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Features of planning an experiment to develop a new paint and varnish composition for the formation of protective and decorative coatings on wood products

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Abstract. The article discusses the features of experiment planning in the development of paint compositions for the formation of protective and decorative coatings on wood products. Conclusions are drawn about the relevance of the study, problems are identified when finishing wood with epoxy paints and varnishes and requirements for them are given, as well as a characteristic of the substrates on which the coating was formed during the experiment. The chemical composition of the paint composition based on epoxy resin is considered. The authors proposed a structural scheme of the coating, as well as the technology of its formation with the expected operating parameters. An experiment plan has been developed and variables and constant factors have been selected. The limiting concentrations of the components of the paint and varnish composition based on epoxy resin have been determined.

1. Introduction

Currently, the paint and varnish industry can be classified as an intensively developing industry, which has acquired an international character over time.

In the Russian Federation, it is considered one of the main types of industries, since the manufactured products are needed in large quantities for various types of industry.

Paints and varnishes (PVM) have found wide application in the woodworking and furniture industry, since the finish of the PVM provides high decorative properties of the coating and its protection from mechanical damage, temperature drops, humidity, etc.

Despite the availability of many types and types of paints and varnishes for finishing wood products from Russian and foreign manufacturers, there is still a need for new paints and technologies for creating protective and decorative coatings that would satisfy both the consumer and the manufacturer.

To create a coating, various paintwork materials are used, which are chosen depending on the purpose of the product and the requirements for the coating.

The development of a paint and varnish composition is carried out on the basis of epoxy resins, since coatings based on them are actively gaining popularity at the moment, and also have high physical, mechanical and decorative properties [1].

Epoxy resin has a number of clear advantages over other paints and varnishes:

- high index of resistance to scratching;
- chemical resistance;

- good indicator of adhesion of the coating to the substrate;
- low moisture permeability;
- lack of shrinkage or a small indicator during the operation of products;
- provides high indicators of hardness, elasticity, abrasion resistance, frost resistance, heat resistance and water resistance.

It should be noted that epoxies are susceptible to yellowing and destruction (chalking) when exposed to ultraviolet radiation, which limits their scope, which must be taken into account when introducing modifying additives into the composition.

- However, at the moment, there are the following problems when finishing wood with currently available paints and varnishes based on epoxy resin:
- Impossibility to use more technologically advanced equipment;
- Increased time of film formation in comparison with other paints and varnishes;
- Difficulty in intensifying drying of the coating;
- Impossibility of serial production of products [1].

Based on the foregoing, we can conclude about the relevance of creating a new paint and varnish material based on epoxy resin.

2. Materials and Methods

2.1 Requirements for the developed PVM

When planning an experiment, it is necessary to take into account many factors: both the requirements for protective and decorative coatings on wood products in general, and the requirements that we can theoretically impose on the PVM group with which we work.

The developed material based on epoxy resins should have the following properties:

1. Have a low viscosity, which will allow to ensure deep penetration of PVM into the surface layer of wood, as a result of which - high adhesion strength.
2. Film formation time should not exceed 180 minutes.
3. The possibility of using new methods of application and intensification of drying of the coating (vacuum drying), in order to accelerate the process of film formation and reduce the percentage of defects on the coatings (bubbles).
4. Have a dry residue in the working viscosity of at least 60%.
5. Cure without significant volumetric shrinkage and internal stress.
6. Have a good indicator of thixotropy, while forming an even coating.
7. The resulting coating based on the developed material should have high decorative qualities, as well as provide high indicators of hardness, elasticity, abrasion, frost, heat and water resistance [2].

2.2 Composition, substantiation of components and limits of concentration of components of the developed paint and varnish composition.

The developed PVM has four components: epoxy resin, hardener, accelerator and SAS.

1. The developed paint and varnish material has a base - epoxy resin based on bisphenol A (4.4 / - dioxydiphenylpropane - 2.2) - ESBA [3]. The structure of such resins is shown in Figure 1.

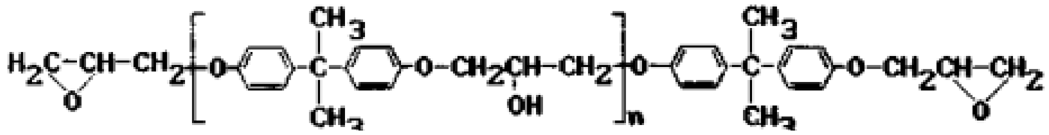

Figure 1. Structure of bisphenol A epoxy resins.

Where **n** is the average degree of polymerisation of the resin.

2. A hardener and accelerator in a formulation based on epoxy resin.

For epoxy resin, the amine type hardener OT-2 was selected. Hardeners in this group are the most versatile; they polymerize both at room temperature and using a drying chamber. This hardener provides a composition with an epoxy resin with increased impact-resistant properties of the coating, excellent moisture-resistant properties and protection from UV radiation [4].

Determine the concentration of the PVM hardener 50-60% by weight of the epoxy resin.

3. In order to reduce the curing time of the coating, it was decided to add an accelerator to the developed paint and varnish material, also of the amine type US-1 in a concentration of 0 to 3% by weight of the epoxy resin.

The scheme of interaction of epoxy resin with hardeners and amine type accelerators is shown in Figure 2.

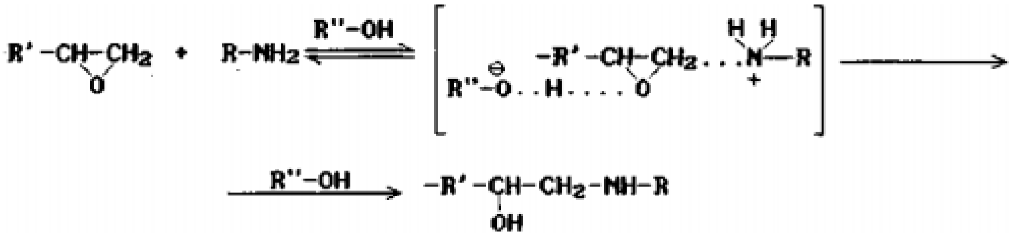

Figure 2. Scheme of the interaction of epoxy resin with amine-type hardeners.

3. SAS in the developed composition based on epoxy resin

To increase the plasticity of the coating, as well as to normalize the spreadability index, we introduce a non-ionic surfactant OP-7, which belongs to the group of oxyethylated alcohols, into the developed composition (block diagram - Figure 3). Prepared by the action of ethylene oxide on aliphatic alcohols at 140–160 ° C in the presence of a 5% alkali solution, alkali metal alcoholates, boron trifluoride or tin tetrachloride with vigorous stirring of the reaction mixture. Individual syntanols are obtained by the interaction of alkali metal alcoholates with halogenated polyethylene glycols. Allowable concentration of SAS in the composition is from 0 to 1%. OP-7 corresponds to GOST 8433-81 "Substances OP - 7 and OP - 10. Technical conditions"

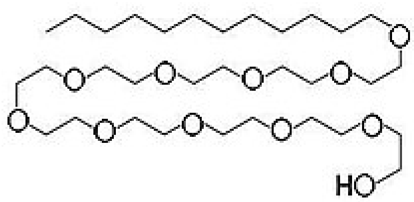

Figure 3. Structural diagram of ethoxylated alcohols.

Thus, we have determined the approximate composition of the material being developed.

2.3 Characteristics of materials used in experimental studies

The coatings were formed on glass plates with a size of $2\times90\times120$ mm and plates of tin with a thickness of 0.2 - 0.3 mm and dimensions of $20\times100\times150$ mm, cleaned from scale and rust with polished sandpaper No. 6 and washed with white spirit.

The experiment was carried out with tangent sawn timber. Tangential sawn timber has a higher strength, less wear than radial sawn timber, since in the process of finishing wood with paints and varnishes, the difference between radial and tangential sawn timber is in the percentage of late and early wood. Paints and varnishes penetrate into wood unevenly. This is because cells of early and late wood, being looser and less resinous, absorb paint and varnish material more strongly, while cells of

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late wood, denser and thicker, contain a large amount of resinous substances, absorb less paint and varnish material.

For the experiment, 42 samples of pine wood substrates were prepared with dimensions of 300× 150×20 mm. The blanks were obtained from sawn timber with a moisture content of 8 - 12%. Wood samples were preliminarily polished for finishing to a roughness of ≤16 μm, after which dust was removed from them.

2.4 Experiment methodology

The formation of the coating on the samples and tests were carried out in the wood finishing laboratory of the department of mechanical wood processing and industrial safety of the Ural State Forestry University.

The process of finishing with epoxy-based paints and varnishes consists of the following stages:

1. Surface preparation (dust removal) by hand with lint-free wipes.
2. Preparation of the working composition of paintwork materials, according to the plan of the experiment.
3. Heating the composition in the chamber at 40 ° C for 5 minutes.
4. Exposure of the composition for 2 minutes at room temperature.
5. Application of the first layer (primer) paintwork based on epoxy resin with a brush.
6. Drying the layer in a chamber at a temperature of 40 ° C.
7. Intermediate sanding of the coating by hand with a sanding sponge # 220-280.
8. Removing dust by hand with lint-free wipes.
9. Preparation of the working composition for the second layer according to the grid of the experiment.
10. Heating the composition in the chamber at 40 ° C for 5 minutes.
11. Exposure of the composition for 2 minutes at room temperature.
12. Application of the second layer of epoxy paintwork with a brush.
13. Drying the layer in a chamber at a temperature of 40 ° C.

The coating scheme on the samples is shown in Figure 4.

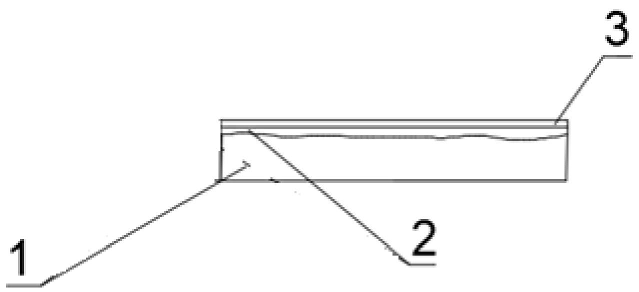

Figure 4. Structural diagram of the coating on the samples.

To compare the drying time, as well as the effect of temperature and components in the paint and varnish composition on the aesthetic, physical and mechanical properties of the coating, samples were prepared with coatings dried at room temperature.

Also, in some of the samples, the conventional drying chamber was replaced by a vacuum chamber; curing in it also occurred at 40 ° C.

The samples obtained are ready for further testing on them, which are carried out to determine the compliance of the properties of the films obtained with the requirements established by the current standards and specifications for a specific type of coating. The main indicators reflecting the functional side of the quality of coatings are thickness, hardness, bending and impact strength, adhesion to the substrate, heat, frost, and water resistance.

The aesthetic aspect expresses the compositional solution of the finishing of products and acts as an indicator of quality that reflects the external signs of coatings: color, texture, degree of gloss or dullness, transparency or opacity, general expressiveness.

2.5 Developing an experiment plan

When testing paints and varnishes, second-order plans are usually used, for example, Box-Hunter, Kono, Box, Hartley plans, depending on the number of varied parameters.

In second-order plans, each of the independent variables must take at least three values. It is often necessary to give preference to plans with a minimum number of levels of variation [5].

For the planned study, the Box plan was chosen m = 3.

Let's make the coding of the factors:

X_1-hardener

X_2-accelerator

X_3 – surfactant (SAS)

Each experiment is repeated 3-5 times.

Output parameters:

1. Consumption of paintwork materials, g / m2;
2. Drying time, min;
3. Coating thickness, microns;
4. Gloss of the coating, %;
5. Strength for flexibility;
6. Hardness on the pendulum device M-3, conv. units [6];
7. Impact strength;
8. Adhesion;
9. Heat resistance of the coating;
10. Moisture absorption;
11. Sclerometric hardness.

3. Results and Methods

The optimal design of the second order experiment was developed, which is presented in tables 1 and 2. Table 1 presents the initial data of the experiment:

Table 1. Factor coding table.

Argument	code	Natural meanings		
		X1	X2	X3
Lower level X-	-1	50	0	0
Main level X	0	55	1,5	0,5
Upper level X +	1	60	3	1
Variation step λ	-	5	1,5	0,5

The experiment matrix is presented in table 2.

Table 2. Matrix of the experiment according to the Box's plan m = 3.

№	X_1	X_2	X_3
1	1	1	1
2	-1	1	1
3	1	-1	1
4	-1	-1	1

5	1	1	-1
6	-1	1	-1
7	1	-1	-1
8	-1	-1	-1
9	1	0	0
10	-1	0	0
11	0	1	0
12	0	-1	0
13	0	0	1
14	0	0	-1

After carrying out a multifactorial experiment, it is necessary to carry out statistical processing, on the basis of which a mathematical model will be built to obtain the regime parameters for creating a protective and decorative coating.

4. Conclusion

The article substantiates the choice of developing a paint and varnish composition based on epoxy resins for wood products, as well as its components and their limiting concentrations. The principles of the experiment planning methodology for further research are presented. As a result of the experiment, statistical processing will be carried out and the optimal formulation of the paint and varnish composition will be found. At the stage of experiment planning and testing, we can assume that the developed PVM will have the following properties: have an optimal viscosity for the use of more technologically advanced equipment (spraying), provide a shorter coating film formation time than existing coatings (up to 180 minutes), which will reduce finishing production cycle several times.

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