The Dependence of Sander Dust as a Filler of Amino-Formaldehyde Adhesives and its Technological Properties

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***Abstract*—One of the main characteristics of the quality of plywood is its environmental friendliness, which is characterized by the content of free formaldehyde. It is necessary to use low-toxic amino-formaldehyde resin for the production of plywood with a low emission of formaldehyde. These resins have a low final viscosity, which can lead to the decrease in the strength properties of plywood due to excessive penetration of glue into the wood. It is possible to change the viscosity of solution adhesive with the help of fillers. Woodworking shops accumulates a large amount of sander dust. Sander dust in terms of moisture, bulk density and fractional composition is comparable to wood dust. The article explores the possibility of using sander dust as filler for amino-formaldehyde adhesives for the production of plywood.**

Keywords — plywood, strength, filler, sander dust, viscosity

I. INTRODUCTION

Nowadays, Russian industry consumes approximately 1.2 million tons of formaldehyde-containing resins. According to forecasts of specialists the need for resins will increase to 2.5 - 2.73 million tons by 2020.

In woodworking enterprises, amino-formaldehyde resins (AFR) are widely used in the manufacture of plywood, chipboard, when veneering furniture panels, etc. [9, 11].

Russian plywood enterprises produce large volumes of products to both national and international markets. It is obvious that access of Russian companies to these markets, in particular the markets of EU countries, is possible only with full compliance of the quality and emission class of formaldehyde E1, E2 of supplied plywood with the imposed requirements [10, 13]. For the production of plywood with a low content of free formaldehyde, low toxicity AFRs are used. These resins are synthesized at a lower final viscosity, which leads to the decrease in strength properties. In order to compensate the low viscosity of low-toxic resins, the introduction of fillers is recommended [12].

For the increase of the viscosity of low-toxic resins, the authors investigated different types of fillers: wood flour, rye flour and kaolin [4]. As a result of the research, the authors came to the conclusion that wood flour has a high adsorption capacity, as well as 2-5 m.ph wood flour per 100 m. h. resin increases the viscosity from 60 to 180 by the viscometer VZ-246 [5].

One of the technological operations in the production of plywood is the grinding of layers. As a result, a huge amount of fire-hazardous sander dust is accumulated at plywood plants. This dust must be disposed.

In terms of its properties, sander dust is comparable to wood flour, however, its use is currently limited, and therefore, the study of additional possibilities of using sander dust, in particular, as filler for AFR is a relevant task.

Thus, we decided to use plywood production wastes - sander dust, as a filler of low-toxic AFR.

II. METHODS AND MATERIALS

In order to compare the properties of wood flour [1] and sander dust obtained on different equipment during processing of different materials, the residue on the grid, humidity and bulk density were determined by the standard method [2].

We used sander dust obtained at the holding company Chernozemie Furniture while grinding oak blanks on an automatic grinding machine (oak 1), pines on a ShIPS machine (pine), oak manual grinding (oak 2), MDF and chipboard on Costa's calibration and grinding line (MDF, Chipboard), beech, ash, oak on the calibration-grinding machine, beech on the automatic grinding machine at Volgogradmebel company named after Yerman (beech), as well as grinding dust, obtained by grinding birch plywood at “Kyummene-Chudovo”, Chudovo, Novgorod region (birch 1) and “Nelidovsky DOK” (birch 2).

The main criterion for the quality of plywood is its strength, which is characterized by the limit of strength of the adhesive layer, determined according to All-Union State Standard 9624-2009 [3].

In order to determine the effect of the fractional composition of sander dust on the strength characteristics of glued plywood, the sander dust from birch of three fractions were used: 0.25, 0.18, and 0.125. Three-ply birch plywood of 400x400 mm format, 4 mm thick was glued with glue consumption of 120 g / m2 glue line, specific pressure - 1.8 MPa, the temperature of press plates was 140 ° C, the duration of holding in a press was 2 minutes.

In order to estimate the effect of sander dust on the technological properties (dynamic viscosity, pH of the medium, gel time at 100 ° C) of adhesive solutions, not only the fractional composition of sander particles was taken into account, but also the wood from which they were obtained.

During the preparation of working adhesive solutions, the conditional viscosity was measured using a VZ-246 viscometer with an opening diameter of 4 mm. A peculiarity of sander dust is that when adding it in an amount of more than 2 phr per 100 phr AFR glue gets so foamed in nature that it is impossible to accurately determine its conditional viscosity.

It is probable that with the introduction of sander dust, the glue from the Newtonian fluid goes into non-Newtonian and requires the determination of dynamic viscosity.

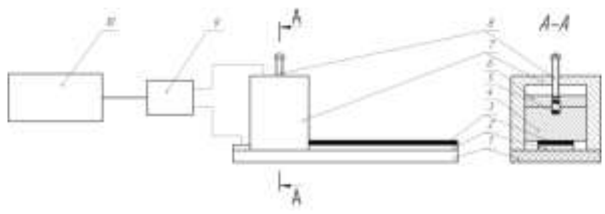
Therefore, the authors obtained reliable viscosity results for glue filled with sander dust using the rotary viscometer MT-202. At the same time, a higher rotor and a high rotation speed were used for low viscosity adhesives, a small rotor and a slow rotation speed were used for high viscosity adhesives. For the ranges of viscosity adhesives the authors used rotor number 2, changing the speed from 30 to 3 rpm.

The rate of adhesive curing is closely related to its acidity. Also, the pH value is important when choosing the amount of hardener. Therefore, we controlled the pH indicator of the glue filled with sander dust with a pH-meter of the pH-150MI brand.

The gel time is the period during which the adhesive passes from a liquid to a solid state. This indicator directly determines the duration of bonding materials and hence the performance of adhesive equipment. The essence of the method for determining the gel time at 100 ° C consists in measuring the time during which the glue in a test tube immersed in boiling water passes into a solid state.

It is obvious that the bonding strength depends on the magnitude of the internal stresses formed in the adhesive layer during its curing and exploitation. For the continuous determination of internal stresses arising during the curing of the adhesive layer, the Voronezh State Forest Engineering Academy developed a method [7] in which the bending amount of the glued plates f is permanently fixed by measuring the capacitance of a flat capacitor formed by the plates with the adhesive layer with the measuring cell.

The installation (Figure 1) consists of a working cell in which the glued plates, consisting of wooden plates of 10 Sm long and 1 sm wide with a thickness ratio of 1:10 and an adhesive layer of a given thickness between them, are fixed with a cantilever. The glued plates are connected to a constant current source and a digital device for converting analog signals to digital ones.



1 – basement; 2 – fixed condenser coating; 3 – the sample of non-fixed condenser coating; 4 – bearing; 5 – coil; 6 – pressure-bearing; 7 – holding rod; 8 – screwnail; 9 – digital transducer; 10 – PC

Fig. 1. Schematic diagram of the installation for the study of internal stresses in adhesive layers

In order to study the effect of the amount of slander dust on the amount of internal stresses, 2 veneer strips (10 × 100 mm thick) with a thickness of 0.4 and 0.8 mm with glue stitches of a given thickness were fixed to the console. Aluminum foil was glued to the veneer of lesser thickness in order to use the sample as the top capacitor plate. The bottom plate of the capacitor was the metal base of the installation. During the curing of the adhesive, bending in the direction of the veneer of a smaller thickness occurs, changing its capacity as a condenser.

Controlling the maximum deviation of the end of the adhesive pair, the internal stresses were calculated using the following formula:

$$\sigma_v = \frac{2 f_{\max} \cdot E_1 J}{S_2 (h_1 - y_i + 0,5 h_2) L^2} + \frac{2 f_{\max} (h_1 - y_i + 0,5 h_2) E_2}{L^2}$$

Where:

F_{max} – maximum deviation of the end of the adhesive pair, mm;

E1 – the modulus of the elasticity of plates material, MPa;

J – the product of inertia over the plate section, kg·m^2;

h_1 – larger veneer thickness, mm;

y_i – length to the center of gravity of the adhesive sample, mm;

h_2 – adhesive layer thickness, mm;

E_2 – modulus of normal elasticity of interlayer, MPa;

S_2 –surface of adhesive layer section, mm^2;

L – adhesive pair length, mm.

III. RESULTS

The fractional composition of sander dust is larger and does not meet the requirements for wood flour, as shown in table 1. But the content of particles of the necessary fractions ranges from 20.4 to 93.8%, depending on the type of material to be ground and the equipment used. Virtually any kind of sander dust, presented in table 2, corresponds to the compound content of wood flour and does not exceed 8%.

The bulk density is exceeded in the sander dust of pine and a compound of particleboard and MDF (not included in 100-140 kg / m^3).

TABLE 1. THE RESIDUE OF SANDER DUST ON A GRIND, %

Gap in grid holes, mm	Oak 1	Pine	Beech	Oak 2	MDF, chipboard	Birch 1	Birch 2	Hardwood compound
0.125	91.5	100	99.0	100	77.4	92.0	88.7	51.2
0.18	86.9	80.9	81.0	80.2	67.9	89.5	71.6	32.4
0.25	61.7	21.1	11.0	30.9	42.4	79.6	45.9	6.2

TABLE 2 .HUMIDITY AND SANDER BULK DENSITY

Parameter	Oak 1	Pine	Beech	Oak 2	MDF, chipboard	Birch 1	Birch 2	Hardwood compound
Humidity, %	8.29	6.5	8.53	6.34	6.17	7.73	7.11	7.57
sander bulk density, kg/m^3	93.88	136.9	131.33	128.15	159.46	77.67	118.46	125.31

Thus, after sorting out the sander dust fraction 0.25; 0.18; 0.125 can be used as filler for AFR in the production of plywood and lining furniture panels.

The results of the experiments, presented in Figure 2, showed that the introduction of sander dust from the fraction passing through a 0.25 grid is ineffective, since the AFR has a fairly high viscosity. Bonding strength has increased by only 12.8%.

However, using smaller fractions resulted in a significant increase in strength. Moreover, with a decrease in particle size, the optimal proportions of filler also decreased.

For example, for the fraction passing through a 0.18 grid, the optimal proportion of filler is 1 mph per 100 mph resin, with the bonding strength increased by 35%, for the fraction passing through a grid of 0.125 with 1 pm filler, the bonding strength respectively was 63%.

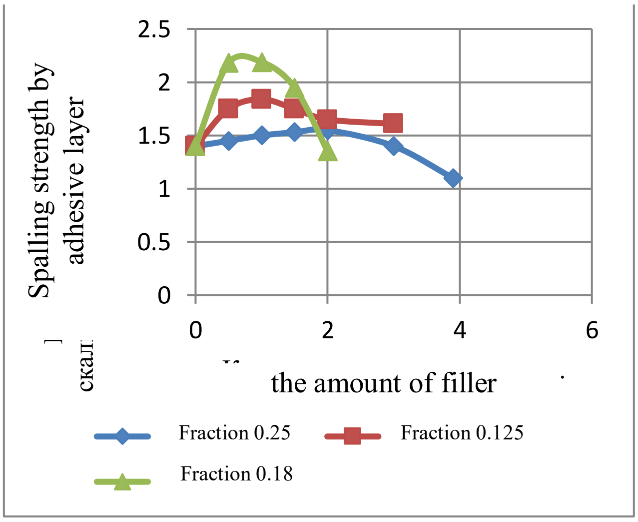


Fig. 2. The effect of the amount of sander dust of different fractional composition on the strength of plywood

The results indicate the feasibility of using sander dust obtained by grinding birch plywood as a filler for AFR [6].

From the diagram (Figures 3 - 5), it can be seen that with an increase in the amount of filler, the viscosity of the adhesive increases with the use of sander dust of any kind. But if the maximum viscosity of the adhesive component when using birch sander dust is 1000 sP, then for pine 6500 sP, and for a compound of hardwood 8500 cP. Moreover, the effect of the fractional composition on the increase in viscosity for sander dust of various rocks varies. So for a compound of hardwood and pine, smaller fractions produce less viscosity growth than large ones. Birch situation is similar, but the influence of particle size is less significant. This is probably due to the formation of carboxylic acid as a result of an increase in temperature during the process of plywood grinding. The presence of carboxylic acid is confirmed by the characteristic reddish discoloration of adhesive component with birch sander dust. Carboxylic acid significantly reduces the processes of water and moisture in wood [8], which leads to less swelling of the particles of sander birch dust.

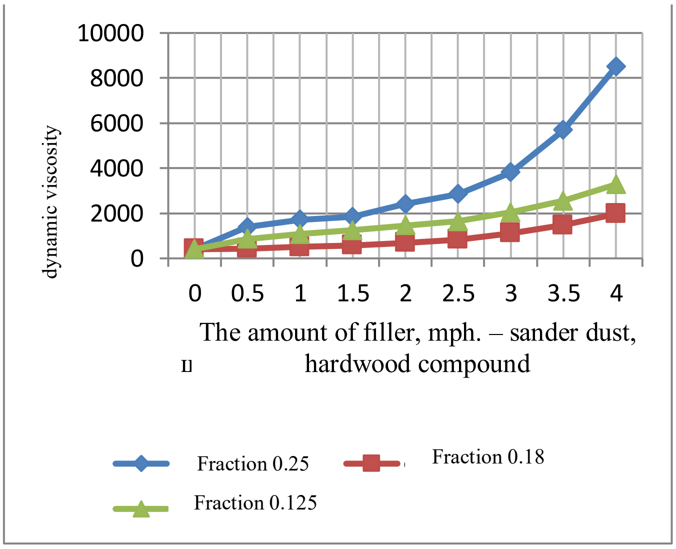


Fig. 3. The dependence of the dynamic viscosity of filled adhesives on the amount of filler

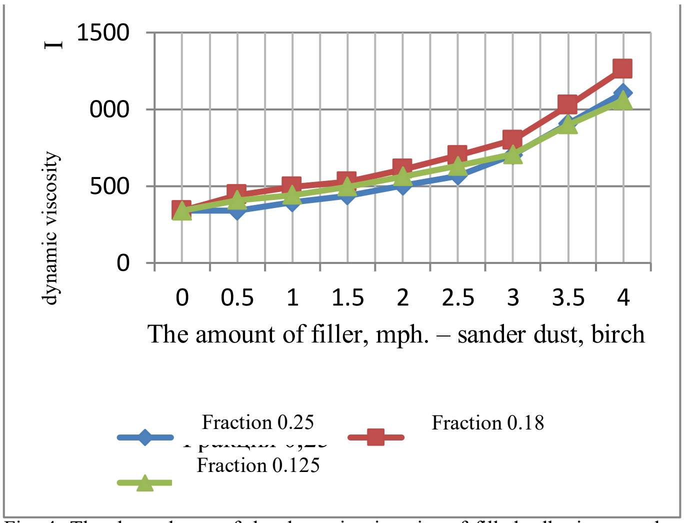


Fig. 4. The dependence of the dynamic viscosity of filled adhesives on the amount of filler

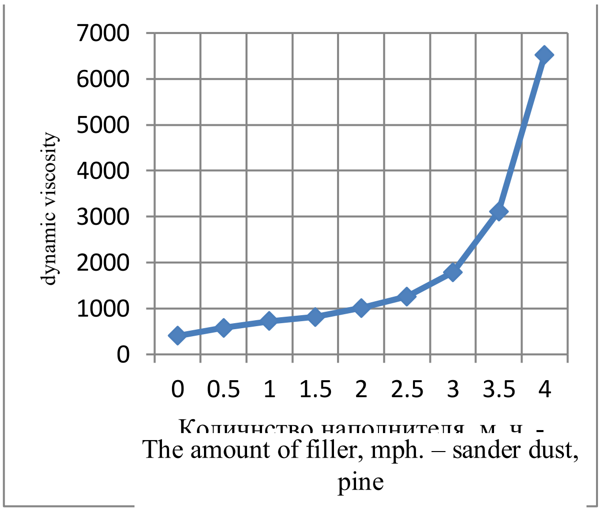


Fig. 5. The dependence of the dynamic viscosity of filled adhesives on the amount of filler

The results of studies of the effect of rock, the amount and fractional composition of sander dust on pH and gel time at 100 ° C, directly affecting the length of gluing plywood, are presented in Figures 6-10.

The analysis of the diagrams (Figures 6–10) shows that the introduction of filler of different wood species changes the pH of adhesive composition in the direction of a neutral and slightly acidic medium. As a result of this, the gel time at 100 0 C decreases to the level of 55-60 s already at 1 pm filler and does not change with a further increase in the amount of filler. Wood species sander dust does not have a significant effect on the pH and gel time of adhesive component, because the amount of filler in adhesive component is insignificant (not more than 4 mph).

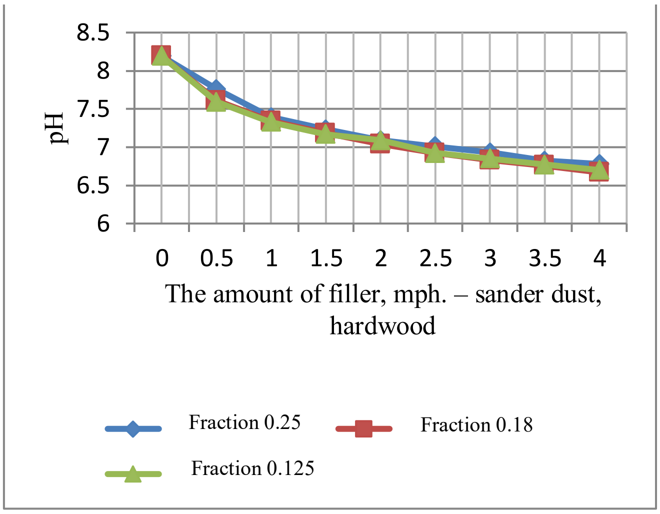


Fig. 6. The dependence of pH on the amount of filler

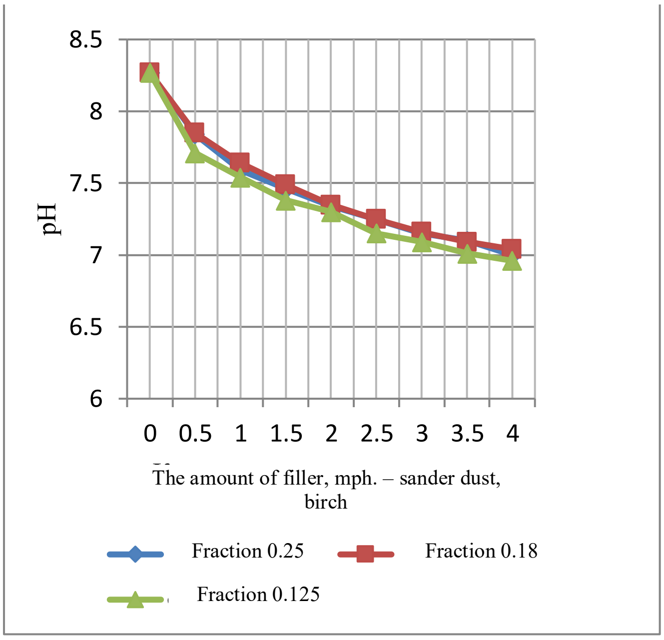


Fig. 7. The dependence of Ph on the amount of filler

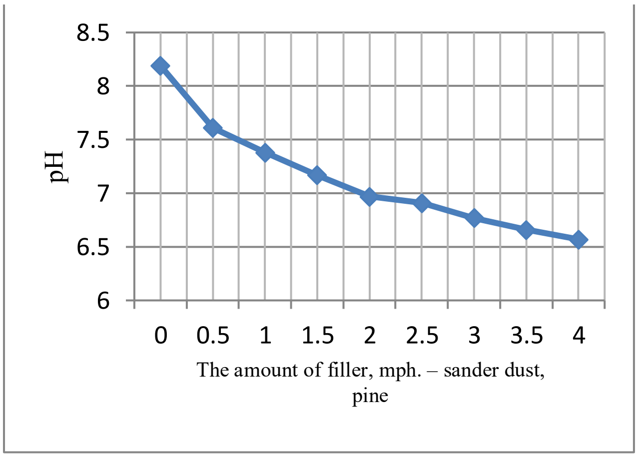


Fig. 8. The dependence of Ph on the amount of filler

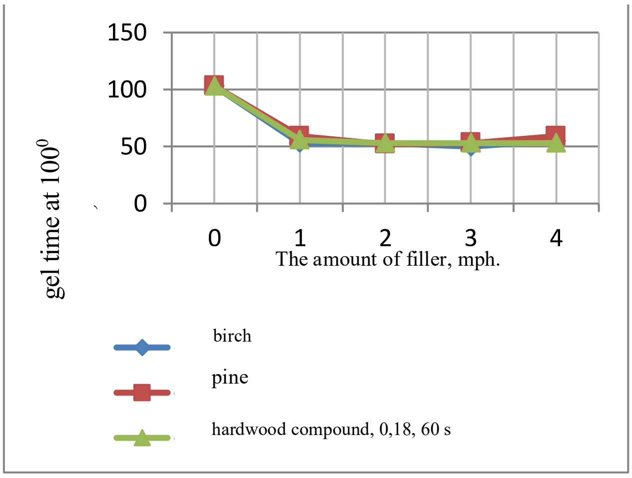


Fig 10. The dependence of gel time at 1000 C on the amount of filler

The results of determining the internal stresses in the adhesive layer are shown in Figure 11. With the increase in the amount of filler to 0.5; one; 2 mph, which corresponds to a filler fraction of 0.125; 0.18; 0.25, the internal stresses of the adhesive line are reduced. Subsequent increase in the amount of filler leads to a slight increase in the internal stresses of the adhesive layer, which reduces the bonding strength.

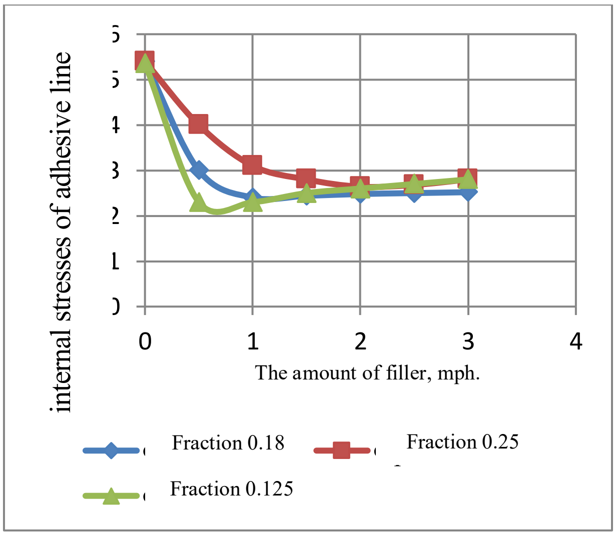


Fig. 11. The dependence of internal stresses of adhesive line on the amount of filler

IV. Conclusion

1. Sander dust obtained by grinding of plywood and solid wood blanks is comparable in its properties to wood flour. After sorting out the sander dust fraction 0.25; 0.18; 0.125 can be used as filler for AFR.

2. The introduction to low-toxic low-viscosity AFR into sander dust increases the bonding strength.

3. When using smaller fractions of particles of sander dust, the growth of bonding strength is higher and less than the optimal proportion of filler.

4. With the increase in the amount of filler, the dynamic viscosity of adhesive component increases, and smaller fractions give less viscosity growth than large ones.

5. When sander dust is added, the pH of adhesive composition shifts towards a neutral and slightly acidic medium, and the gel time decreases to 55-60 s.

6. Filling AFR with sander dust leads to the decrease in internal stresses in the cured adhesive layer.

Thus, the conducted studies prove the possibility of using sander dust as a filler of low-toxic and low-viscosity AFR.

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