

STUDY OF THE INFLUENCE OF COMPOUNDS OF THE ANO_3 AND $\text{ANO}_3 \cdot n\text{H}_2\text{O}$ TYPES ON RHEOKINETIC AND COLLOID-CHEMICAL PROPERTIES OF ALUMINOSILICATE ADHESIVES FOR WOOD

Sergii Guzii¹, Ihar Bazhelka², Vasyl Lashchivskiy³

¹Scientific laboratory LLC Geofip, Kropyvnytskyi, Ukraine
sguziy2@gmail.com

ORCID: <http://orcid.org/0000-0003-0147-5035>

²Department of Woodworking Technology, Belarusian State Technological University, Minsk, Republic of Belarus

bikbstu@mail.ru

ORCID: <http://orcid.org/0000-0002-7599-6944>

³Department of Industrial, Civil Construction and Engineering Structures, National University of Water and Environmental Engineering, Rivne, Ukraine

v.v.lashchivskiy@nuwm.edu.ua

ORCID: <http://orcid.org/0000-0001-5178-4317>

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ABSTRACT

In the technology of gluing solid wood, various adhesives are used, which, in addition to ensuring the strength of the gluing, must also be characterized by a number of rheological and colloidal-chemical properties, namely: have acceptable viscosity, low contact angles, have good spreading and enveloping ability, penetrate deep into the wood, providing reliable cohesive-adhesive contact and much more. Today, adhesives based on PVA dispersions and urea formaldehydes are used, the properties of which have been sufficiently studied and tested in practice. An alternative to organic-based adhesives is mineral adhesives, in particular aluminosilicate adhesives, which are non-flammable and have high mechanical strength.

Object of research: rheokinetic patterns and processes of formation of colloidal-chemical structures of aluminosilicate adhesives modified with compounds of the ANO_3 and $\text{ANO}_3 \cdot n\text{H}_2\text{O}$ type.

Investigated problem: Considering that aluminosilicate adhesives are multiphase reactive suspensions, the viscosity of which changes over time and affects their viability, the issue of viscosity stabilization due to the introduction of electrolyte salts into their composition is relevant, and will also contribute to improving the wettability and spreading of the adhesive during applying them to substrates and gluing samples from various types of wood.

Main scientific results: The effect of the concentrations of compounds of the ANO_3 and $\text{ANO}_3 \cdot n\text{H}_2\text{O}$ type on the rheokinetic and chemical-colloidal properties of the aluminosilicate adhesive has been established, which will make it possible to use aluminosilicate adhesives in practice for gluing wood of various species, as well as to work out possible technological methods of their application, taking into account the obtained data on the viscosity, wetting and spreadability of the modified adhesive on the surface of the wood substrate.

Area of practical use of the research results: woodworking enterprises for the production of glued solid wood products.

Innovative technological product: aluminosilicate adhesives modified with ANO_3 and $\text{ANO}_3 \cdot n\text{H}_2\text{O}$ nitrate additives for gluing wood of various species.

Scope of application of an innovative technological product: the application of these approaches will make it possible to obtain glued materials from wood from different species with improved technological and physical and mechanical properties of the glue seam and, accordingly, to increase the quality and reliability of products.

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1. Introduction

According to the data of works [1, 2], wood is a natural polymer of the cellular-fibrous structure, which is characterized by uneven density, significant porosity and hydrophilicity. Due to the different structure of coniferous and deciduous wood, the application of mineral glue to the surface of substrates has its own specifics, first of all, associated with wetting and spreading, and secondly, penetration deep into the substrate.

1. 1. The object of research

The object of research is the rheokinetic patterns and processes of the formation of colloidal-chemical structures of aluminosilicate adhesives modified with compounds of the AlNO_3 and $\text{AlNO}_3 \cdot n\text{H}_2\text{O}$ type, intended for gluing wood.

1. 2. Problem description

The problem is simple – the rheokinetic and chemical-colloidal properties of aluminosilicate adhesives for gluing solid wood have not been studied due to the novelty of this product and insufficient experience of its use in gluing technology.

There are only a few works devoted to the use of mineral adhesives, especially aluminosilicate composition, for gluing wood of different species. They mainly reflect the physical and mechanical aspects that describe the properties of the adhesive joint depending on the composition of the aluminosilicate adhesive [3], and also provide data confirming the incombustibility of the adhesive seam with ensuring the bearing capacity (strength) of glued wood products in a fire [4].

In works [5, 6] attention is paid to the physical and mechanical characteristics of composite board materials obtained on the basis of aluminosilicate adhesives, as well as similar materials with increased resistance to fire [7].

In [8, 9], the influence of the Si/Al molar ratio on the microstructure and mechanical properties of ultra-low density wood fiber composite material was noted.

In one of the first works [10], on the problem under consideration, a relationship was established between the concentrations of an organomineral complex with the stability of the colloidal-chemical properties of aluminosilicate dispersion as a basis for adhesives for gluing wood. Subsequent work [11] provides data on the effect of organic and mineral modifiers of a high-silica aluminosilicate binder (Si/Al=5...6) on the rheological properties of adhesives for wood.

In the process of practical approbation of aluminosilicate adhesive (gluing solid wood, making plywood, fiberboard and other wood materials), problems of a purely technological nature arose associated with the fluidity of the adhesive, its viability, high adhesion properties to metal feed paths, uniform distribution over the substrate surface, wettability of surfaces and others.

Therefore, it was decided to search for and study the effect of a number of mineral compounds on rheokinetics and chemical-colloidal properties of the initial (base) composition of the aluminosilicate adhesive in order to eliminate the above technological problems.

1. 3. Suggested solution to the problem

The solution to the problem can be started with the question of studying the effect of modifying additives – compounds of the AlNO_3 and $\text{AlNO}_3 \cdot n\text{H}_2\text{O}$ type on the rheokinetic and chemical-technological properties of aluminosilicate adhesives.

The aim of research is to study rheokinetic patterns and processes of formation of colloidal-chemical structures of aluminosilicate adhesives modified with compounds of the AlNO_3 and $\text{AlNO}_3 \cdot n\text{H}_2\text{O}$ type.

2. Materials and methods

To obtain an aluminosilicate adhesive, a binder of $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot (4,5-6)\text{SiO}_2 \cdot (17,5-20)\text{H}_2\text{O}$ type was used with the ratio of the main structure-forming oxides $\text{SiO}_2/\text{Al}_2\text{O}_3=6$ and $\text{SiO}_2/\text{H}_2\text{O}=20$. Correction of the composition of the binder for alkaline oxides was carried out using their aqueous solutions.

To control the physical and rheological characteristics of the aluminosilicate adhesive, chemically pure compounds of the AlNO_3 and $\text{AlNO}_3 \cdot n\text{H}_2\text{O}$ type, namely: $\text{LiNO}_3 \cdot 3\text{H}_2\text{O}$, NaNO_3 , KNO_3 and NH_4NO_3 were introduced into its composition.

The preparation of an aluminosilicate adhesive with functional additives was carried out in a laboratory dissolver. To analyze the effect of modifiers on colloidal-chemical and rheokinetic properties, the following parameters were chosen as the initial parameters: the work of the forces of adhesion, cohesion and wetting, spreading and wetting coefficients, dynamic and plastic viscosity, surface tension and contact angle on substrates of pine, beech and oak wood treated to a surface roughness of Rz60.

The choice of substrates is due to the following assumptions, namely: pine wood as the main material in the manufacture (gluing) in industrial conditions of massifs and various structural

elements and products; beech wood as the main substrate for testing the physical and mechanical properties of adhesive joints in accordance with EN; oak wood as the main substrate for the physical and mechanical properties of flooring materials, in particular parquet.

The numerical values of the parameters were obtained on devices and according to the methods used in paintwork. The dynamic viscosity was determined using a Brookfield LVDV2T viscometer using an LV-3C (67) spindle. Surface tension, contact angle, work of forces of adhesion, cohesion and wetting, as well as the values of the coefficients of spreading and wetting were calculated by the formulas given in [12]. The error in measuring the values of the surface tension and the contact angle, when using the instruments and devices described in [12], did not exceed 10 %.

3. Results and experimental confirmation

3.1. Influence of nitrate concentration on the change in the dynamic and plastic viscosity of adhesives

The amount of adhesive applied per unit area of the glued surfaces depends primarily on its concentration and viscosity, and secondly, on the required thickness of the adhesive layer, the temperature of the wood and the environment, and the quality of preparation of the glued surfaces.

In the original aluminosilicate adhesive, the dry matter concentration is 62.3 %, and the dynamic viscosity is 51222 cP.

Let's consider how the concentration of nitrate additives, which change the concentration of the adhesive on dry matter from 62.8 to 63.8 %, affects the change in the dynamic values in the range of low spindle speeds. In general, the nature of the curves is related to the pseudoplastic state of fluids. With an increase in the spindle rotation speed, the values of dynamic viscosities decrease (**Fig. 1**).

So, the introduction of lithium nitrate hydrate in an amount from 0.5 to 1.5 wt. % promotes an increase in the initial values of dynamic viscosity from 56400 to 97200 cP, which, on average, is 1.4 times higher than the viscosity of the initial adhesive. In the range of speeds from 0.3 to 2 RPM, the influence of concentrations on the change in the viscosity of adhesives is still visible, then, starting from a speed of 5 RPM and higher, the differences in the values of viscosities are insignificant (**Fig. 1, a**). In general, the addition of 0.5–1 % lithium nitrate hydrate does not significantly increase the viscosity value over the original adhesive.

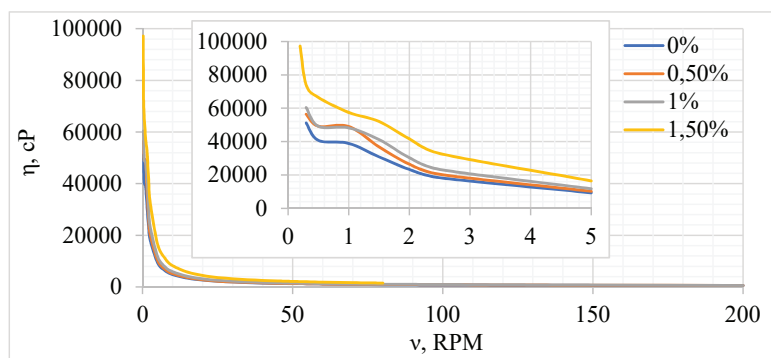
The introduction of sodium nitrate in an amount from 0.5 to 1.5 wt. % contributes to a sharp increase in the initial values of the dynamic viscosity from 103,200 to 136,800 cP, which, on average, is 5.3 times higher than the viscosity of the initial adhesive. Sodium nitrate helps thicken the adhesive. In the range of speeds from 0.2 to 5 RPM, the viscosity curves of adhesives containing sodium nitrate in an amount of 0.5–1.5 % coincide, and at a spindle speed of 50 RPM and higher, they coincide with the curve of the viscosity change of the initial adhesive (**Fig. 1, b**).

The introduction of potassium nitrate in an amount from 0.5 to 1.5 wt. % promotes not as sharp as in the previous variant, an increase in the initial values of the dynamic viscosity from 85200 to 100800 cP, which, on average, is 1.8 times higher than the value of the initial adhesive viscosity. In the range of speeds from 0.2 to 2 RPM, the viscosity curves of adhesives containing sodium nitrate in an amount of 0.5–1 % coincide, and at a spindle rotation speed of 40 RPM and higher, they coincide with the curve of changes in the viscosity of the initial adhesive (**Fig. 1, c**).

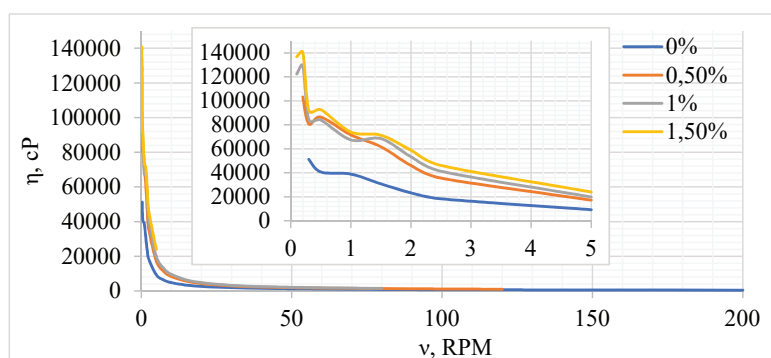
The introduction of ammonium nitrate is 0.9 times compared with the viscosity of the original adhesive, and in an amount from 1–1.5 wt. % promotes an increase in the initial values of dynamic viscosity from 75,000 to 129,600 cP, which, on average, is 2.8 times higher than the viscosity of the initial adhesive. In the range of speeds from 0.2 RPM and higher, the viscosity curves of the initial and adhesive containing ammonium nitrate in an amount of 0.5 wt. % coincide, and at a spindle rotation speed of 40 RPM and above, the curves of viscosity change also coincide at other values of the additive concentration (**Fig. 1, d**).

In general, regardless of the types of additives, the pattern of changes in the dynamic viscosities of adhesives is identical.

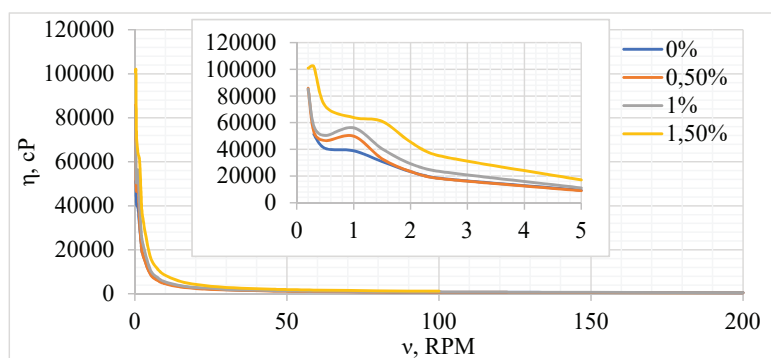
The effect of the concentration of nitrate additives on changes in the values of plastic viscosity [10], determined from the cotangent of the slope of the curves in the dependence $v=f(M)$ (**Fig. 2**), is more clearly seen.



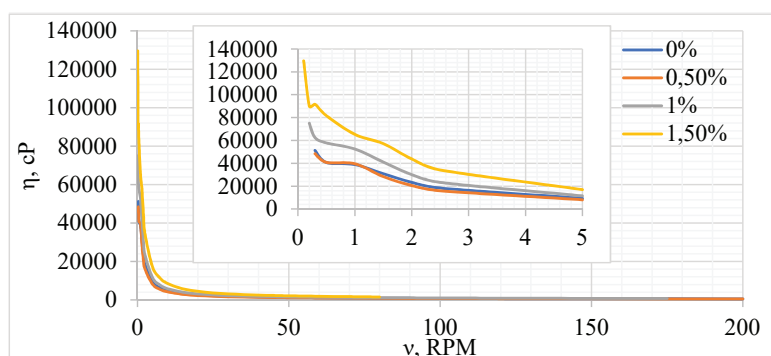
a



b



c

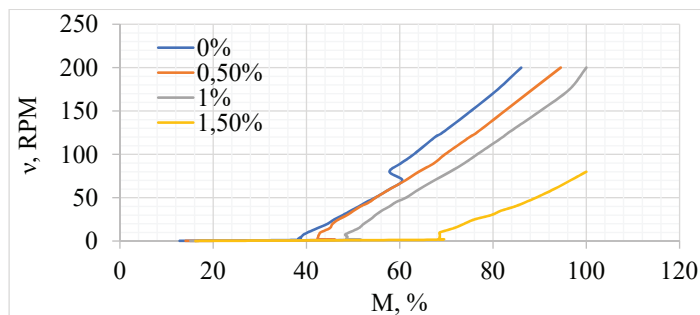


d

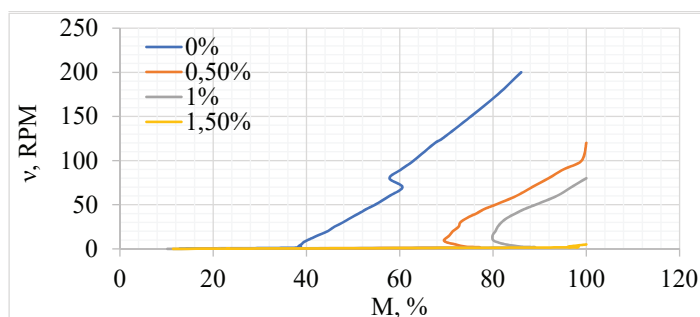
Fig. 1. The kinetics of changes in the dynamic viscosity of the aluminosilicate adhesive depending on the type and concentration of nitrates (%): *a* – $\text{LiNO}_3 \cdot 3\text{H}_2\text{O}$; *b* – NaNO_3 ; *c* – KNO_3 ; *d* – NH_4NO_3

In the speed range from 10 to 200 RPM, the amount of plastic viscosity is significantly influenced by the spindle torque. So, with the introduction of lithium nitrate hydrate and potassium nitrate

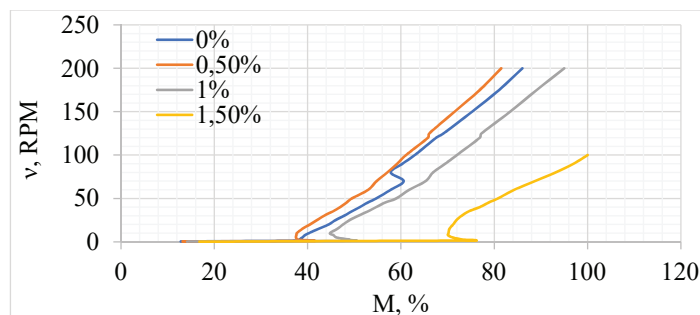
into the adhesive in an amount of 0.5–1.5 wt. % the values of plastic viscosities practically coincide. The plastic viscosity of the initial adhesive has a value of 50.95 cP, with the addition of the above nitrates in the amount of 0.5 wt. %, on average, 61.6 cP; at 1 wt. % – 70.02 cP; at 1.5 wt. % – 118.13 cP (Fig. 2, a, c).



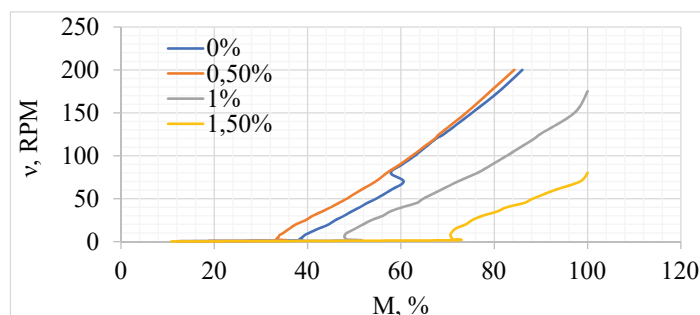
a



b



c



d

Fig. 2. Kinetics of changes in the plastic viscosity of the aluminosilicate adhesive depending on the speed and torque of the spindle, the type and concentration of nitrates (%):
 a – LiNO₃·3H₂O; b – NaNO₃; c – KNO₃; d – NH₄NO₃

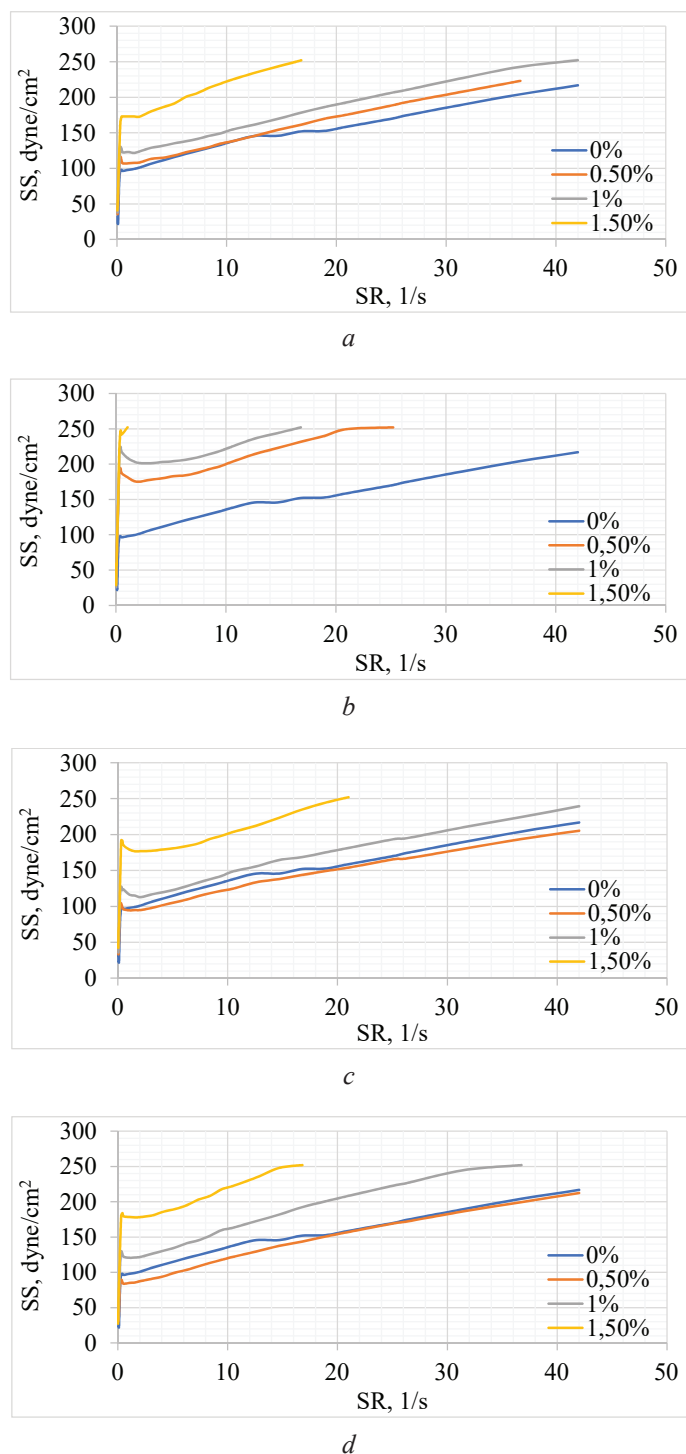


Fig. 3. Kinetics of change in the shear force of the aluminosilicate adhesive depending on the shear rate, type and concentration of nitrates (%):
a – $\text{LiNO}_3 \cdot 3\text{H}_2\text{O}$; *b* – NaNO_3 ; *c* – KNO_3 ; *d* – NH_4NO_3

3. 2. Influence of nitrate concentration on the change in the chemical and colloidal properties of adhesives

According to [10], the more completely the substrate is wetted by the adhesive, the greater the loss of energy (from the wetting condition):

$$S = s_c - s_a - s_a - c \geq 0.$$

The higher the spreading coefficient s , the more complete the wetting. And for this, it is necessary that the free surface energy at the adhesive-substrate (s_a-c) interface be minimal, which is possible only if the molecular nature of the adhesive and the substrate is close. Considering that the molecular nature of the mineral adhesive and the substrate is far from close, many factors must be taken into account for complete wetting and spreading of the substrate, namely: surface tension, contact angle, work of forces of adhesion, cohesion, wetting, etc. Critically, this assumption can be displayed as follows: $\Theta_{av} < 70^\circ$, $s \rightarrow \max$ and $f \rightarrow \min$.

Let's consider the effect of the concentration of lithium nitrate hydrate on changes in the chemical and colloidal properties (**Table 1**). As can be seen from the data presented, the introduction of lithium nitrate hydrate in an amount from 0.5 to 1.5 wt. % promotes a 1.2-fold increase in the surface tension of the adhesive compared to the initial one and a decrease in these values with an increase in the amount of lithium nitrate hydrate in the adhesive. On substrates of pine, beech and oak, the initial adhesive has the lowest contact angle and the highest flow coefficient. The closest to these values is the adhesive, which contains $\text{LiNO}_3 \cdot 3\text{H}_2\text{O}$ in an amount of 0.5 wt. %. Changes in the indicators of the work of the forces of adhesion, cohesion and wetting are relevant similar to the change in the previous indicators and will be taken into account when determining the physical and mechanical properties of adhesives.

Table 1Chemical-colloidal properties of aluminosilicate adhesive modified with $\text{LiNO}_3 \cdot 3\text{H}_2\text{O}$

C, %	γ , mN/m	Θ_{av}	$\cos\Theta_{av}$	W_a , mN/m	W_k , mN/m	W_w , mN/m	s	f , mN/m
pine								
0	49.93	48°	0.66913	83.34	99.86	33.41	0.83457	-16.52
0.5	58.67	50°67'	0.63383	95.86	117.34	37.19	0.81694	-21.48
1	57.42	54°67'	0.57828	90.63	114.84	33.2	0.78918	-24.21
1.5	53.68	55°67'	0.56401	83.96	107.36	30.28	0.78204	-23.4
beech								
0	49.93	51°67'	0.62019	99.86	99.86	30.97	0.81013	-18.96
0.5	58.67	48°	0.66913	97.93	117.34	39.26	0.83458	-19.41
1	57.42	60°67'	0.48989	85.55	114.84	28.13	0.74495	-29.29
1.5	53.68	52°	0.61566	86.73	107.36	33.05	0.80784	-20.63
oak								
0	49.93	47°	0.681998	83.98	99.86	34.05	0.84098	-15.88
0.5	58.67	49°	0.65606	97.16	117.34	38.49	0.82802	-20.18
1	57.42	50°33'	0.63832	94.07	114.84	36.65	0.81914	-20.77
1.5	53.68	55°	0.57358	84.47	107.36	30.79	0.78679	-22.89

Note: C – concentration of nitrate compounds, %; γ – value of surface tension, mN/m; Θ_{av} – the average value of the wetting angle of the substrate with the adhesive; W_a , W_k , W_w – work of forces of adhesion, cohesion and wetting, mN/m; s , f – coefficients of wetting and spreading of the adhesive over the surface of the substrate, mN/m.

Also similar in terms of performance adhesives, including 1.5 wt. % $\text{LiNO}_3 \cdot 3\text{H}_2\text{O}$, and adhesives containing 1 wt. % $\text{LiNO}_3 \cdot 3\text{H}_2\text{O}$ by their characteristics fall out of the general pattern (**Table 1**).

The introduction of NaNO_3 in an amount from 0.5 to 1.5 wt. % promotes a 1.5-fold increase in the surface tension of the adhesive in comparison with the initial one. On substrates of pine, beech and oak, the initial adhesive has the lowest contact angle and the highest flow coefficient. The closest to these values is characterized by the adhesive, which contains NaNO_3 in an amount of 0.5 wt. % (**Table 2**).

The introduction of KNO_3 in an amount of 0.5 and 1.5 wt. % increases the surface tension of the adhesive by a factor of 1.1 as compared to the initial one. With the content of KNO_3 in the amount of 1 wt. %, the surface tension values are identical. On substrates of pine, beech and oak, the initial adhesive has the lowest contact angle and the highest flow coefficient. The closest to these values on the pine substrate is the adhesive, which contains NaNO_3 in an amount of 0.5 wt. %; on a substrate of beech and oak, characterized by an adhesive containing 1 and 1.5 wt. % potassium nitrate (**Table 3**).

Table 2
Chemical and colloidal properties of aluminosilicate adhesive modified with NaNO_3

<i>C</i> , %	γ , mN/m	Θ_{av}	$\cos\Theta_{av}$	<i>Wa</i> , mN/m	<i>Wk</i> , mN/m	<i>Ww</i> , mN/m	<i>s</i>	<i>f</i> , mN/m
pine								
0	49.93	48°	0.66913	83.34	99.86	33.41	0.83457	-16.52
0.5	72.4	52°67'	0.60640	116.3	144.8	43.9	0.80318	-28.5
1	74.9	55°67'	0.56396	117.14	149.8	42.24	0.78198	-32.66
1.5	74.9	56°	0.55919	116.78	149.8	41.88	0.77957	-33.02
beech								
0	49.93	51°67'	0.62019	99.86	99.86	30.97	0.81013	-18.96
0.5	72.4	58°	0.52992	110.77	144.8	38.37	0.76499	-34.03
1	74.9	57°67'	0.53479	114.96	149.8	40.06	0.76742	-34.84
1.5	74.9	57°	0.54464	115.69	149.8	40.79	0.772296	-34.11
oak								
0	49.93	47°	0.681998	83.98	99.86	34.05	0.84098	-15.88
0.5	72.4	52°67'	0.60640	116.3	144.8	43.9	0.80318	-28.5
1	74.9	49°67'	0.64719	123.37	149.8	48.47	0.82356	-26.43
1.5	74.9	60°33'	0.49500	111.98	149.8	37.08	0.74753	-37.82

The introduction of NH_4NO_3 in an amount of 0.5 to 1 wt. % promotes a 1.2-fold increase in the surface tension of the adhesive as compared to the initial one (Table 4).

Table 3
Chemical and colloidal properties of aluminosilicate adhesive modified with KNO_3

<i>C</i> , %	γ , mN/m	Θ_{av}	$\cos\Theta_{av}$	<i>Wa</i> , mN/m	<i>Wk</i> , mN/m	<i>Ww</i> , mN/m	<i>s</i>	<i>f</i> , mN/m
pine								
0	49.93	48°	0.66913	83.34	99.86	33.41	0.83457	-16.52
0.5	52.43	45°33'	0.70302	89.29	104.86	36.86	0.85152	-15.57
1	49.93	65°33'	0.41739	70.77	99.86	20.84	0.70869	-29.09
1.5	53.68	56°33'	0.55441	83.44	107.36	29.76	0.77720	-23.92
beech								
0	49.93	51°67'	0.62019	99.86	99.86	30.97	0.81013	-18.96
0.5	52.43	54°	0.58779	83.25	104.86	30.82	0.79392	-21.61
1	49.93	54°	0.58779	79.28	99.86	29.35	0.79391	-20.58
1.5	53.68	55°	0.57358	84.47	107.36	30.79	0.78679	-22.89
oak								
0	49.93	47°	0.681998	83.98	99.86	34.05	0.84098	-15.88
0.5	52.43	56°67'	0.54946	81.24	104.86	28.81	0.77475	-23.62
1	49.93	51°	0.62932	81.35	99.86	31.42	0.81464	-18.51
1.5	53.68	51°	0.62932	87.46	87.46	33.78	0.81464	-19.9

With an NH_4NO_3 content of 1.5 wt. %, the surface tension values are identical. On substrates of pine, beech and oak, the initial adhesive has the lowest contact angle and the highest flow coefficient. The closest to these values on the pine substrate is characterized by an adhesive containing 1.5 wt. % NH_4NO_3 ; on a beech substrate is characterized by an adhesive containing 0.5 and 1.5 wt. % ammonium nitrate; on the oak substrate is characterized by an adhesive containing 0.5 wt. % ammonium nitrate (Table 4).

Table 4Chemical and colloidal properties of aluminosilicate adhesive modified with NH_4NO_3

<i>C</i> , %	γ , mN/m	Θ_{av}	$\cos\Theta_{av}$	<i>W_a</i> , mN/m	<i>W_k</i> , mN/m	<i>W_w</i> , mN/m	<i>s</i>	<i>f</i> , mN/m
pine								
0	49.93	48°	0.66913	83.34	99.86	33.41	0.83457	-16.52
0.5	53.68	54°33'	0.58312	84.98	107.36	31.3	0.79154	-22.38
1	62.42	50°	0.64279	102.54	124.84	40.12	0.79154	-22.38
1.5	49.93	55°67'	0.56396	78.09	99.86	28.16	0.78199	-21.77
beech								
0	49.93	51°67'	0.62019	99.86	99.86	30.97	0.81013	-18.96
0.5	53.68	46°67'	0.6862	90.52	107.36	36.84	0.84314	-16.84
1	62.42	50°33'	0.63836	102.27	124.84	39.85	0.81921	-22.57
1.5	49.93	49°33'	0.6517	82.47	99.86	32.54	0.82586	-17.39
oak								
0	49.93	47°	0.681998	83.98	99.86	34.05	0.84098	-15.88
0.5	53.68	51°	0.62932	87.46	107.36	33.78	0.81464	-19.9
1	62.42	49°33'	0.6517	103.1	124.84	40.54	0.82586	-21.74
1.5	49.93	55°	0.57358	78.57	99.86	28.64	0.78680	-21.29

4. Discussion

The significance of the results of the work is quite obvious and, first of all, is aimed at practical originality, which will help to solve the problem of stabilizing the rheokinetic properties of aluminosilicate adhesives modified with compounds of the ANO_3 и $\text{ANO}_3 \cdot n\text{H}_2\text{O}$ type, namely: the values of dynamic and plastic viscosity in the range of working speeds of the adhesive the surface of coniferous and deciduous wood substrates; ensure the formation of colloidal-chemical structures with minimum contact angles and maximum values of the spreading coefficient.

When gluing solid wood from pine, beech and oak substrates along the length, tenon joints are usually used. Horizontal studs are used in joints that do not require high strength properties, vertical studs in structural joints. The application of the adhesive can be done by brush, dipping, or comb-type glue rolls. The above rheokinetic properties of adhesives modified with lithium nitrate trihydrate and potassium nitrate in an amount of 0.5 wt. % and ammonium nitrate in the amount of 1 wt. % are quite applicable for the first two methods in the speed range from 0.3 to 5 RPM (**Fig. 1**); when using comb rollers, taking into account their rotation speed (usually in the range of 0.2–0.6 m/s), it is possible to use adhesives containing up to 1 wt. % lithium nitrate trihydrate, potassium and ammonium nitrates. The noted concentration of nitrates in the considered range of velocities will provide acceptable values of the shear force, varying in the range of 150–250 dyne/cm² (**Fig. 3**).

When gluing solid wood from pine, beech and oak substrates across the width, the adhesive is applied to the surface by the contact method (comb-type glue rollers) and the pouring method. The adhesive in the method of pouring the substrate is supplied through slots or nozzles under pressure. It is possible to assume that the considered regularities of changes in viscosity values in the range of speeds of 0.2–0.6 m/s and colloidal-chemical properties of adhesives (spreadability coefficient 0.76–0.84, **Tables 1–4**) modified with lithium nitrate trihydrate and potassium nitrate in an amount of 0.5 wt. % and ammonium nitrate in the amount of 1 wt. % are quite applicable for this method.

The use of sodium nitrate as a modifier is impractical, since its introduction contributes to the thickening of the aluminosilicate adhesive regardless of concentration.

In the future, studies will continue on the effect of the same compounds: on the fluidity of adhesives at elevated pressures; on the physicochemical and deformation properties of the glue seam, as well as on the study of the physicochemical processes occurring in the aluminosilicate adhesive in order to form water-resistant phases with a low value of the elastic modulus, to identify the features of the formation of the contact zone between the substrate and the adhesive, to determine the depth of penetration of the adhesive into the structure substrate.

In this context, the compounds of nitrates of alkaline earth elements will also be considered with the identification of their role in the above described phenomena and processes.

5. Conclusions

As a result of the research, the effect of compounds of the ANO_3 and $\text{ANO}_3 \cdot n\text{H}_2\text{O}$ type was studied on the rheokinetic and chemical-colloidal properties of aluminosilicate adhesives for laminating wood of various species. According to the effectiveness of the effect on changes in dynamic viscosity, plastic viscosity, surface tension, contact angle and wetting and spreading coefficients, nitrate additives can be placed in the row: $\text{LiNO}_3 \cdot 3\text{H}_2\text{O} > \text{KNO}_3 > \text{NH}_4\text{NO}_3 > \text{NaNO}_3$. It was found that 0.5 wt. % nitrates $\text{LiNO}_3 \cdot 3\text{H}_2\text{O}$, KNO_3 , NH_4NO_3 is the optimal amount to stabilize the change in the dynamic and plastic viscosity of the aluminosilicate adhesive over time, as well as to ensure the wetting and stability of the flow of adhesives on a pine, beech and oak substrate.

References

- [1] Shields, J. (1980). Adhesives: a reference book. Moscow: Mashinostroenie, 368.
- [2] Kovalchuk, L. M. (1987). Production of glued timber structures. Moscow: Forest industry, 248.
- [3] Krivenko, P., Petropavlovsky, O., Vozniuk, G. (2018). Alkaline Aluminosilicate Binder for Gluing Wood Board Materials. Key Engineering Materials, 761, 11–14. doi: <http://doi.org/10.4028/www.scientific.net/kem.761.11>
- [4] Guzii, S. G., Krivenko, P. V., Bondarenko, O. P., Kopylova, T. (2019). Study on Physico-Mechanical Properties of the Modified Alkaline Aluminosilicate Adhesive-Bonded Timber Elements. Solid State Phenomena, 296, 112–117. doi: <http://doi.org/10.4028/www.scientific.net/ssp.296.112>
- [5] Tsapko, Y., Zavialov, D., Bondarenko, O., Pinchevs'ka, O., Marchenco, N., Guzii, S. (2019). Design of fire-resistant heat- and soundproofing wood wool panels. Eastern-European Journal of Enterprise Technologies, 3 (10 (99)), 24–31. doi: <http://doi.org/10.15587/1729-4061.2019.166375>
- [6] Berzins, A., Morozovs, A., Gross, U., Iejavs, J. (2017) Mechanical properties of wood–geopolymer composite. Engineering for rural development, 16, 1167–1173. doi: <http://doi.org/10.22616/erdev2017.16.n251>
- [7] Bahrami, M., Shalbfafan, A., Welling, J. (2019). Development of plywood using geopolymer as binder: effect of silica fume on the plywood and binder characteristics. European Journal of Wood and Wood Products, 77 (6), 981–994. doi: <http://doi.org/10.1007/s00107-019-01462-3>
- [8] Chen, T., Wu, Z., Niu, M., Xie, Y., Wang, X. (2015). Effect of Si–Al molar ratio on microstructure and mechanical properties of ultra-low density fiberboard. European Journal of Wood and Wood Products, 74 (2), 151–160. doi: <http://doi.org/10.1007/s00107-015-0986-x>
- [9] Chen, T., Xie, Y., Cai, L., Zhuang, B., Wang, X. A., Wu, Z. et. al. (2016). Mesoporous Aluminosilicate Material with Hierarchical Porosity for Ultralow Density Wood Fiber Composite (ULD_WFC). ACS Sustainable Chemistry & Engineering, 4 (7), 3888–3896. doi: <http://doi.org/10.1021/acssuschemeng.6b00691>
- [10] Guzii, S., Kryvenko, P., Guzii, O., Yushkevich, S. (2019). Determining the effect of the composition of an aluminosilicate binder on the rheotechnological properties of adhesives for wood. Eastern-European Journal of Enterprise Technologies, 6 (6 (102)), 30–38. doi: <http://doi.org/10.15587/1729-4061.2019.185728>
- [11] Guzii, S. G., Guzii, O. I., Yushkevich, S. V., Bazhelka, I. K. (2020). Study of the influence of organic and mineral modifiers on physical and rheological properties of aluminosilicate adhesives for gluing of wood. Bulletin of Odessa State Academy of Civil Engineering and Architecture, 79, 70–77. doi: <http://doi.org/10.31650/2415-377x-2020-79-70-77>
- [12] Glazacheva, E. N., Uspenskaya, M. V. (2015). Colloidal chemistry. Methodical instructions for laboratory work. Saint Petersburg: ITMO University, 62.