



IMPACT OF DRYING REGIMÉ OF VEENERS ON FIRE PROPERTIES OF TREATED PINE PLYWOOD

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Abstract

The paper describes the effect of temperature drying pine veneer impregnated with salt formulation wood preservative containing boric acid, butylokarbaminian and quaternary ammonium compounds, for fire resistance are derived from three-layer plywood. Secured veneers dried at three different temperature: 60°C, 80°C, 105°C. Plywood were tested for reaction to fire and the oxygen index test method. Achieved varying degrees of flammability of the material. In addition, there was determined the veneers modification impact of selected mechanical properties of plywood produced.

Key words: *fire resistance, plywood, flammability, drying regimé*

INTRODUCTION

Modification of wood-based materials is an important direction of research in the field of wood science. It allows to obtain materials with greater resistance to physical, mechanical and biotic factors. The additives like synthetic materials and alternative lignocellulosic raw materials allows to reduce the amount of wood used to wood-based material production (Borysiuk *et al.* 2008, 2010, Kowaluk 2011). Another aspect of wood-based materials modification concerns the improvement of fire resistance, particularly wood-based materials that are used in construction, such as plywood, OSB. There are many possibilities of improving the fire resistance of wood-based materials for example acetylation (Mohebbi *et al.*, 2007) or saturation of raw salt retardants, e.g.: polyphosphate, diammonium hydrogen phosphate (DAP), hydroxide magnesium, boron compounds (Grexa *et al.* 1999, 2003, Kozłowski *et al.* 1999). An important aspect of composite wood modification is characteristic of the influence of impregnation on mechanical properties of the material. As indicated the funding aqueous salt solutions are highly hygroscopic and can cause adverse effects on the quality of adhesive joints, especially in the plywoods (Kartal *et al.* 2007). Another aspect involves the verification of the assumption if a better solution is the introduction of flame retardants to the process, or modification of the finished board.

It is known that at high temperature on the surface of wood impregnated with retardants is formed coating which limits the escape of flammable gases. The high temperature during the drying of veneers and pressing charges may adversely affect the properties of plywood manufactured from veneers initially impregnated.

In the present study was to determine how the temperature of drying pine veneer impregnated with salt and bio-agent containing such fireproof boric acid will affect the mechanical properties and fire resistance of pine three-layer plywood.

MATERIAL AND METHODS

Veneers of pine (*Pinus sylvestris* L.) with dimensions 350 x 350 x 1.8 mm³, the density of 490 kg/m³ were impregnated with substance containing: boric acid, butylokarbaminian and quaternary ammonium compounds. Concentration of the preparation (aqueous solution) was 50%. Veneers are immersed in a cuvette with impregnant and placed in a vacuum chamber in which the sequence produced 100 mbar vacuum. After 20 minutes the vacuum in the chamber was reduced to atmospheric pressure. After removing the veneer from the chamber, its mass was determined in order to determine the retention of impregnant. The average value of the retention measure was 98 kg/m³. Then the veneers have been subjected to conditioning at 22°C for 7 days. The set time allowed for an even, slow evaporation of water excess from the material. After seasoning the veneers were tested under three variants of drying in a drying oven with forced air circulation, which then made of plywood:

WI - veneer drying temperature of 60°C for 30 min,

WII - veneer drying temperature of 80°C for 20 min,

WIII - veneer drying temperature of 105°C for 10 min.

During the study the drying temperature above 105°C was not applied, as intensified release of gases which limit the flameability as a result of active ingredient decomposition may occur. After drying the average moisture content of veneers, depending on the variant drying ranged from 6 to 8%. The study frameworks also included use of unmodified veneers which were used to plywood production processes in the control variant (C). Modified and unmodified veneers were used for 3 – layers plywood production, bonded with UF resin based glue (unit glue recipe: resin – 100 part by weight, hardener – 10% (NH₄)₂SO₄ solution – 4 p.b.w., aggregate (wheat flour) – 15 p.b.w., water – 10 p.b.w.). Plywood production parameters are presented in Table 1.

Table 1. Plywood production parameters

Parameter	Value
Glue spread	160 g/m ²
Pressing temperature	110°C
Unit Press pressure	1,2 MPa
Time of pressing	360 s

After the production, plywood was conditioned for 5 days in the laboratory. Next, samples from each variant were prepared for further tests. Flammability of obtained plywood was tested by two methods: method of reaction to fire testing according to EN ISO 11925-2 (as a result of measurement, it was recorded: whether the ignition of the sample took place, whether the top of the flame reached a height of 150 mm above the location on which the flame work, what is the visual condition of the sample) and oxygen index method based on the standard ISO 4589-2 (used to compare the flammability of different materials while assessing the modification of the same type of material). Additionally the plywood was characterized in terms of mechanical properties: determination of modulus of elasticity in bending and of bending strength according to EN 310 and bonding quality according to EN 314-1.

RESULTS AND DISCUSSION

The results of reaction to fire

Table 2 presents results of reaction to fire and flammability by oxygen index method for tested plywood. Additionally the condition of samples after the test for reaction to fire is presented in Figure 1.

Table 2. Results of the test for reaction to fire.

Variant	Inflammation of sample	The average height of the flame's top reached after 30 sek. [mm]	General condition of samples
C	Yes	94	Very bad, strongly burned
W I	No	24	Good, no reaction with flames
W II	No	19	Very good, no reaction with flames
W III	No	26	Good, no reaction with flames

The best fire resistance showed veneers which were dried at 80°C degree (W II). The material showed high resistance to fire. Slight damage occurred only at the spot where the flame was applied. Within the time of 30 seconds impregnated samples did not ignite. Plywood veneers dried at 60°C (W I) and 105°C (W III) showed a slightly lower resistance, but compared with the unsecured plywood (C) can be considered high. Unprotected material quickly caught fire. After 60 seconds the samples had to be put out the fire, because the fire spread strongly.



Figure 1. The condition of samples after the test for reaction to fire.

The results of flammability by oxygen index

The results of flammability by oxygen index method tests are shown in Figure 2. Samples from control variant (C) bursts into flame at 26% concentration of oxygen in air mixture. According to the european standar, the oxygen index for wood falls in the range of

22,4-26%. The best fire resistance of the sample obtained WII variant, because it caught fire only when the oxygen concentration was 82% and within 180 seconds only 15 mm of sample burned down.

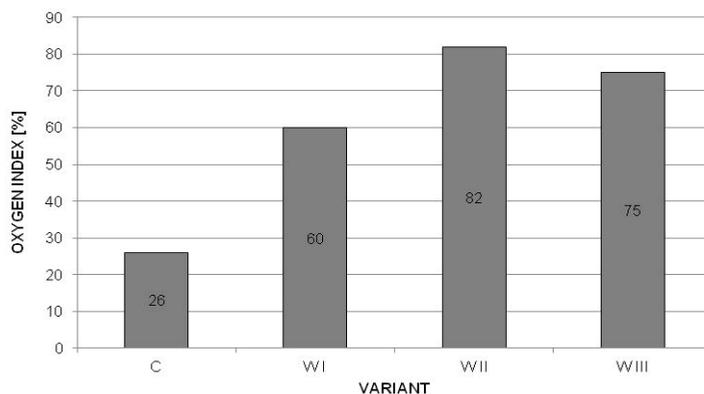


Figure 2. Results of oxygen index flammability test for peculiar variants

The results of mechanical properties (MOR, MOE, bond quality)

The results of MOR and MOE, allowed in accordance with the standard EN 636 derived plywood classification as follows: plywood control (C): F 30/50 E 10/60; plywood variant WI: F 10/30 E 5 /; plywood variant WII: F 10/60 E 5/60, 30, plywood variant WIII: F 5/50 E x/50. The obtained values of modulus of rupture and modulus of elasticity shown in Table 3. Figure 3 shows the values of bonding quality in the study of shear.

Table 3. Research results of modulus of rupture and modulud of elasticity

Variant	MOR [N/mm ²]	Standard deviation [N/mm ²]	MOE [N/mm ²]	Standard deviation [N/mm ²]
C				
Along grain	86,8	12,2	6853	709
Cross grain	30,3	6,1	1401	171
W I				
Along grain	53,2	7,8	3959	474
Cross grain	17,4	5,4	987	193
W II				
Along grain	92,3	7,2	6684	516
Cross grain	16,3	2,6	684	78
W III				
Along grain	78,4	5,6	5872	203
Cross grain	11,9	1,9	341	89

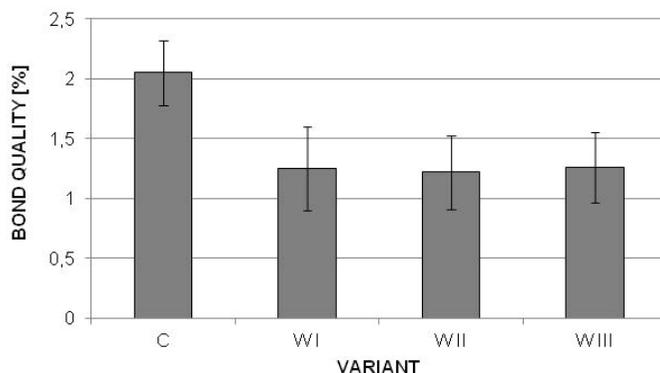


Figure 3. Shear strength of pine plywood made of impregnated and non-impregnated veneers

The standard EN 636 defines several classes of plywood bending strength and elastic modulus along and cross grain. Strength and elastic modulus of control plywood (C) has been classified as a middle value in a statement reported in the standard. This strength in the longitudinal direction was close to 87 N/mm^2 and 30 N/mm^2 in transverse direction. While the elastic modulus along the fiber was 6853 N/mm^2 and 1401 N/mm^2 across the grain. These are the correct values for plywood used in dry conditions. The best properties (similar to those of the control material) revealed the plywood from variant WII. Bending strength in the longitudinal direction was 92 N/mm^2 , while strength in the transverse direction decreased by half. Elastic modulus of plywood WII variant in the transverse direction has also been classified in a class lower in comparison with the control plywood, while the module along the fibers had similar value.

Bonding quality tests showed that the samples impregnated by fire protection preparation shows nearly half the shear bond strength than not impregnated samples. Bonding quality in the control variant was 2.05 N/mm^2 . Bonding in the plywood produced in WI variant showed an average strength of 1.25 MPa . Strength of bonding in WII variant has reached the lowest average value in the study: 1.22 MPa . The highest bond has been obtained for the samples in WIII variant: 1.26 MPa .

CONCLUSION

- Impregnation of veneers with a preparation containing boric acid, butylokarbaminian and quaternary ammonium compounds increases the fire-resistant of three-layer pine plywood.
- The most optimal drying temperature of veneers impregnated with the preparation containing boric acid, butylokarbaminian and quaternary ammonium compounds is the temperature of 80°C and time 20 minutes.
- Applied protection does not affect the strength of the material in static bending.
- The addition of impregnation negatively affects the quality of the adhesive bond, but obtained values of strength meet the requirements of the standard.

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