

The technology of low-toxic chipboard using an amino-formaldehyde binder

Vyacheslav Tsvetkov^{1*}, *Olga Machneva*¹, *Vladimir Podolny*¹, *Vladimir Semenchko*¹, and *Victoria Yakobashvili*¹

¹Bauman Moscow Technical University, ul. Baumanskaya 2-ya, 5/1, 105005 Moscow, Russia

Abstract. This paper considers one of the key production problems associated with the production of environmentally friendly particle boards (reinforced wood particle board) based on aminoformaldehyde binders that meet all the necessary requirements of modern standards. One of the promising solutions to this problem can be the use of reactive technological additive, which has a complex action: catalyst for curing the binder and acceptor of free formaldehyde contained in the binder. The proposed action will allow to produce boards with high physical and mechanical characteristics and minimum content of free formaldehyde, which can indicate a high quality of the products and expand the scope of these composite materials, including production of furniture for home and children's institutions.

1 Introduction

The problem of obtaining environmentally safe (low-toxic) and high quality chipboard (reinforced wood particle board) is still quite urgent for the woodworking industry and, in particular, for manufacturers of wood-based panel products from milled wood and synthetic binders. First of all, it is related to the quality of the binder used [1-3].

Most often in the manufacture of wood boards are used amino-formaldehyde binders, which, depending on the formulation, may contain: urea, melamine, caprolactam, polyatomic alcohols (glycerin, ethylene glycol, diethylene glycol), various modifying additives, water, and also necessarily formaldehyde, which, as is known, is a toxic substance. Phenol-formaldehyde or epoxy polymers are used less frequently in board production, although it is important to note that interest in such products is not decreasing [4-8].

At the same time, the need to use formaldehyde to produce synthetic resins, which will later form the basis of a binder for the production of wood-based panel materials, cannot be overestimated. Formaldehyde is used in the synthesis of synthetic resins in the form of an aqueous solution of 37% concentration, called formalin, which may also be present in small amounts and methanol [9-12].

* Corresponding author: helga35781@yandex.ru

It is known that by increasing the amount of formaldehyde in synthetic resins, their adhesive capacity and bonding strength will be as high as possible, but such binders cannot be classified as low-toxic or environmentally safe [13-17].

Obviously, the low toxicity of the binder is associated with its low content of formaldehyde, which entails a decrease in the adhesive capacity and, as a consequence, the strength and water resistance of the boards are markedly reduced, which is an extremely undesirable consequence.

There are currently many different technologies for obtaining low-toxic binders, but even these do not always produce high-strength and environmentally friendly wood-based materials. Therefore, manufacturers of wood-based panels need to develop various technological methods and techniques to obtain materials of proper quality [18-20].

One of these methods is devoted to the present work, which aims to develop the technology of low-toxic particle board (reinforced wood particle board) with the use of aminoformaldehyde binder.

The essence of the proposed measure is to select a certain technological additive with high reactivity and complex action in relation to the binder to the glue amino-formaldehyde resin obtained in real production conditions, namely, the proposed additive should be both a hardener of glue resin and an acceptor of formaldehyde when processing the solution of the additive surface reinforced wood particle board.

As a complex additive modifier is proposed, which is designated as "D"..

2 Methodology and materials of the experiment

The object of the study in the current work was modifier "D".

Modifier "D" is a powder of white color whose aqueous solution allows to use it both as a hardener for amino-formaldehyde binder and as a formaldehyde acceptor, actuated by its spraying on the surface of reinforced wood particle boards during their manufacture.

To confirm the effectiveness of the proposed measures in the laboratory "Wood boards and plastics" of the department FT9 "Chemistry and chemical technologies in the forestry complex" Mytishchi branch of the Bauman Moscow State Technical University were made particle boards using a binder, the basis of which was synthesized in factory conditions aminoformaldehyde resin in combination with a solution of additive modifier "D" as a hardener.

Then it was decided to produce three reinforced wood particle boards under identical conditions: pressing temperature - 180 ° C, pressing pressure - 2.5 MPa, binder consumption - 12%, the amount of hardener "D" - 3%, holding time in the hot press - 8 minutes (that is, 0.5 min/mm thickness of the pressed material).

The size of the boards was 300×130×16 mm, their density - 700 kg/m³ [8-11].

For the manufacture of slabs wood particles in the form of chips underwent special preparation. First, drying of wood particles to a moisture content of 4% was carried out, for this purpose a laboratory heat cabinet was used. Then dried particles were subjected to separation, i.e. sorting on a laboratory sorter, which allows to separate wood particles into fractions (sizes), since it is known that in the manufacture of three-layer wood particle boards the larger fraction of wood particles goes to form the inner layer, and the smaller fraction - to form the outer layers [18-20].

The difference in the technologies of manufacture of the boards was that one board was made without treatment with formaldehyde acceptor "D" and immediately after manufacture it was sent for technological ageing to stabilize the properties and internal stresses, while the second board had the acceptor applied before pressing on both surfaces of the particle board mat, and the third board was made in the same way as the second board, but after pressing both surfaces of the board were also treated with acceptor "D"

The slabs were made when they were simultaneously loaded in a hot press [8, 12], which minimized the influence of random technological factors, such as differences in temperature, dwell time, or pressure.

In the experiment, amino-formaldehyde resin produced by METADYNEA LLC was used, and its basic physical and chemical properties were studied. For these purposes a set of standard laboratory equipment was used: to determine viscosity - Viscometer brand VZ-4, to determine the refractive index (refraction coefficient) - refractometer brand IRF-454B2M, to determine the hydrogen index - pH-meter brand pH-340, to determine time of gelatinization (hardening) - hardener "D" in an amount of 3%.

3 The results of experiments and discussion

3.1 Quality assessment of amino-formaldehyde resin

Before using an aminoaldehyde resin as a binder base the basic properties were studied, including the content of free formaldehyde, although initially it was known that this resin is low-toxic and its content of formaldehyde should not exceed 0.15%. The properties of the resin are presented in Table 1.

Table 1. Properties of the applied amino-formaldehyde resin

Indicator name	Measurement unit	Indicator value and descripti
1	2	3
Appearance	Visual assessment	Viscous white polymer without pungent odors
Viscosity according to VZ-4 viscometer	Sec.	68
Refraction coefficient (refraction)	-	1,460
Hydrogen index (pH)	-	7,5
Resin concentration (dry residue)	%	58
Gelatinization (curing) time	Sec.	68
Free formaldehyde content	%	0,15

The data in Table 1 allow us to conclude that the amino-formaldehyde resin has all the necessary characteristics that are important to obtain the proper quality boards.

It is also important to note that the hardening of the resin was carried out with different hardeners: with ammonium sulfate and chloride, as well as with the proposed additive "D". The data obtained are presented in Table 2.

Table 2. Comparative data on the hardening of amino-formaldehyde resin with different hardeners

Curing speed of amino-formaldehyde resin with different hardeners, sec.		
Ammonium chloride (3%)	Ammonium sulfate (3%)	Modifier "D" (3%)
79	84	68

The analysis of Table 2 leads to the conclusion that the proposed additive "D" as a hardener allows the binder to cure much faster, which will undoubtedly lead to increased productivity in the production of reinforced wood particle board.

3.2 Evaluation of the obtained boards quality (reinforced wood particle board)

After assessing the quality of amino-formaldehyde resin, and then the curing rate of the binder according to the methodology and parameters described above, the boards were made.

After the time necessary for stabilization of properties and alignment of internal stresses arising in the process of pressing, physical and mechanical properties of obtained boards were studied, as well as the determination of free formaldehyde content by WKI method and by perforating method in a specialized factory laboratory.

The physical and mechanical properties of the boards are presented in Table 3.

Table 3. Physical and mechanical properties of the obtained reinforced wood particle board

Indicator name	Measurement unit	Значение показателя			
		1 slab (without treatment "D")	2 slab (with treatment "D" before pressing)	3 slab (with treatment "D" before and after pressing)	GOST 10632-2014
1	2	3	4	5	6
Flexural strength	MPa	21,6	20,65	16,3	Not less than 11
Tensile strength at break perpendicular to the plate	MPa	0,46	0,42	0,35	At least 0.35
Board moisture	%	8	8	8	5-13
Swelling along the thickness	%	22	23	28	-
Free formaldehyde content according to the WKI method	mg/100 g dry board	7,1	3,9	3,2	Less than 8 for E1
Free formaldehyde content according to the punching method	mg/100 g dry board	7,0	1,62	1,59	Less than 4 for E0.5
Toxicity class by punching method	-	E1	E0,5	E0,5	E0,5-E1

In Table 3, the properties of the obtained boards are compared with the properties of boards of P2 grade, according to GOST 10632-2014. It should be noted that the current standard regulates the strength properties of reinforced wood particle board for the P1 and P2 grades, as well as the toxicity class (formaldehyde emission). The properties of P2 boards are higher than those of P1 boards. In this case, the indicator of swelling on the

thickness of the latest edition of the standard is excluded, since modern aminoformaldehyde resins, being low mol, low-toxic and, accordingly, having a minimum content of free formaldehyde, can provide good (sufficient) strength to the boards, but can not provide minimum swelling on the thickness, thus bringing modern boards to a toxicity class E1 and E0,5 [21, 22].

Table 3 also shows that the proposed particle board manufacturing technology has shown to be fully effective during the studies conducted. This is indicated by high strength characteristics, satisfactory thickness swelling and low free formaldehyde content.

4 Conclusions

1. The proposed technology for obtaining low-toxic particle board has shown good efficiency.
2. Modifier "D" is effective both as a hardener and as an acceptor.
3. The perfection of the suggested technology of environmentally safe particle boards is required, since it is obvious that the durability of the boards obtained is close to that of moisture-resistant boards of P3 and P5 grades (GOST 32399-2013).
4. The proposed technology will produce board materials that will have a wide demand, including the manufacture of furniture for home and children's institutions.

References

1. M. Y. Ekimova, Investigation of the Chemical Composition of Aminoformaldehyde Materials by the IR Fourier Spectrometric Method, *Polymer Science, Series D*, **152**, 205-208 (2022) doi:10.1134/S1995421222020046. – EDN NPTXZX.
2. V. E. Tsvetkov, Obtaining lined environmentally friendly wood-based panels, *Journal of Physics: Conference Series, Moscow, Moscow*, **2021**, 012073 (2020) doi:10.1088/1742-6596/1990/1/012073
3. M. Y. Ekimova, Aminoformaldehyde Oligomers Modified with Salts of Polyfunctional Acids, *Polymer Science, Series D.*, **14(1)**, 13-16 (2021) doi:10.1134/S199542122101007X
4. V. E. Tsvetkov, Impregnating Compositions for Lamination of Wood, *Polymer Science, Series D*, **13(1)**, 31-33 (2020) doi:10.1134/S1995421220010232
5. O. P. Machneva, Polyatomic Alcohols as Urea–Formaldehyde Resin Modifiers, *Polymer Science, Series D*, **12(2)**, 124-127 (2019) doi:10.1134/S1995421219020126.
6. A. A. Nikitin, Y. A. Semochkin, N. N. Tsvetkova, Properties of Composites Based on Melamine–Formaldehyde Binding Agents, *Polymer Science, Series D.*, **15(1)**, 49-53 (2022) doi: 10.1134/S199542122201021X
7. N. N. Tsvetkova, S. V. Priorova, M. Yu. Zueva, Patent No. 2537620 C2 Russian Federation, IPC C08G 12/12, C08L 61/32, B27N 3/02. Method of making urea-formaldehyde oligomer: No. 2013119168/05: application. 25.04.2013 (2015)
8. N. N. Tsvetkova, S. V. Priorova, M. V. Razuvaeva, Patent № 2547749 C2 Russian Federation, IPC C08L 61/28. Method of manufacturing glue for the production of water-resistant plywood: no. 2013119164/05, application. 25.04.2013 (2015)
9. M. Yu. Zueva, M. V. Razuvaeva, I. A. Ekimova, Patent № 2527524 C1 Russian Federation, IPC B27N 3/02. Method of manufacturing non-toxic particleboards: № 2013119166/13: application. 25.04.2013 (2014)

10. N. N. Tsvetkova, M. V. Razuvaeva, M. Yu. Zueva, Patent No. 2527786 C1 Russian Federation, IPC C08G 12/36, C08L 61/32, B27N 3/02. Method of making urea-formaldehyde oligomer: No. 2013119163/05: application. 25.04.2013 (2015)
11. N. N. Tsvetkova, S. V. Priorova, M. V. Razuvaeva, Patent No. 2534549 C1 Russian Federation, IPC C09J 161/28, C08L 61/28, B27G 11/00. Method for the production of glue for the production of glued wooden beams: № 2013119173/05: application. 25.04.2013 (2014)
12. O. P. Machneva, Modified urea-formaldehyde resins in the manufacture of chipboard, *Science without Borders*, **25(8)**, 15-18 (2018)
13. O. P. Machneva, Particle boards based on urea-formaldehyde resins modified by paraform: speciality 05.21.05 "Wood science, technology and equipment of wood processing": abstract of thesis for the degree of Candidate of Technical Sciences, Moscow, 18 (2006)
14. V. E. Tsvetkov, Study of chemical degradation processes of paraform at synthesis of urea-formaldehyde oligomers, *Moscow state forest university bulletin - Forest Bulletin*, **6**, 106-112 (2007)
15. A. S. Pasko, A. A. Tesovsky, Y. A. Semochkin, Features of decorative paper laminates based on melamine-formaldehyde resins, *Building Materials*, **7**, 71-73 (2016)
16. M. Y. Ekimova, R. I. Viklov, D. S. Duzhakov, Impregnating resins for the production of laminated chipboard, *Scientific and Technical Conference of the Bauman Moscow State Technical University: Abstracts, Mytishchi, June 01-30, 2017, Mytishchi: Limited Liability Company "Scientific-Innovation Center"*, 144-146 (2017)
17. A. A. Tesovskiy, V. P. Grachev, M. L. Bubnova, Decorative paper-layered plastic on the basis of modified melamine-formaldehyde resins, *Adhesives. Sealants. Technologies*, **9**, 34-37 (2019). DOI 10.31044/1813-7008-2019-0-9-34-37
18. Y. I. Tsoi, A. K. Blinov, S. A. Ugryumov, A. R. Birman, Features of Gluing a Wood-Polymer Material, *Polymer Science, Series D.*, **15(2)**, 229-231 (2022) DOI 10.1134/S1995421222020290
19. S. A. Ugryumov, *Urea-formaldehyde resins on the basis of preconcentrate for the production of plywood and wood boards, Improving the efficiency of the forest complex*, Proceedings of the Seventh All-Russian National Scientific Conference with international participation, Petrozavodsk, May 25, 2021. - Petrozavodsk: Petrozavodsk State University, 190-191 (2021)
20. D. S. Rusakov, A. M. Ivanov, G. S. Varankina, An Investigation of Gluing and Facing Plywood with a Microthin Veneer Using Powder Adhesive, *Polymer Science, Series D.*, **13(3)**, 282-285 (2020) DOI 10.1134/S1995421220030144
21. GOST 10632-2014. Chipboard. Technical conditions. Interstate standard.
22. GOST 32399-2014. Chipboard moisture-resistant boards. Technical conditions. Interstate standard.