Effect of surface preparation on the strength properties of the joint between cast epoxy resin and solid wood

Vliv přípravy povrchu na pevnostní vlastnosti spoje mezi litou epoxidovou pryskyřicí a masivním dřevem

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Summary

This paper deals with the influence of surface preparation on the strength properties of joints between solid wood and cast epoxy resin with the aim of increasing the aesthetic and functional value of the final product. Traditional surface preparation methods, such as sanding and brushing, are compared with modern technologies including plasma treatment and dry ice blasting. The experimental part focuses on the evaluation of tensile strength and impact toughness. FTIR analysis was also performed for more detailed verification of the results.

Key words

surface preparation, tensile strength, impact toughness, solid wood and epoxy resin bonding, FTIR analysis, meranti, dry snow, plasma treatment,

Introduction

In recent years, bonding solid wood with cast epoxy resin has become a popular technology in the manufacture of designer and aesthetically striking elements, particularly in the furniture industry. This combination of materials makes it possible to create products with a unique appearance and interesting mechanical properties. At the same time, however, it presents a technological challenge, especially in terms of the quality and reliability of the joint itself.

The quality of the joint between epoxy resin and wood is influenced by many factors, including, above all, the method of surface preparation. This significantly affects the adhesion, wettability, and resulting strength characteristics of the joint. Traditional methods such as sanding and brushing are often used because of their simplicity, but modern technologies such as plasma treatment or dry ice blasting can improve adhesion properties without significantly disturbing the structure of the wood.

Given the growing popularity of these materials and their use in furniture design, it is essential to examine in detail the effect of individual surface preparation methods on the strength and mechanical properties of the resulting joint.

The influence of surface preparation on joint strength

Proper preparation of the wood surface is an essential step in achieving a strong and durable bond between solid wood and epoxy resin. Surface treatment significantly affects the mechanical properties of the bonded joint, and its effectiveness depends not only on the type of wood and adhesive used, but above all on the consistency of the individual technological steps [1]. Before applying the resin, it is necessary to remove all dirt, grease, and dust that could reduce the adhesion of the materials [2].

One of the key parameters is the roughness of the wood surface. An overly smooth surface reduces the mechanical anchoring of the epoxy resin, while an excessively rough surface can lead to uneven distribution of the adhesive and subsequent weakening of the joint [3]. Experimental studies have shown that optimal roughness values, corresponding to sanding around P80 grit, provide the best results in shear strength tests [2].

The strength of the joint is further influenced by the time that elapses between sanding and the actual bonding. A longer delay leads to surface degradation due to oxidation and dirt accumulation. Wood moisture content is also an important parameter [4]. For optimal results, it is recommended that the moisture content of the wood does not exceed 8 – 10% during bonding. Excessive moisture causes a deterioration in adhesion, thereby reducing the strength of the joint.

In recent years, physical methods have been investigated to improve the chemical and mechanical properties of the wood-resin interface [6]. Among the most promising is plasma surface treatment, which activates functional groups [5].

In recent years, physical methods have been investigated that improve the chemical and mechanical properties of the wood-resin interface [6]. Among the most promising is plasma surface treatment, which activates functional groups on the wood surface and promotes the formation of stronger chemical bonds between the substrate and the resin. At the same time, it removes moisture and organic contaminants, leading to a significant improvement in adhesion [7].

In addition to plasma treatment, dry ice cleaning is increasingly being used as an environmentally friendly alternative to conventional mechanical or chemical cleaning [8]. Dry ice is produced by the desublimation of carbon dioxide (CO_2) at temperatures below − 80 °C and, thanks to direct sublimation, leaves no liquid residue. Its application ensures the complete removal of impurities and microorganisms from the surface without the creation of secondary waste.

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The cleaning process is carried out using a stream of compressed air, which accelerates dry ice particles to a speed close to the speed of sound. When the particles strike the surface, the contaminated layer is rapidly cooled, reducing its adhesion and subsequently removing it [10]. This thermal shock is accompanied by gas expansion during CO_2 sublimation, which helps to peel off dirt without the need for abrasive action. The result is effective surface cleaning without damaging the wood structure – the method is therefore particularly suitable for materials sensitive to mechanical stress [11].

Methodology

Materials used

Meranti wood was selected for testing the strength properties of the joint, with samples having a moisture content of 8–10%. Epoxy resin from a foreign manufacturer was used as the bonding material, prepared in a ratio of 1 part resin (A) to 2 parts hardener (B). The curing time of the system is 5 days, followed by a maturation period of 21 days. This system can be cast to a thickness of 10 cm. It was designed with a long gelation time in a block with low exothermic heat accumulation. It does not contain volatile organic compounds, which increases safety and reduces environmental impact..

Samples

The samples were cast in larger formats and then, after curing and maturing, cut to dimensions for tensile strength testing of 10 x 20 x 100 mm (epoxy resin cast part 10 x 20 x 20 mm) and impact strength test 10 x 10 x 100 mm (epoxy resin cast part 10 x 10 x 20 mm).

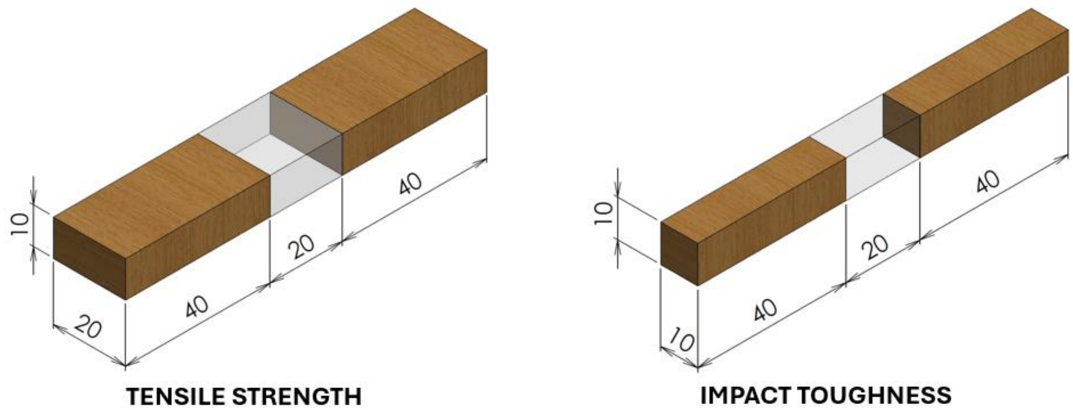

Figure 1. Sample dimensions

Surface preparation methods

Before starting the experiments, control measurements were performed to determine the optimal conditions and calibrate the surface preparation equipment. The subsequent experiments were carried out under the following parameters: brushing was performed at 1200 rpm, grinding with an eccentric sander at 8000 rpm. Dry snow blasting was performed at a pressure of 6 bar with a flow rate of 30 kg per hour. A power of 144 W was used for plasma treatment.

Measurement methodology

Mechanical tests were performed in accordance with the principles of the relevant standards. Specifically, the tensile test was performed in accordance with standards ČSN EN 205 (668508) and ČSN EN 1465 (668510). The impact strength test was based on the principles of ISO 179.

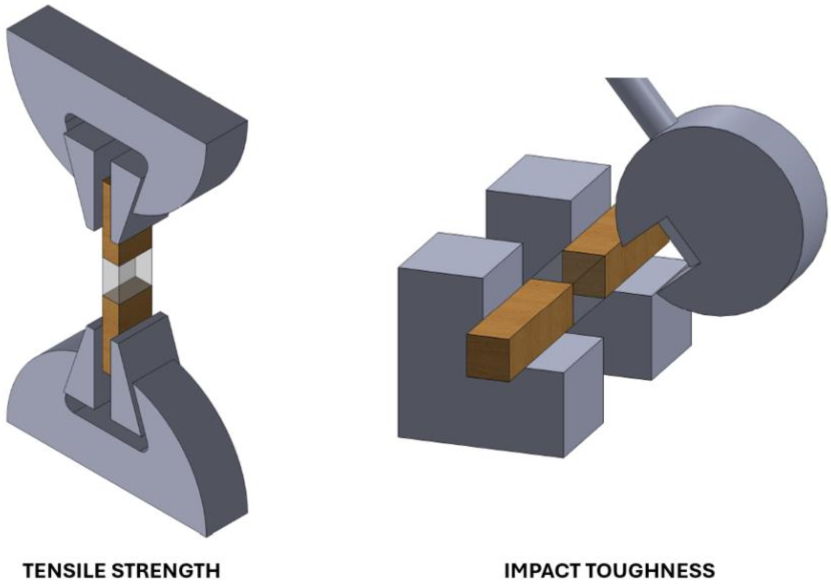

Figure 2. Methods of storing samples during measurement

Results and discussion

Influence of surface preparation on the tensile strength test

This article analyzes the tensile strength of the bond between epoxy resin and wood in order to evaluate the effect of different types of surface preparation on its durability. The results are presented in graphs, including statistical evaluation.

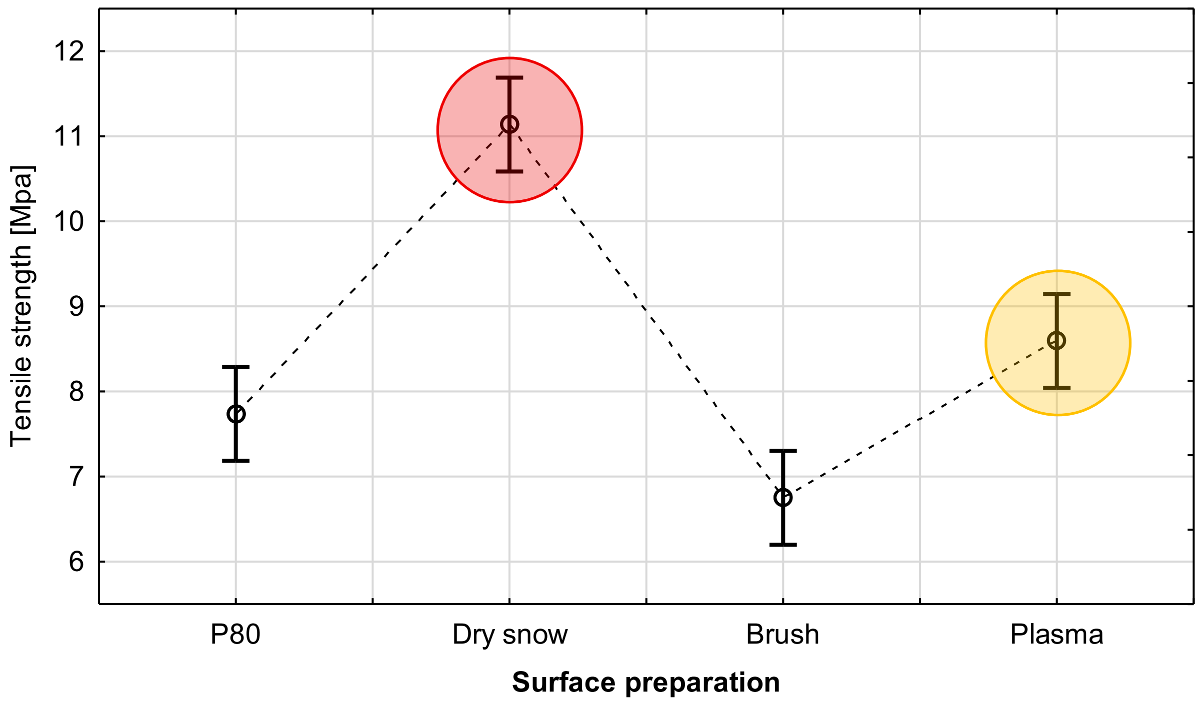

Figure 3. Graph of 95% probability interval of measured values of ultimate tensile strength for meranti

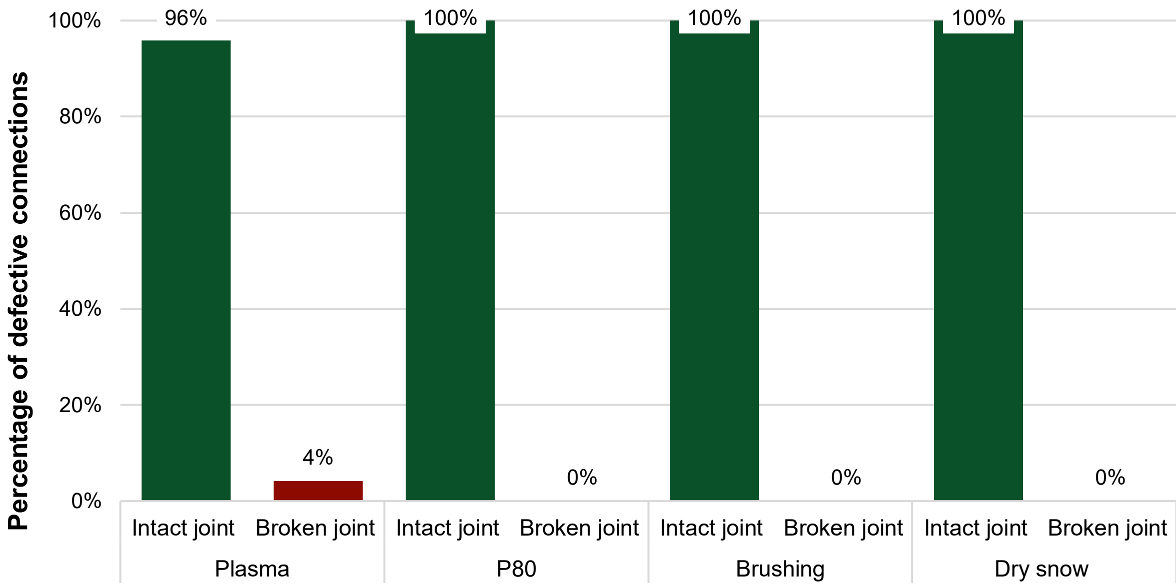

Figure 4. Evaluation of the quality of the connection in the ultimate tensile strength test

In Figure 3, we can observe statistically significant differences between the values measured for modern technologies compared to traditional ones. The highest tensile strength values were measured for dry snow blasting surface preparation, namely 11.14 MPa. The lowest values were observed for brushing, at 6.75 MPa. In terms of joint quality, no significant changes were observed.

Influence of surface preparation uin impact toughness testing

The purpose of the impact strength test was to determine how the joints between epoxy resin and solid wood resist mechanical energy.

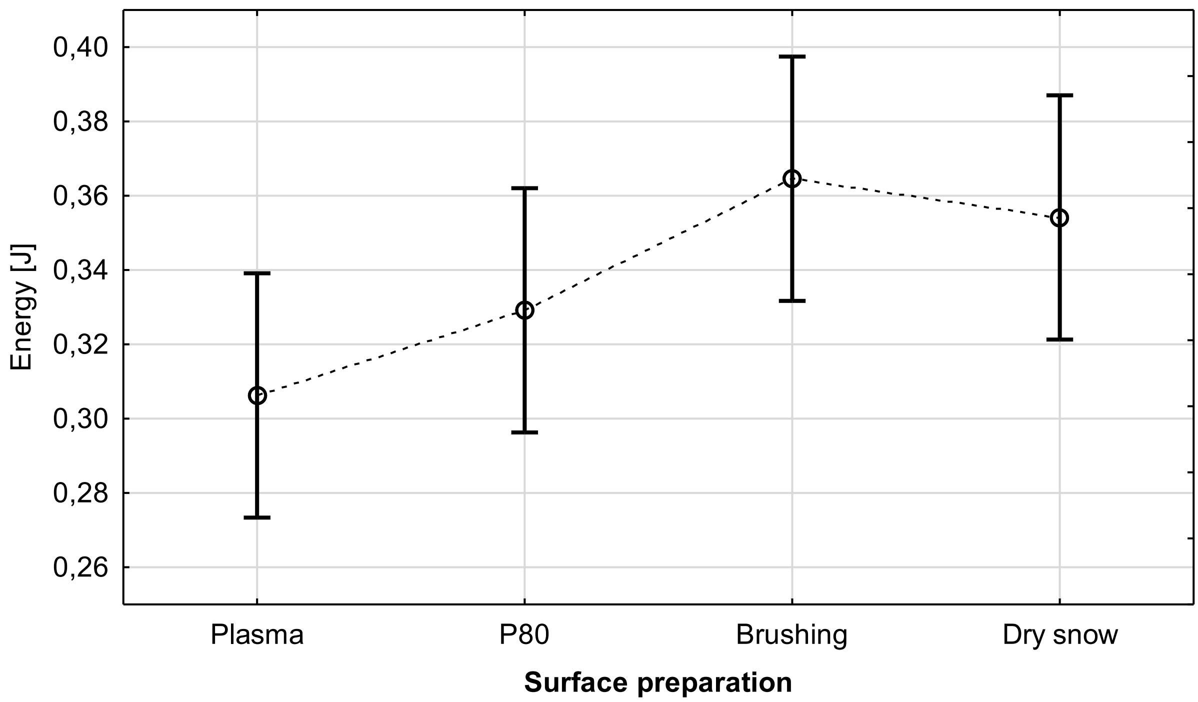

Figure 5. Graph of 95% probability interval of measured impact toughness values for meranti

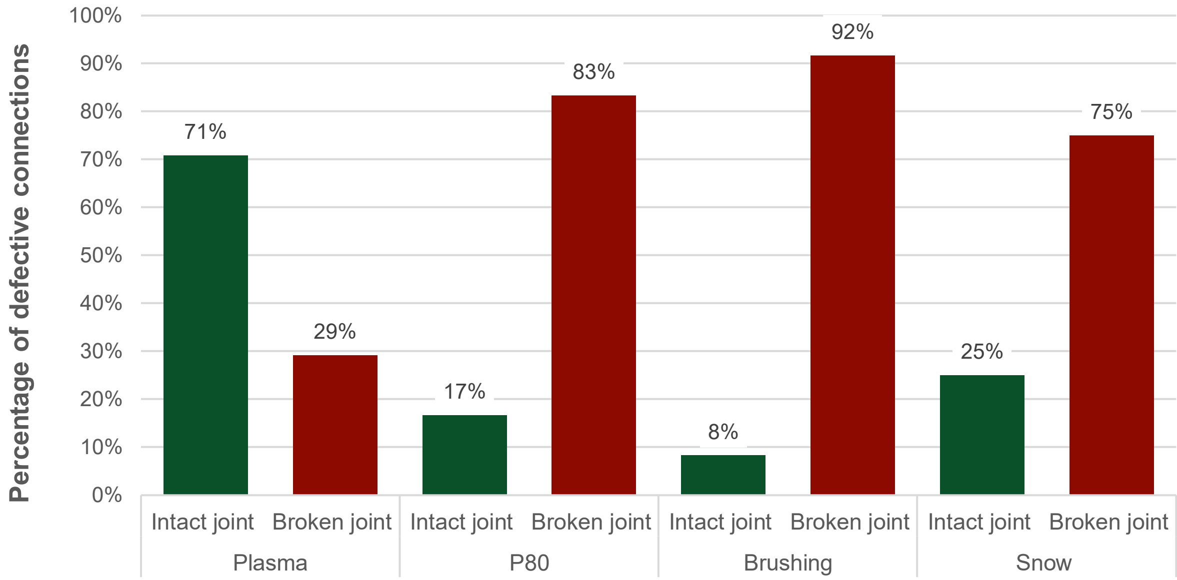

Figure 6. Evaluation of the quality of the meranti connection

In Figure 5, we do not observe statistically significant changes in the measured impact toughness values, but in Figure 6, we can see a higher number of defective joints in all joints, with the highest number detected in the brushing method.

FTIR analysis results

The aim of the test is to determine whether preparing the surface with dry snow has a significant effect on the surface properties.

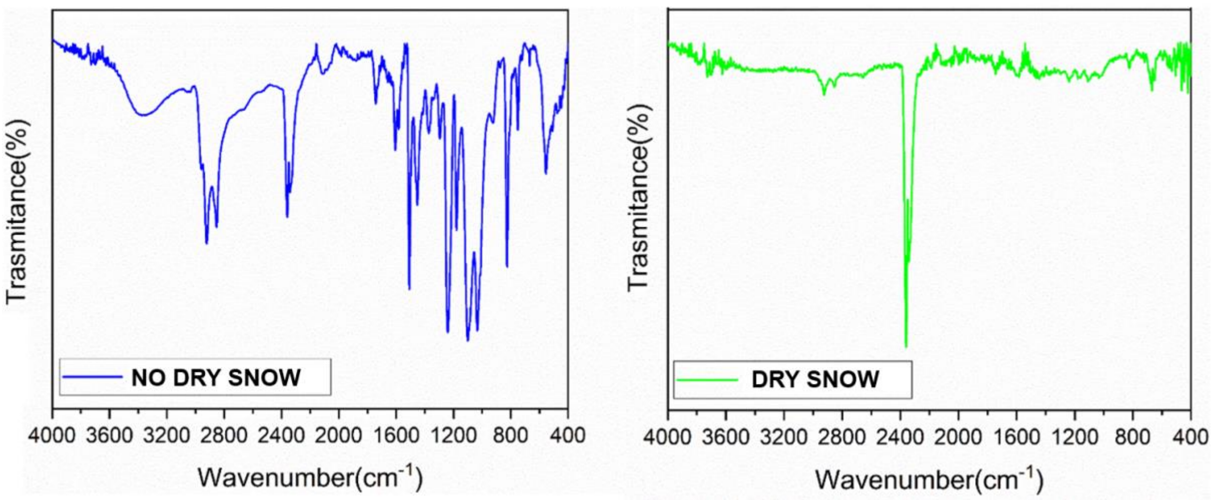

Figure 7. Results FTIR analysis

Figure 7 shows that surface preparation with dry snow affects the final properties of the surface cured with epoxy resin.

Conclusion

The results of the experiments confirmed that the method of surface preparation has a significant effect on the strength properties of the bond between solid wood and cast epoxy resin. The tensile strength values obtained show that modern surface treatment methods, in particular dry ice blasting and plasma treatment, achieve better results than traditional methods such as sanding or brushing. Dry ice blasting resulted in the highest tensile strength values, while brushing showed the lowest results.

No statistically significant differences between the individual methods were observed in the impact toughness tests, but in terms of joint quality, modern treatment methods proved to be advantageous here as well, showing fewer defects. FTIR analysis confirmed that dry ice surface preparation affects the chemical composition of the surface and can thus contribute to improving the adhesive properties of the joint.

Overall, it can be concluded that modern physical methods of surface preparation represent a promising direction for improving the quality and reliability of wood-epoxy resin joints while maintaining the environmental friendliness of the process.

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