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Development of a continuous wood surface densification process with a reduced environmental impact

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Surface densification has the potential to greatly increase the hardness of the outer parts of wood materials. This increases the value of low-density species, such as Scots pine and Norway spruce, which are largely found in boreal forests. The density, strength, and hardness of these species are lower than those of commonly used hardwood species such as oak, and the use of these species is rather limited in applications such as flooring and table tops. Through densification, a significant improvement in the mechanical properties can be achieved, thereby opening new fields of application.

The state of the art in the field of surface densification is well described by Navi & Sandberg (2012), Rautkari (2012), and Laine (2014). Recent studies in wood surface densification have focused on processing parameters and their effect on the properties of the densified wood. Laine *et al.* (2013a) examined the effects of compression temperature and press closing time on the hardness of surface-densified Scots pine. Rautkari *et al.* (2013) investigated the effects produced from varying degrees of densification. The thermodynamic characteristics of surface-densified Scots pine have been studied by Kutnar *et al.* (2012).

An important aspect related to densified wood is how to eliminate the set-recovery after pressing, especially when the densified wood is exposed to variations in moisture. Rautkari *et al.* (2010) observed complete set-recovery of surface-densified spruce and beech without any post-treatment (e.g. heating) of the densified wood material. Gong *et al.* (2010) were able to reduce the set-recovery of densified wood by a post-treatment involving steam injection. Laine *et al.* (2013b) used a combination of steam injection at 200°C and drying with hot air. A common feature of all these processes is the long treatment time, where the thermal treatment process exceeded 4 hours even with small laboratory specimens.

In recent research, only limited focus has been put on the economic and environmental aspects of the densification process. Rautkari (2012) studied three different surface densification approaches, two of them using an ordinary heated press and one adapting a friction welding technique. All surface densification processes are time-consuming batch processes, where a post-treatment stage is necessary in order to reduce set-recovery. This means that low value wood species become not only high value products but also high cost products, eliminating their potential advantage over inherently more expensive and harder wood species such as oak, beech, or tropical woods.

The objective of the research project proposed by Luleå University of Technology is the development of a continuous wood-surface-densification process, the aim being to shorten the process time and to lower the energy consumption in order to reduce the costs and environmental impact.

The first stage of the project focuses on determining the validity of the existing batch process parameters in the context of a continuous wood-surface-densification process, the purpose being to evaluate whether an economic, continuous surface-densification process is feasible within the process parameter limits found in the literature.

Thereafter, the focus will be on optimizing the process on a laboratory scale and improving its robustness. There is however, a realistic risk that the current batch process approach cannot be transformed into an economically feasible continuous process, in which case, further experiments will focus on reducing the process time by other wood modification means, such as impregnation. Inoue *et al.* (2008) presented an interesting approach in this context.

The later stages of the project will focus on transforming the laboratory process into an industrial process, and on evaluating the environmental impact of the process. For this purpose, it will be necessary to evaluate the process from both an economic and an environmental perspective, including the creation of an environmental product declaration (EPD).

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