Bulletin of the *Transilvania* University of Braşov
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 8 (57) No.2 - 2015

STRUCTURES OBTAINED FROM THIN WOOD OF SPRUCE AND MAPLE, BY LIGNIN ACTIVATION

Ramona E. DUMITRAŞCU[1]

Abstract: *The wood obtained from forest thinning, with small dimensions (Ø=14 cm), is today a potential raw material for furniture design. The main objective of the paper is to present the possibility of obtaining new structures by an innovative method of joining. Two species, a resinous one (spruce, Picea abies L.) and a broad-leaved one (maple, Acer platanoides L.) were selected for this research. The results have shown that the joints between dowels and support are uniform and compact, even if the structures combine two wood species with specific characteristics. The high lignin content of this raw material could be an advantage. The conclusion is that the newly proposed structures represent potential alternatives for the classical joints with adhesive.*

Key words: *thin wood, thinning, maple, spruce, structures, lignin activation, rotational friction.*

1. Introduction

Wood is one of the first materials used by humans and deepening the knowledge in this regard, has always been a challenge. The evolution of wood joints, from antiquity to the present, is indisputable through the variety of products which are today on the market. However, finding new and efficient bonding solutions remains an open issue [2], [3], [5], [10], [11]. Traditionally, the wood joints used in furniture design ever since ancient times, could be achieved today by innovative technologies. Joining wood at high temperature, through friction, is an unconventional method, by which wood can be bonded without adhesives [6], [8].

Friction activates the chemical wood components, especially the lignin, this one being a natural binder for structural joints [6], [7]. It is known that the thin wood resulted from forest thinning, has a higher lignin content (52.39% for spruce) than normal wood (33.25% for spruce) [2]. Thin wood is still a less used category of wood in the furniture industry, but it has potential applications in design [2]. Its use for the purposes of developing innovative structures, means ensuring efficient value to these wood resources. Also, by applying new technologies and methods, this approach leads to the development of new research directions, such as: at industrial level, it requires redesigning the manufacturing processes of the products.

[1] Eco-Design of Furniture, Restoration and Certification in Wood Industry, *Transilvania* University of Brasov, Colina Universităţii no. 1, Brasov 500063, Romania.
Correspondence: Ramona E. Dumitraşcu; email: r.dumitrascu@unitbv.ro.

Joining the wood resulted from thinning, by new methods and in new combinations, will contribute to the advancement of the knowledge in the field.

This paper is based on a theoretical and experimental study aimed at obtaining new wooden structures by activating the lignin in wood.

2. Objectives

This paper aims at proposing new wooden structures, which can be achieved by activating lignin, as a binder, without the use of adhesives. The direction of the dowel-insertion, depending on the species and fibre orientation, was investigated.

3. Material and Methods

The wood material used for testing, was harvested from thin trunks (Ø = 14cm) resulted by thinning. The proposed structures consist in two wood species (S1≠S2). From the softwoods category, we opted for spruce *(Picea abies* L.), one of the dominant species, in a proportion of 22.62% within the overall resinous of 29.77% [12]. The lignin content of the spruce wood from thin trunks, resulted by thinning, reaches up to 52.39% [2].

From the hardwoods category, we opted for maple *(Acer platanoides* L.), which is a species with 27.38% lignin content [9]. The raw material was harvested from a Romanian complex, namely from Zărneşti production unit. The general steps were:

After its natural drying, the wood material was ready to be cut in timber; then subjected to ripping, cutting, planning, profiling; and afterwards prepared for joining. The manner of obtaining the samples that form the structure is shown in figure 1.

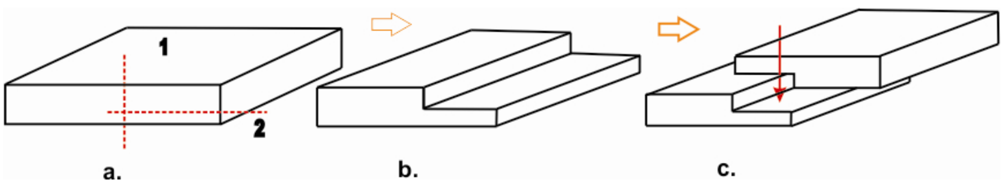


Fig. 1. *The main procedure for obtaining the samples: a. cutting; b. profiling; c. joining*

For the compatibility of species, a theoretical analysis was made (Table 1). The sample dimensions and the formation type of the proposed structures is shown in figure 2.

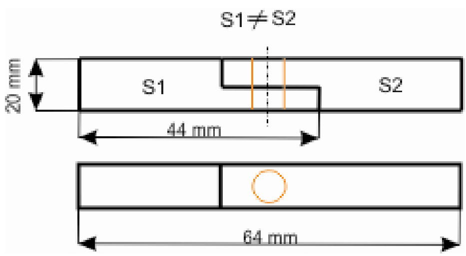


Fig. 2 *Dimensions and type of structures proposed for joints without adhesive*

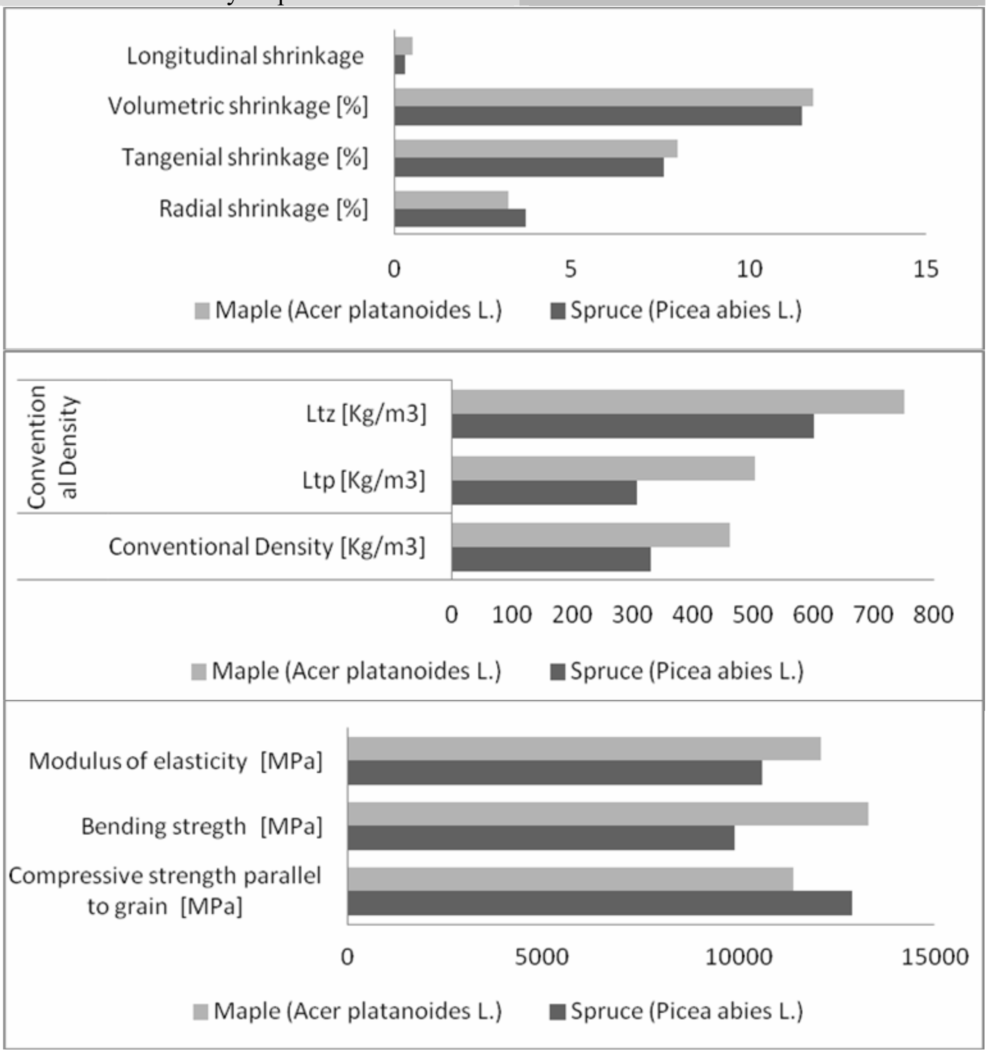
The method used for the purposes of obtaining joints without adhesives is the *rotational friction using wood dowels*. It is an innovative method, less known and applied in Romania.

Due to friction, the temperature generated by the rotational rate and other parameters, activates the lignin, which acts as a natural binder. One of the pieces must be fixed (support: maple or spruce samples) and the other one must be mobile (wood dowel). This study was made on a drilling machine, provided with a special clamping device. For joining, commercial beech wood dowels (*Fagus sylvatica* L.) with a diameter of 8 mm and 35 mm in length, ere used. Thus, the ribbed dowels were inserted by a fast movement of 1600rpm, using a manually-operated drill, in pre-drilled holes of 6 mm diameter.

Table 1

Theoretical compatibility between beech and maple depending on their known characteristic properties – comparative variation of the average values [1], [2]

Maple (*Acer platanoides* L.)	**Spruce** (*Picea abies* L.)
(microscopical and macroscopical characteristics)	
wood with small pores evenly dispersed	wood without pores, with fine structure and uniform



In four samples, the dowels were inserted first in spruce; and in other four samples, the dowels were inserted first in maple. Before their connection, the samples were conditioned at 55 – 60 relative humidity (RH). The moisture of the samples ranged between 8 (±1) % – for the wood dowels, and 11.2 (±1) % – for the wood support. The connection time (from the entrance in the material to the end of process) varied between 0.1 – 0.2 seconds.

4. Results and Discussions

Joining a softwood species and a hardwood species is a process less common in current applications.

In this sense, there was made a synthesis of the literature in the field on the compatibility between spruce (*Picea abies L.* – as softwood) and maple (*Acer platanoides* L. – as hardwood), for the uses in the same structure.

Analyzing the variation of the average values, as described in the literature, for the two species, in terms of shrinkage, the difference is small.

Both the modulus of elasticity and the strength are higher at maple than at spruce.

The conventional density is also higher at maple than at spruce, as well as the bending strength.

In a combination of this type, it is possible for the maple (*Acer platanoides* L.) to compensate the low resistance of the spruce (*Picea abies* L.).

Also, in terms of lignin content, both species are among those with high substance content. It is known that the joints of two wood pieces without adhesive, are based on the activation of the main chemical components in wood, especially lignin [6], [8]. In these conditions, the author considers that a high lignin content has a positive impact on the joints and favours the rotational-friction method.

The results of the experimental tests are shown in figures 3 and 4. As a first observation, the manual force required for the insertion of the dowels in the spruce wood (*Picea abies* L.) is lower than the one necessary for the insertion in the maple wood (*Acer platanoides* L.).

This facilitates an easy and quick process of connection.

For both types of joints, upon the entering of the dowels in the material, on the surface, a dark contact area does not form as obviously as in the case of the joints in normal wood, at the same rotation rate (1600rpm).

Fig. 3. *The structures obtained by insertion of dowels first in maple and then in spruce*

Fig. 4. The *structures obtained by insertion of dowels first in spruce and then in maple*

At international level, the researchers [6] and [4] show that the *dark line* (of about 1 mm) in the contact area, is an optical disadvantage. A wide *dark line* also means poor resistance of the structure [7], [11].

From this point of view, it is possible for this type of wood (wood with small diameters obtained from thinning) and its specific chemical components, to be an important factor for joints.

This could be a solution for reducing the *dark area*, on the surface of the structures (considered as a disadvantage) in addition to changing other process parameters.

On the other hand, this *dark line* may be considered as a design element.

The proposed structures facilitate the joints in width, on the longitudinal edge; being often used in order to form decorative elements or panels.

Thus, with a view to obtaining decorative panels, in furniture design, the *dark line* can be an advantage.

Also, the fibre orientation gives the structure a special design, which increases its value.

Achieving products with constructive performance and aesthetic aspect, could lead to competitiveness and efficiency.

In addition to aesthetical aspects, the good connection of the joints is essential.

The direction of the dowel insertion, in correlation with the species layer and wood fibre orientation, represents an important factor for a good connection.

In this study, S1 is represented by spruce; and S2, by maple (Figure 5 and Figure 6). When the dowels are inserted, first in maple (*Acer platanoides* L.) and then in spruce (*Picea abies* L.), the inferior layer of the structure may have a poor connection. This can affect the strength of the entire structure. The same situation can occur when the dowels are inserted first in spruce and then in maple.

The dowels become conical due to their progressive densification (Figure 5). The reduced dowel diameter, towards the end of the insertion, entails poor joints.

To compensate the strength of the structure, the dowels could be alternatively inserted, from front to back and from back to front. For laboratory applications, this is possible; but for industrial applications, targeted on efficiency, this technique needs professional equipment, provided with a special clamping device.

There are no significant differences between the two possibilities of dowel insertion; yet, obviously, depending on the species.

In both cases, the dowels were inserted perpendicularly to the wood fibre, on tangential section.

Fig. 5. *Sections through the structure - direction 1*

Fig. 6. *Sections through the structure - direction 2*

It is known that the insertion of the dowel on the tangential section provides good results, as compared to the insertion in radial direction, for beech wood [6].

In section, the contact line between wood support and dowel, is uniform and visibly narrower, as compared to the joints obtained in normal wood. This means that the thin wood fibre, by heating to the high temperatures generated by friction, has a perfect overlap, and forms a compact area (no visible free spaces between support and wood dowels were registered).

The international studies in the field show that the parameters of the process depend on each species, for a good connection. In this case, at the same rotation rate (1600 rpm), both the spruce and the maple used in the same structure showed good connection results (Figure 7).

Therefore, even if the species are different in terms of category of material, being a combination between a softwood and a hardwood material, each one with specific characteristics, one component has almost similar values: the high lignin content. In this sense, as an important factor for the joints without adhesive, an approximately similar lignin content could be the element leading to good connections between two different species.

In other way, the stability of the joints is an important factor. The fibre orientation to form the structure has a great influence on stability and of course for sustainable joints.

The structures proposed and thus obtained had been maintained for 4 weeks, under normal conditions of temperature (20 ± 5^0C) and relative humidity (58 ± 5 RH, relative humidity). After this period, the joints were analysed, in order to notice the stability of the structure. No significant dimensional changes or deformations were registered in the contact area, between spruce and maple.

The uniformity of the contact area, in section, was analysed, using a negative image obtained with a special software and measuring the contact area with *Image J* software. The analysing procedure and the results are shown in figure 7. The thickness of the contact area, in pixels, is almost similar (A and B), for the insertion of the beech wood dowel in both pieces of wood (maple and spruce).

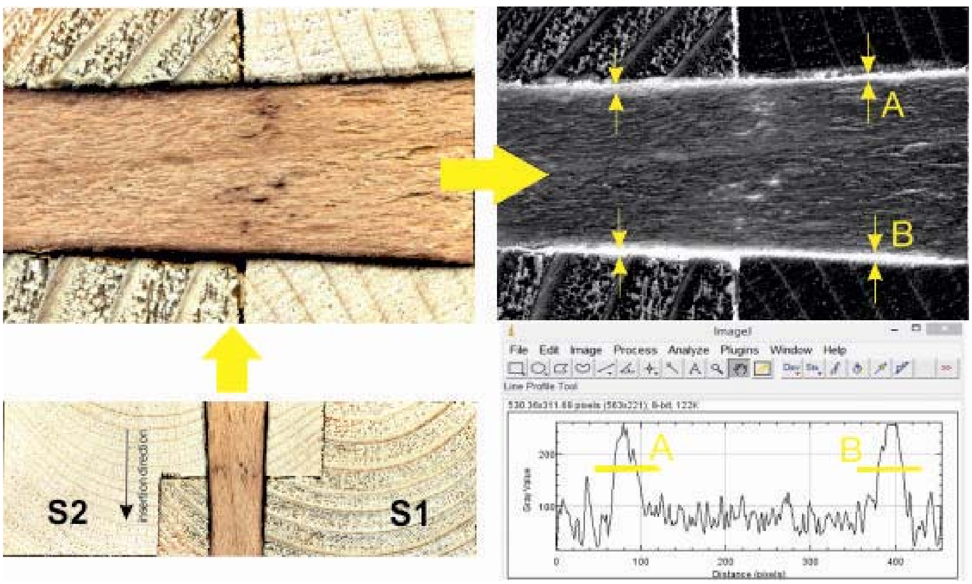


Fig. 7. *The contact area between wood dowels and spruce - maple wood material*

5. Conclusions

The structures obtained through rotational friction lead to a new way of research and represent potential alternatives to the classical joints with adhesives. It is possible for this type of wood (wood with small diameters obtained from thinning) and its specific chemical components, to be an important factor, for the joints.

In general, this method is efficient for local joints, on small surfaces, and it has high applicability in the structure of the small pieces of furniture, for the decorative elements.

As an advantage, for obtaining decorative elements/ panels through this method, it is worth mentioning that they do not require the pressing operation, as in the case of obtaining panels with adhesives.

Obtaining new structures by an innovative method, based only on the chemical components of wood, will contribute to the advancement of knowledge and thus to the expansion of the range of products that are easy to be recycled, easy to be reintegrated in other products, at the end of their life.

This research has been a challenge and it might be extended over other classical or new types of joints that could be obtained by this method, without adhesives.

Acknowledgements

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the project number POSDRU/159/1.5/S/134378.

References

1. Curtu I., Ghelmeziu N., 1984. Mechanical wood and wood-based materials (in Romanian). Technical Press, Bucharest.
2. Dumitraşcu R. E., 2012. Contributions to the value enhancement beech and spruce wood resulting from forest thinning in order to achieve some ecostructures (in Romanian). PhD thesis – Transilvania University of Brasov, Romania. Coordinator: prof. univ. dr. eng. Loredana A.-M. Bădescu
3. Dumitraşcu R. E., Bădescu L. A. M., 2015. Aspects regarding wood welding in the context of applicability in the least developed countries. In: Proceeding of International Conference 10th Wood Science and Engineering in the Third Millennium – ICWSE. Editor Mihaela Câmpean, Brasov, Romania, 5-7 November 2015, Publisher Transilvania University of Brasov, pp. 785–790.
4. Denis R., Esch J., 2009. Lineares Holzschweißen. Fischerkunststoff, Switzerland.
5. Ebnera M., Petutschnigga A., Schnabela T., et al. 2014. Development of an automated wood welding process. In: Journal Adhesion Science Techonolgy, vol. 28 (18), pp. 1783–1791.
6. Ganne C. C., Pizzi A., 2005. Parameter interaction in two-block welding and the wood nail concept in wood dowel welding. In: Journal Adhesion Science Technology, vol. 19 (13–14), pp. 1157–1174.
7. Jung K., Kitamori A., Komatsu K., 2008. Evaluation on structural performance of compressed wood as shear dowel. In: Journal of Wood Science, vol. 62(4), pp. 461–467.

8. Pizzi A., Leban J.M., 2004. Wood dowel bonding by high-speed rotation welding. In: Journal Adhesion Science Technology, vol. 18(11), pp. 1263–1278.
9. Tudorachi N., 2007. Composite Materials with Matrix Polymers Thermoplastics (in Romanian). PIM Press, Iaşi.
10. Zupcic I., Mihulja G., Bogner A. et al., 2008. Welding of solid wood. In: Drvna Industrija, vol. 59(3), pp. 113–119.
11. Zupcic I., Mijakovic M., Bogner A. et al., 2010. Investigation of welded joints with linear turned beech elements. In: Acta Silvatica & Ligna Hungarica, vol. 6, pp. 195–200.
12. *** Foresters Association in Romania (ASFOR), may 2013. Available at: http://www.asociatiaforestierilor.ro/.