

ASPECTS REGARDING WOOD WELDING IN THE CONTEXT OF APPLICABILITY IN THE LEAST DEVELOPED COUNTRIES

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Abstract

Furniture, as traditional sector in Romania, is one of the few areas that bring profit. It is a field that contributes to the economical competitiveness through the variety of products for import and export. In this context, joining wood is essential for the production of wood products. Therefore, knowing the environmentally-friendly methods for wood joints could lead to performance and progress. Welding technology of wood as an alternative method to bonding wood elements or wooden structures has not been addressed in Romania until now. The paper presents a review performed with the aim of contribute to the knowledge of this innovative technology, to show the problems and the possibilities, of least developed countries, to contribute at this area of reasearch.

The general aim is to present the main methods and to analyze their advantages and disadvantages in the context of development in the least developed countries. The results showed that both methods, at low and hight temperature, has benefits but there are and some economic and knowledge barriers for extended the technology. The overall conclusion of this research is to find efficient solutions for wood welding in order to obtain new better and cleaner wood products.

Key words: wood welding; methods; advantages; disadvatages; least developed countries.

INTRODUCTION

Joining wood through the welding technology can be today a highly competitive opportunity at national and international level for applications in the furniture industry.

Wood welding is an *environmentally friendly technique* that describes an innovative procedure for joining wood pieces without the use of adhesives or any other material than wood (Gerber 2005; Pizzi 2005). Starting with 2005, this technology was scientifically studied by a team from France and Switzerland which opened the door to extensive research. The research was further extended in the USA and United Kingdom. More recent research work was carried out in Sweden.

The research was extended at international scale for applications in the field of aircraft manufacture, constructions, wood industry and the process was studied at molecular, cellular and macroscopic level but also as a building process.

In Romania, this technology has not been explored until now. At industrial level, the *wood welding* term is known and used in constructions for joining beams with multi-nail connectors applied under pressure (Fig. 1). This is the only technique named „wood welding,, which is applied in Romania at this moment.

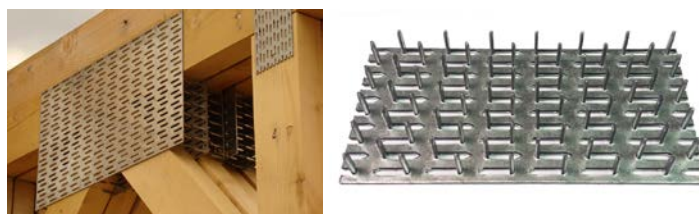


Fig. 1.

a - Wood welding with multi nails boards; b – multi-nailed boards from pre-galvanized steel sheet (www.mitek.ro)

At scientific level, wood welding without adhesives began in 2013, through a postdoctoral research project coordinated by the authors of this paper.

Several methods for joining wooden materials are known (Fig. 2). Each of these methods has characteristics that make it different as process, applicability, equipment used and results obtained.

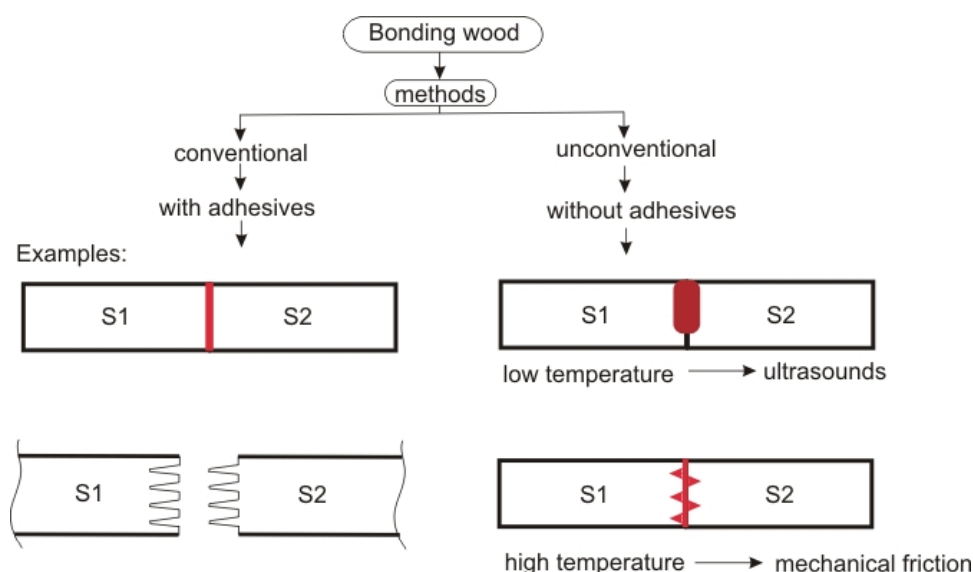


Fig. 2.
General classification of existing wood bonding methods

The present research deals with the possibility to apply wood welding, as an innovative technology in Romania, in order to use it in wood industry for furniture design. To this purpose, two factors seemed of outstanding importance to decide the efficiency of this technology for the least developed countries: the economical and the ecological factor - in the context of subsequent recycling and cost-benefits.

OBJECTIVE

Knowing the advantages and disadvantages of wood welding as an alternative to existing conventional methods, this paper aims at raising the interest of industry with a view to applying this modern technology in the least developed countries, as well.

To this purpose, the paper presents a review regarding the main wood welding methods applied so far at international scale, along with a thorough analysis of their advantages and disadvantages, leading to a verdict concerning the opportunities and risks of applying this technology in Romanian wood processing enterprises.

METHODS AND EQUIPMENT

Previous researches demonstrated the applicability of this revolutionary welding technology for wood and wood-based products. Today, we can identify the following existing methods of wood welding (Pizzi 2005, Bernhard 2005, Ganne 2008):

• Welding at low temperature - using the ultrasonic welding technique

This method requires that one of the elements to be transparent. Ultrasonic welding of wood is made by using substances/items which are not normally weldable but which melt easily (Shelley 2000). The method consists in using a plastic dowel as connection element. The plastic material is melted whilst it is introduced by ultrasonification in the wood structure, using an ultrasonic device (Fig. 3). At the international level, the process has been successfully tested on materials such as: solid wood, fibre board, plywood. The main parameters that influence the process are frequency, amplitude and time of welding.

Ultrasonic welding involves the use of *high-frequency sound* energy (20, 30 or 40 kHz) and low amplitude, in order to reach the melting point. Joining can be done – partially or totally – by inserting a plastic sheet between two wooden surfaces as in Fig. 4.

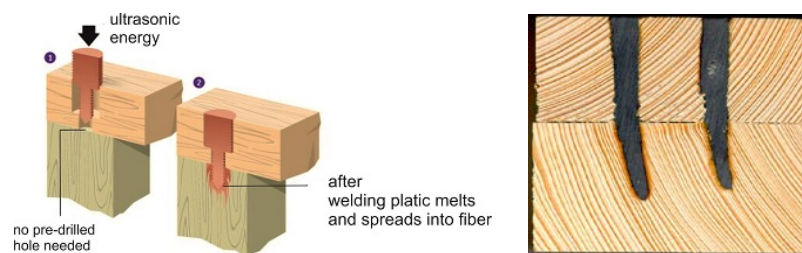


Fig. 3.

Ways for welding wood at low temperature with plastic dowels: a - plastic dowel insertion b - section of welded dowels (Shelley 2000, Gerber 2005)

This technique is very efficient for thin wood pieces and is recommended for small surfaces joints, for local applications.

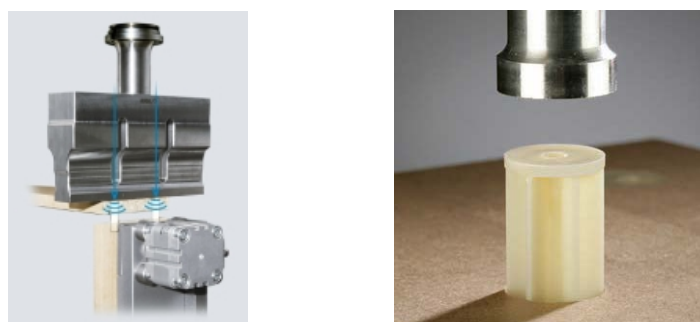


Fig. 4.

Equipment used for wood welding through ultrasonic technique (<http://www.titusplus.com>)

It is widely used in developed countries (e.g. France), it is fast and recommended for mass production. It can be applied for joining wooden elements in interior constructions: wooden walls, in-built furniture parts, carpentry, kitchen items, windows, interior doors.

• **Welding at high temperatures - generated by mechanical friction (more than 180°C)**

This technology consists in modifying the lignin and hemicelluloses characteristics, when the wood cell walls enter into a melting phase (Gerber 2005). By melting, the structure and the chemical properties of wood are completely changed (Bernhard 2005). The process it is possible at frequencies much lower than ultrasonic welding (100- 260Hz) and high amplitude (4-2 mm), depending on species. This method is recommended for large surfaces joints and is applied distributed on all surface.

There are three main types of friction (vibration) welding:

- **rotary-type friction** – when between the two wooden elements is a circular friction;
- **linear friction** – when there is a linear movement between the two elements (Fig. 5);
- **orbital friction** – when there is an elliptical movement between the two elements.



Fig. 5.

**Oak and beech wood joined by linear friction welding
a – multilayered wood laminated structure obtained at laboratory scale (Navi 2005);
b – product for structural applications (Hahn 2014)**

This type of friction generates a huge amount of heat (up to 420-450°C - Weinand and Bernhard 2006) in the contact area. When the friction movement (of 1-2 seconds) is stopped, the material begins to cool down, then it hardens to form a new structure with a solid contact layer. This process can be applied for welding two pieces of the same or two different wood species. The technique does not require another binder as connection element and can not be achieved in a wet environment.

The main parameters that influence the production of heat are: the machine control parameters (such as frequency, amplitude, pressure, welding time) and the wood properties (such as moisture, ring orientation, density and wood species). There is a very high correlation between these parameters. Research results show that welding through linear movement parallel to the wood grain give better joint strengths because the wood fibers overlap and create a higher-density area than in the case of circular friction. The range of application is the manufacturing of solid wood beams for constructions, as well as floorings.

The pieces of equipment available in the laboratories of ENSTIB-LERMAB Epinal (France) and Swiss Federal Institute of Technology at Lausanne EPFL (Switzerland) for this type of wood welding are presented in Fig. 6



Fig. 6.

Friction welding machine for laboratory applications:

a - for large contact surfaces (www.epfl.ch) b - for small contact surfaces (www.enstib.univ-lorraine.fr)

Another way to weld two pieces of wood at high temperature is by using wood dowels (Fig. 7). The pieces of wood can be welded without any adhesive by inserting the *high-speed rotation* wood dowel in a pre-drilled hole with smaller diameter than the dowel. The temperature (around 244°C at 1000 rpm for sugar maple – Bellville 2012) in the contact area increasing with the rotational speed and depending on species. The generated friction heat creates the connection between the wood fibers.



Fig. 7.

**Ways for welding wood at high temperature with wood dowels: a - welded surfaces with dowels
b - equipment used**

The main parameters that influence the process of welding: rotation speed, wood species, insertion angle, fiber orientation, time, moisture content, hole and dowels diameter. The joining performance depends on these parameters and of their correlation.

This method is recommended for welding small and large surfaces joints and is applied local, on points.

DISCUSSION

The promising results obtained at laboratory scale predict that the wood welding technology will be well received on the European markets, especially now when environment-friendly technologies are more and more encouraged and promoted. It is a known fact that most of the adhesives frequently-used in wood products are toxic for the human body and can lead to severe diseases when being exposed for a long time to their emissions (e.g. formaldehyde emission from chipboards using UF adhesives).

In order to introduce and apply this innovative technology in the field of furniture design – at research and manufacturing level – it is necessary to know the process and its benefits. Each of the above methods has certain peculiarities regarding its benefits and shortcomings:

• Welding at low temperature

The strength of the wood joints achieved at low temperature (with plastic dowel) is comparable to joints obtained by gluing with PVAc adhesives. As an advantage, the time required measures only few seconds compared with the classical technique which requires 24h to achieve the same results. To this purpose, it is necessary to make tests on the equipment for ultrasonic welding which can be expensive for least developed countries. Considering the product life duration and environmental issues, the welding with plastic dowels is not the most suitable solution because the wood welded with plastic dowels is not a recyclable material anymore, while using wood dowels eliminates this shortcoming.

The advantages of welding at low-temperature are: energy efficiency, simple automated production line, high productivity: approx. 1 welded piece/second.

• Welding at high temperature

This process is efficient due to the “binder” existing inside wood (the lignin), which is opened and activated by pressure during the friction. Research results showed that this viscose mass produced in the wood components (lignin, cellulose, hemicelluloses) at high temperatures is able to act as an adhesive. From this point of view, the advantages of this technology are at economical and ecological level. On the other hand there are some studies who related that the energy consumption is at disadvantage compared to the glue-jointing of wood. The machine parameters depending on wood species and contact surface. Further and more detailed research is needed in this area, to clearly delimit the range of efficient applicability in wood industry.

The linear friction welding of timber could radically disrupt the traditional use of fasteners and adhesives in furniture manufacturing. The main advantage of this method is the very good time efficiency, as the process lasts only few seconds. Low frequency (100Hz - up to max. 260Hz) makes short friction welding times possible and increases productivity. The strength of the welded joints is comparable to that of traditional glued joints used for the same purpose ([Ganne 2008](#); [Leban 2005](#)).

As a difference compared to welding at low temperature, friction welding can be applied for continuous welding of wooden panels without any limitation of length ([Properzi 2004](#), [Ganne 2008](#)). The friction welding with dowels can be applied in points. For applying this technique in industrial sectors it is necessary to develop an adequate device, according to the rotational dowel welding characteristics. The welded parts can be easily reused at the end of their life. This technology can be applied to a wide range of wood species but at this time there exists no clear database with specific welding parameters or strength values for all wood species.

Both methods have benefits, such as:

- high productivity: very short time for welding, within a range of seconds;
- reduced number of processing operations;
- comparable strength values;
- environment-friendly character.

At the same time, as an disadvantage for least developed countries, the equipment costs are high and can be a challenge for customers in least developed countries, such as Romania. At industrial level, it requires redesigning manufacturing processes.

From this point of view, the least developed countries are encountering difficulties in applying new technologies to ensure sustainable development through innovation and technological transfer.

CONCLUSIONS

Although international research on wood welding started in 2005, in Romania, in the year 2015, there is still no such equipment for laboratory tests. This is a great opportunity for Romanian researchers to try, by means of industrial support as well, to invest in this field and make new steps in

understanding, controlling and implementing this modern technology in Romanian wood processing enterprises, in order to obtain better and cleaner wood products.

ACKNOWLEDGEMENT

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.

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