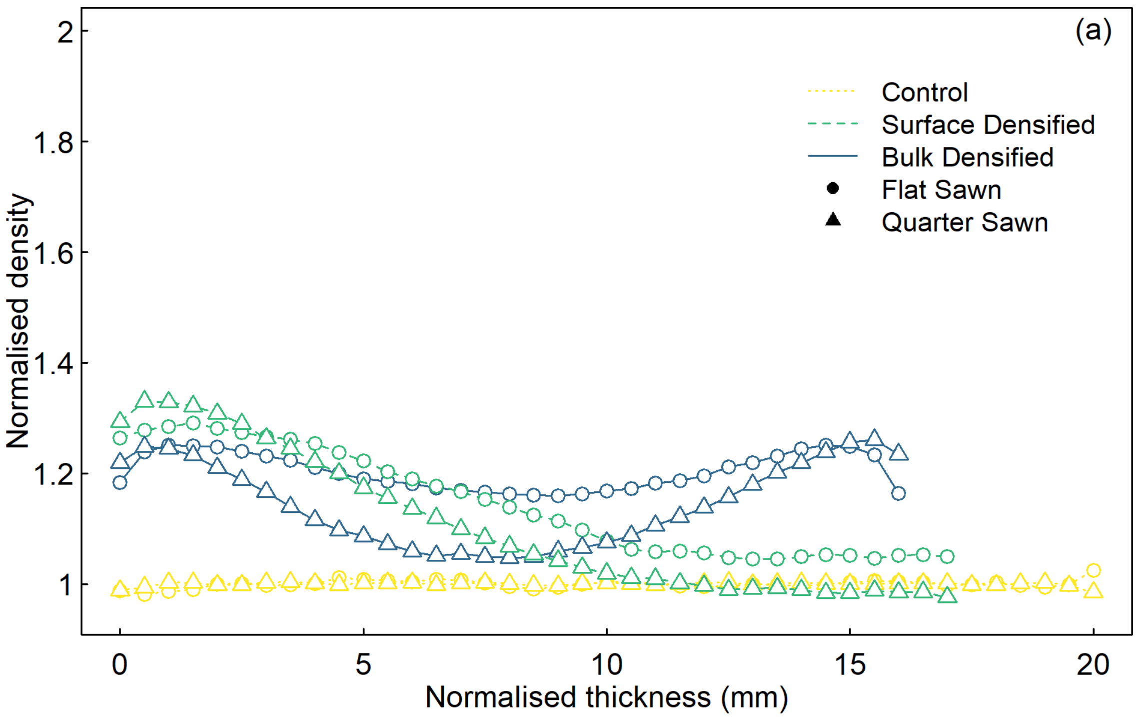

Figure 2: *E. fastigata* average density profiles for different sawing orientations and different levels of densification (density normalised to the average density of the control samples, and thickness normalised to the target thickness of the densification).

Dimensional stability

The results from the water soaking test are shown in Figure 3. Both the *E. nitens* and *E. fastigata* surface densified boards recovered most of their initial thickness following water soaking (i.e. set-recovery values approaching 100%). The bulk densified *E. nitens* boards recovered much less of their initial thickness following water soaking (indicating greater dimensional stability). The bulk densified *E. fastigata* boards showed much more variable dimensional stability, with some boards swelling very little, but many boards swelling to a similar extent to the surface modified boards.

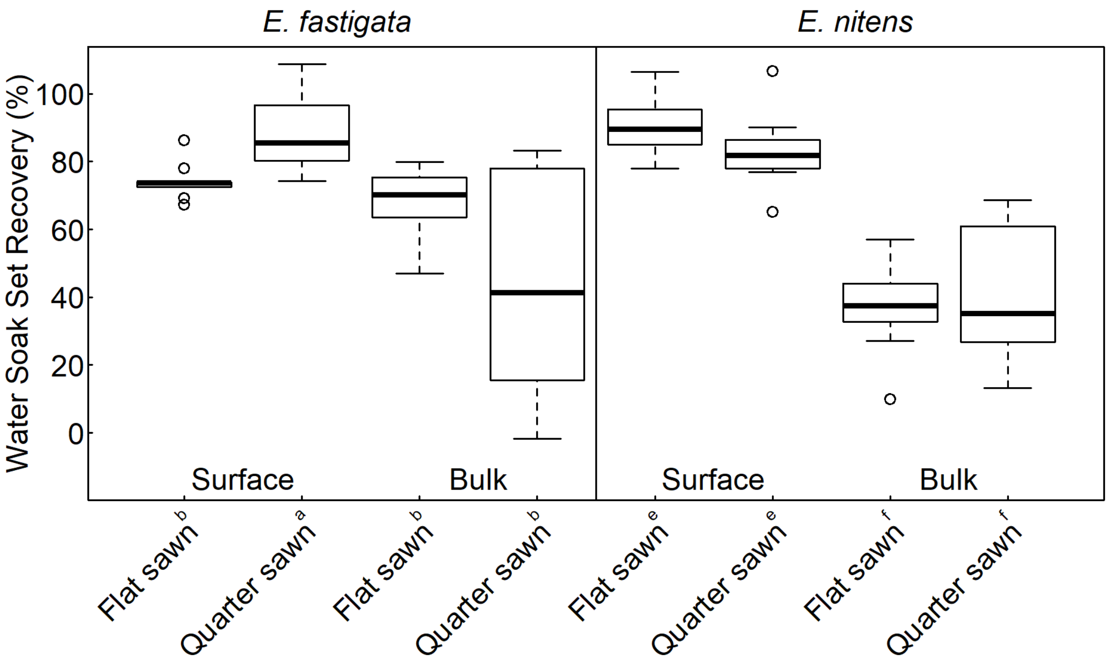

Figure 3: Percentage set recovery following water soaking. Superscript letters indicate treatments within each species that are not significantly different to each other (95% confidence level).

The percentage set-recovery following humidity cycling is shown in Figure 4. Not surprisingly the levels of swelling are much lower than for the water soaking tests. For the *E. nitens* samples the bulk densified samples have significantly lower set recovery than the surface densified boards. The *E. fastigata* boards had higher set recovery overall, and while the surface densified boards tended to have a higher set recovery than the bulk densified boards, this difference was not always significant. Within each species and densification level quarter sawn boards tend to have a lower average set recovery than the flat sawn boards, but these differences are not generally significant.

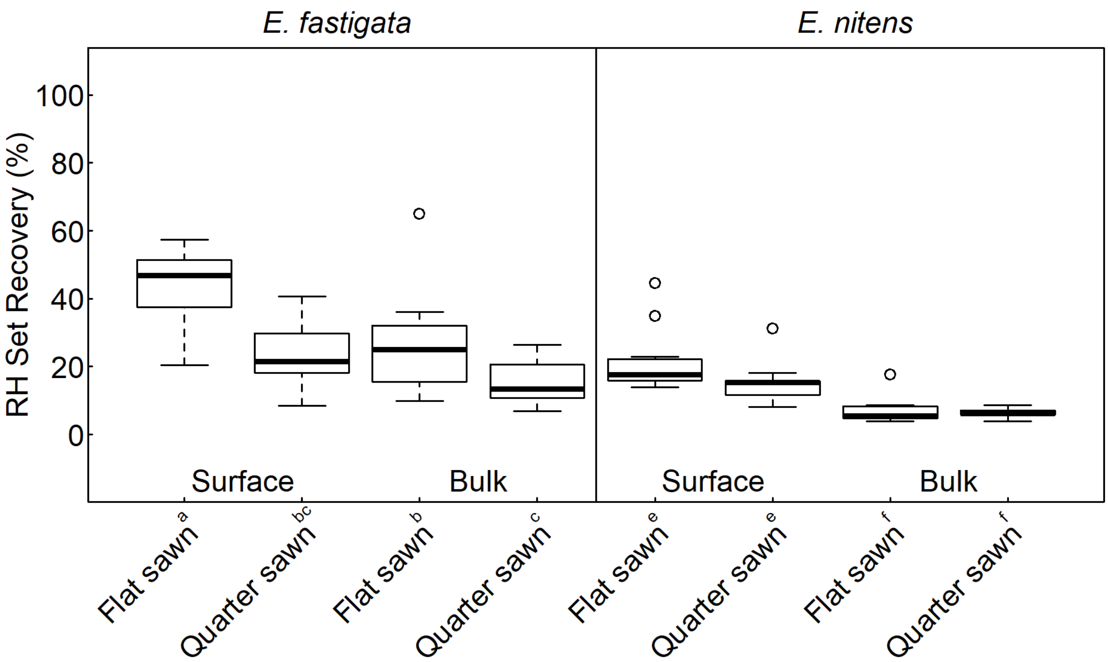

Figure 4: Set recovery following humidity cycling. Superscript letters indicate treatments within each species that are not significantly different to each other (95% confidence level).

Recommendations and conclusions

For both *E. nitens* and *E. fastigata* densification resulted in a density peak at, or very close to, the board surface. This results in the maximum increase in surface hardness for the level of densification applied. For the surface modified *E. nitens* there were some differences in average density profile between quarter sawn and flat sawn boards, with the flat sawn boards having a density profile that peaked a few millimetres below the wood surface. For the other wood types and levels of densification there were no major differences in density profile between quarter-sawn and flat-sawn boards.

The bulk densified *E. nitens* had a significantly lower average set-recovery compared to the other wood types, meaning that it did not swell much when soaked in water, whereas most of the other wood types swelled to close to their original dimensions. The levels of swelling in humid air were much lower than the swelling in liquid water, but there was a similar trend, with the bulk densified *E. nitens* showing significantly lower levels of set-recovery than the other wood types.

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Jamie Agnew (Scion) assisted with the preparation of the boards and subsequent test samples. John Lee and Mark Riddell performed the DiscBot scanning and subsequent density data analysis. Maxine Smith performed the dimensional stability measurements.

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Sargent, R. (2020). *Densification of E. fastigata and E. nitens for improved surface hardness. Results of Scion's SSIF funded work. Report prepared for the Specialty Wood Products Partnership.* Scion, Rotorua.