PAPER • OPEN ACCESS

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To cite this article: K V Nosonovskikh and M V Gazeev 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **949** 012067

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Improving the technology of gluing solid wood due to the impact of negative air ions

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Abstract. Aeroionization is actively used in various fields of science and industry. It plays an important role for medicine, as it is used for disinfecting premises and has a therapeutic effect on living organisms. This paper discusses the use of aeroionization to intensify the curing of the glue line and improve its quality characteristics. The positive effect of negative aeroins on the process of wood gluing is theoretically described and experimentally confirmed.

1. Introduction

One of the main challenges faced by manufacturers of adhesive products is to speed up and simplify the gluing process. There are many different methods of intensifying the process of gluing wood, which consist in accumulating heat, using contact, convective, infrared or high-frequency heating.All of the above methods help to reduce the duration of the gluing cycle, rational use of technological equipment, and reduce production areas, which opens up opportunities for increasing the level of mechanization. and automation of industrial production of glued structures and products [1, 2, 3, 4, 5, 6, 7]. Therefore, accelerated bonding can be considered one of the promising methods of joining materials.

The method of accelerating the bonding process by means of aeroionization seems to be promising and poorly studied. Its main advantages:

1.   Environmental friendliness;
2.   Low power consumption;
3.   Easy to operate;
4.   Reduction of production areas;
5.   Increasing the level of mechanization and automation of industrial production of glued structures and products.

2.Materials and Methods

In the research, we used an adhesive based on PVA dispersion of the FOLCO - LITD3 TC brand. To improve the characteristics of the glue seam, an electro-effluvial air ionization device was used (Figure 1, 2).

For gluing, wooden blocks with a cross section of 20 × 25 mm were chosen, the minimum length is 350 mm. The breed is pine. Humidity - $8 \pm 2\%$, roughness - not less than 100 microns. Temperature - at least 18±2 ℃.

The cold gluing method is used. The process consists of the following operations:
- surface cleaning (removal of dust, dirt, etc.), carried out with a dry brush;

- application of glue to the surfaces to be glued, carried out with a brush, the consumption of glue is 150 g / m ^ 2;

- open exposure under the ionizer, combined with the assembly;

- pressing of blanks, pressure - 0.4 MPa;

- technological exposure.

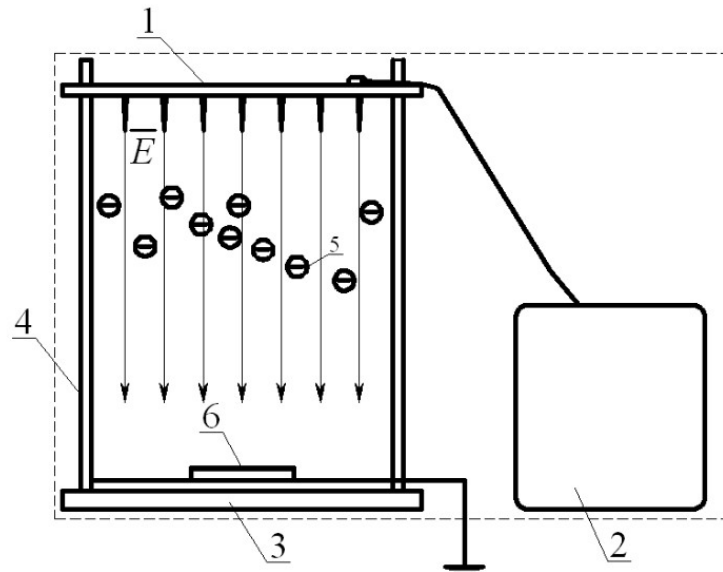The prototypes were tested for shearing along the glue seam in accordance with GOST 33120-2014.

Figure 1. Electroeffluvial air ionization device:
1 - electro-effluvial emitter; 2 - multiplier with high-voltage generator; 3 - bottom panel with a metal plate and grounding; 4 - post; 5 - negative air ions; 6 - sample with applied glue
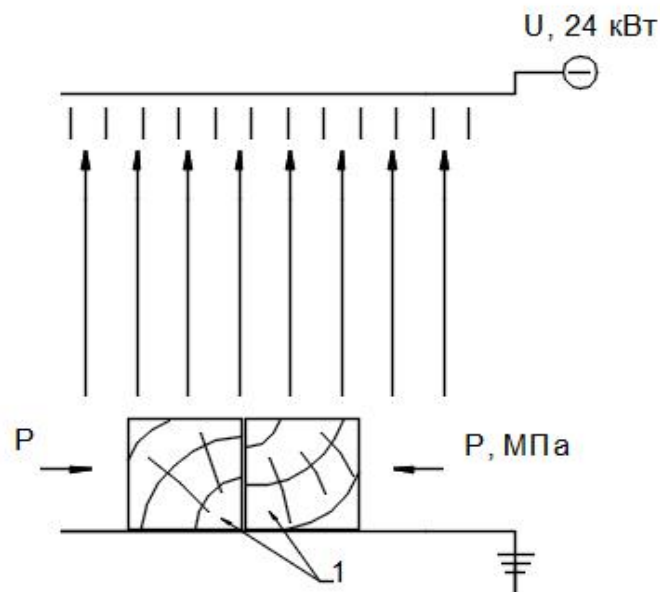

Figure 2. Scheme of aeroionization in the press: 1 - glued samples.

The design of the experiment was performed according to Box's plan for 3 independent variables:
- open exposure time, min;
- pressing time, min;
- the distance from the emitter of air ions to the surface of the wood with the applied glue (glue line).
Constant factors during the experiment were taken:
- pressing pressure, MPa;
- pressing temperature, 0C;
- ambient temperature, 0C;
- humidity of the environment,%;
- wood moisture,%;
- time of technological exposure, min.
The plan of the experiment is presented in the table 1.

Table 1. Plan of the experiment.

EXPERIENCE NO	CONDITIONS	PRESSING (min)	Technological exposure (min)
1	t = 20 ± 2 ° C; W = 65 ± 5%; wood moisture = 8 ± 2%; consumption = 150g / m²;	natural. time = 32	natural. 120
2	t = 20 ± 2 ° C; W = 65 ± 5%; wood moisture = 8 ± 2%; consumption = 150g / m²;	Aeroionification time = 32	natural. 120
3	t = 20 ± 2 ° C; W = 65 ± 5%; wood moisture = 8 ± 2%; consumption = 150g / m²;	natural. time = 32	Aeroionification time = 120
4	t = 20 ± 2 ° C; W = 65 ± 5%; wood moisture = 8 ± 2%; consumption = 150g / m²;	Aeroionification time = 32	Aeroionification time =120
5	t = 20 ± 2 ° C; W = 65 ± 5%; wood moisture = 8 ± 2%; consumption = 150g / m²;	Aeroionification time = 4	Aeroionification time =120
6	t = 20 ± 2 ° C; W = 65 ± 5%; wood moisture = 8 ± 2%; consumption = 150g / m²;	Aeroionification time = 32	Aeroionification time =0
7	t = 20 ± 2 ° C; W = 65 ± 5%; wood moisture = 8 ± 2%; consumption = 150g / m²;	Aeroionification time = 4	Aeroionification time =0
8	t = 20 ± 2 ° C; W = 65 ± 5%; wood moisture = 8 ± 2%; consumption = 150g / m²;	Aeroionification time = 32	Aeroionification time =60
9	t = 20 ± 2 ° C; W = 65 ± 5%; wood moisture = 8 ± 2%; consumption = 150g / m²;	Aeroionification time =4	Aeroionification time =60
10	t = 20 ± 2 ° C; W = 65 ± 5%; wood moisture = 8 ± 2%; consumption = 150g / m²;	Aeroionification time =18	Aeroionification time =120
11	t = 20 ± 2 ° C; W = 65 ± 5%; wood moisture = 8 ± 2%; consumption = 150g / m²;	Aeroionification time =18	Aeroionification time =0

When analyzing the statistical characteristics of the experimental designs, it was found that for 8 variable factors, it is necessary to conduct 56 experiments. For each experiment there are 4 series of gluing:

1 - control samples,

2, 3 and 4 are evaluated for load groups D2, D3 and D4 according to DIN EN 205. The number of repetitions in each series of experiments is 5. The total number of samples is 840.

3. Results and Discussion

On the basis of the experiments carried out, regression equations of the second order (in coded values) (1 - 2) were constructed, which adequately describe the process of gluing solid wood during aeroionization.

$$Y1 = 7.98 + 0.18 \times x_1 - 0.32 \times x_2 + 0.17 \times x_1 \times x_2 - 0.08 \times x_1^2 - 0.64 \times x_2^2 \qquad (1)$$

$$Y2 = 3.41 + 0.31 \times x_1 - 0.03 \times x_2 - 0.09 \times x_1 \times x_2 \qquad (2)$$

$$Y3 = 2.81 + 0.13 \times x_1 + 0.17 \times x_2 - 0.33 \times x_1 \times x_2 + 0.68 \times x_1^2 + 1.62 \times x_2^2 \qquad (3)$$

The reliability of the models is confirmed by the Fisher criterion.

According to the obtained mathematical models, graphs of the dependence of the strength indicators of the glue seam on variable factors were built (Figure 3, 4, 5).
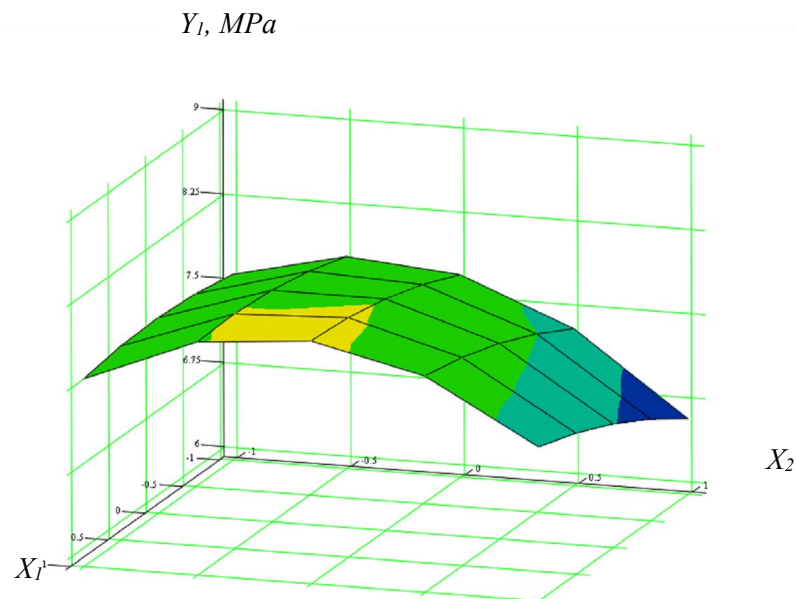
Y₁, MPa

Figure 3. Dependence of the shear strength along the glue seam (Y1) after exposure for 7 days under natural conditions, where X1 is the exposure time of air ions at the stage of technological exposure and X2 is the exposure time of air ions in the press.

With an increase in the time of exposure to air ions at the stage X1 = 1 and X2 = 0, the strength of the glue joint Y increases to 8.25 MPa, which is significantly higher than the indicators of the control samples. A further increase in the exposure time X1 and X2 to 1 leads to a decrease in the strength characteristics (Figure 3).
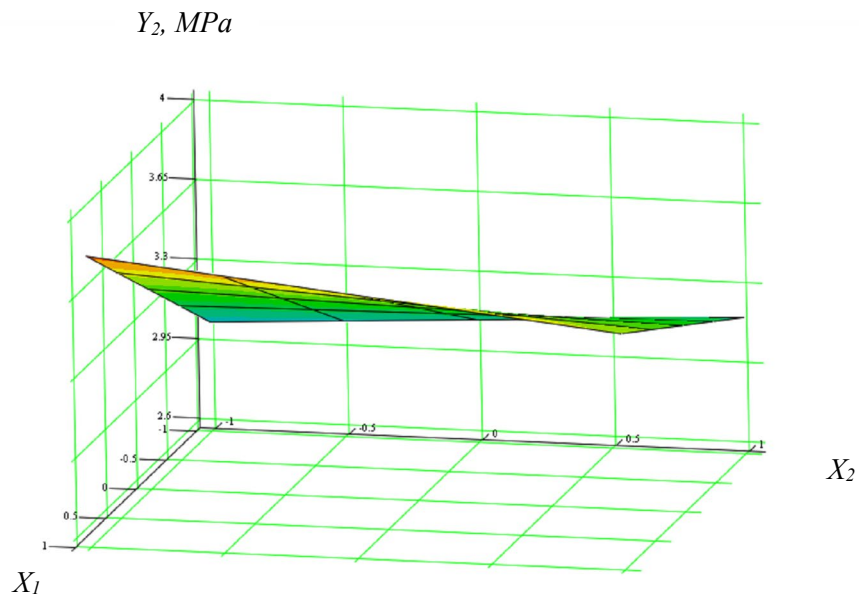
Y₂, MPa

Figure 4. Dependence of the shear strength along the glue seam (Y2) after exposure for 7 days under natural conditions and 4 days in water, where X1 is the exposure time of air ions at the stage of technological exposure and X2 is the exposure time of air ions in the press.

An increase in the time of exposure to air ions at the stage of technological exposure contributes to a significant increase in the strength of the glue seam for chipping along the fibers, while an increase in the exposure time in the press slightly reduces this indicator (Figure 4).
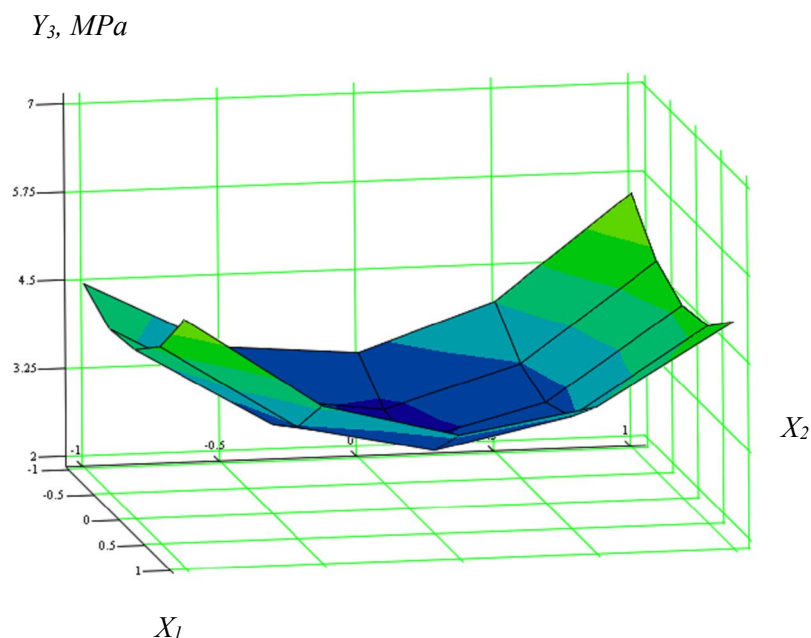
Y₃, MPa

Figure 5. Dependence of the shear strength along the glue seam (Y3) after exposure for 7 days in natural conditions and 4 days in water and another 7 days in natural conditions, where X1 is the exposure time of air ions at the stage of technological exposure and X2 is the exposure time of air ions in the press.

An increase in the exposure time of air ionization along the X1 and X2 axes to 0 leads to a slight decrease in strength Y. A further increase in the exposure time of X1 and X2 to 1 increases the shear strength index along the Y fibers to 5 MPa (Figure 5).

Samples glued under the influence of negative air oxygen ions and field strength show an increase in ultimate shear strength along the glue seam relative to control samples glued in vivo without using an electroeffluvial air ionization device.

PVA adhesives are polymerization adhesives, that is, curing occurs as a result of the polymerization reaction by removing water and increasing the growth of chains of macromolecules [8, 9].

The effect of the electrostatic field makes it possible to activate the glue line and intensify the process of its curing. And, as a result, the curing process of adhesives based on PVA dispersion is accelerated. In this regard, it is advisable to shorten the open exposure time, since otherwise, by the time the bars are assembled, the glue curing reaction is almost complete.

It can be assumed that the destruction of the glue line (Figure 5) occurs due to the fact that the molar volume of the water molecule becomes critical for the density of the cured adhesive network. The more often the spatial grid, the more actively the water molecule reacts. The less frequent the spatial grid, the more freely the water molecule moves in the intergrid space and reacts less with the polymer.

4.Conclusion

The hypothesis about the positive effect of negative air ions on the characteristics of the glue line is confirmed. Interaction with water inevitably leads to its destruction and a decrease in the strength of the structure. The effect of aeroionization, on the other hand, contributes to the compaction of the spatial network of the polymer and, as a consequence, to an increase in the water resistance of the adhesive joint. According to the research results, it can be concluded that aeroionification reduces the curing time of adhesives based on PVA dispersion, and also has a positive effect on the strength of the glue seam. Therefore, this method can be recommended for implementation in production to improve the quality of glued wood products.

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