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# Film-formation of paint coatings of wood in aeroionization

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**Abstract.** Currently, ionization is widely used in various areas where it is necessary to clean indoor air and the therapeutic effects of negative ions on living organisms. The use of aeroionization as a method of accelerated film formation of wood-based paintwork is the application of a well-known solution in a new way and has a novelty. The mechanism of film formation acceleration of paintwork coatings of wood is theoretically described and the effect of aeroionization on the film formation kinetics is experimentally confirmed.

## 1. Introduction

In the technology of the formation of protective and decorative coatings of wood with liquid paintwork materials, they seek to obtain coatings with high protective and decorative properties with a minimum number of technological operations, a minimum consumption of paintwork materials and maximum automation and mechanization of processes. Film formation paintwork coatings is the longest operation, however, its reduction is possible through the use of methods of intensification of film formation or message paintwork materials additional energy. There are various methods of accelerated film formation paintwork: convective drying, infrared, ultraviolet, microwave [1-8].

These methods have the disadvantage of increased power consumption. The government of the Russian Federation sets the industry the task of improving energy efficiency, so enterprises are forced to look for simple, economical and high-performance solutions for manufacturing products. This effect can be achieved through technological measures, so the development of new simple and energy-efficient methods of accelerated film formation of wood-based paintwork is relevant.

Existing methods of intensifying the film formation of wood-based paintwork materials are costly, namely: the equipment used is expensive, it needs increased electricity consumption (from 3 to 20 kW · h), and also taking into account the chemical nature of the used paintwork materials.

Analysis of the literature revealed a new direction to increase the effectiveness of the formation of protective and decorative coatings on wood products by applying the aeroionization method of accelerated film formation of paintwork materials, which provides the required quality of the coatings obtained and at the same time the electricity consumption is about 0.096 - 0.2 kW · h [9, 10].

## 2. Methods and Materials

In carrying out research and experimentation, modern domestic and foreign equipment and devices were used. The physicomechanical and operational characteristics of paintwork materials were evaluated by standard methods. In the conducted research, paintwork materials of domestic and foreign production were used: acrylic lacquer water-dispersion "Ekolak"; transparent ground water-dispersion "Ecogrun". To intensify the film formation of paint and varnish materials, an electric

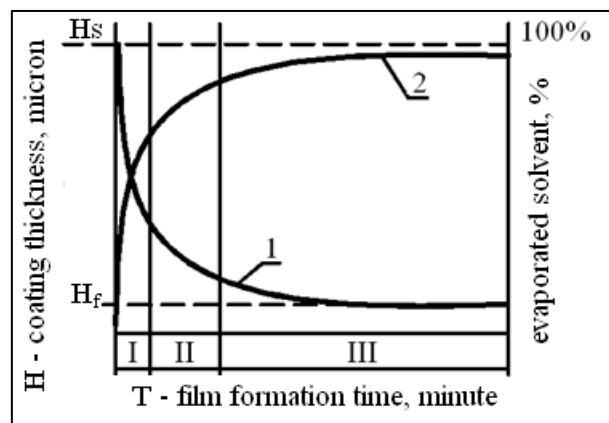


effluvial aeroionization device was developed, which was developed by Mordovia State University. N P Ogareva (Mordovia, Saransk).

The study of the properties of the obtained coatings was carried out on samples of pine wood substrates  $170 \times 70 \times 20$  mm in size, humidity  $W = 8 \pm 2\%$ , surface roughness  $R_m \max \leq 16 \mu\text{m}$ ) and glass plates  $4 \times 90 \times 120$  mm in size. The experiments were performed according to the classical scheme using the methods of statistical processing of their results. Constant factors in conducting research are air temperatures of  $20 \pm 2^\circ \text{C}$  and air humidity of  $65 \pm 5\%$ .

### 3. Results and its discussion

Film formation of water-dispersion paint coatings occurs in a thin layer on the surface of wood and can be represented by three stages (Figure 1): the first stage is the formation of a gel and the accelerated evaporation of the solvent from the free surface; the second stage is the syneresis of the intermediate gel; the third stage is the elimination of the boundaries between adjacent particles. For organic-based varnishes, the movement of the solvent through the layer of cured polymer film to the surface of the coating occurs due to diffusion [1-3].



**Figure 1.** Kinetics of paintwork drying: 1 - changing the thickness of the coating; 2 - kinetic curve of change in the amount of solvent

A wood sample with a layer of liquid paint applied, placed under the electric effluvial aeroionization emitter, can be thought of as a system of three flat series-connected capacitors (Figure 2).

In the paint coatings layer formed on the wood surface, the process of film formation occurs, which is accompanied by the work of moving the solvent from the depth of the layer to the surface, followed by evaporation. According to the law of conservation of energy, work [11] performed by a source can be expressed as:

$$\Delta A_{\text{ist}} = \Delta W + F_{\text{el}} \Delta x \quad (1)$$

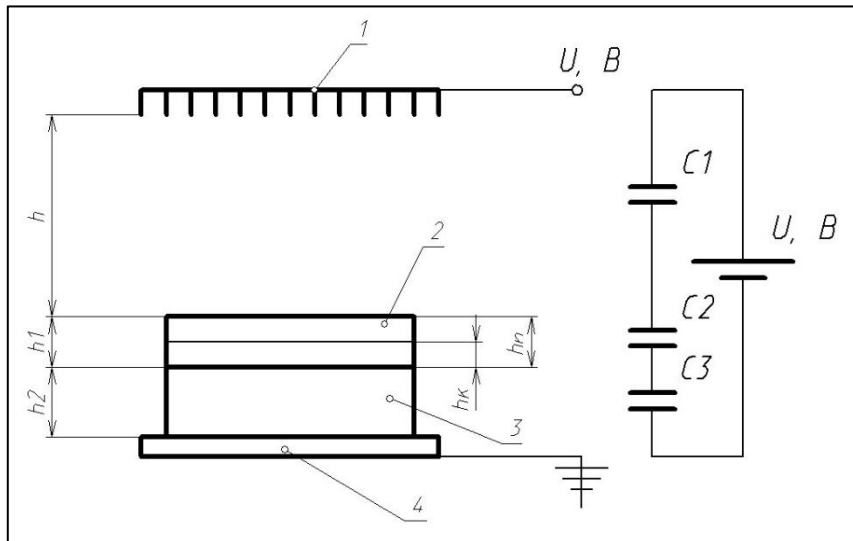
where,  $\Delta W$  is the change in the energy of the capacitor,  $F_{\text{el}}$  is the electric force above the external bodies. If we consider that the force acting on the layer of liquid paint

$$F_{\text{el}} = \frac{\Delta W}{\Delta x} \quad (2)$$

where,  $\Delta x$  is the magnitude of the change in the thickness of the paintwork during film formation (Figure 3). On the example of a capacitor, the energy of a liquid coating material in a thin layer of paintwork, can be conventionally taken as the sum of the energy of a layer of film-forming substance  $W_1$  and a layer of its thinner  $W_2$

$$W = W_1 + W_2 \quad (3)$$

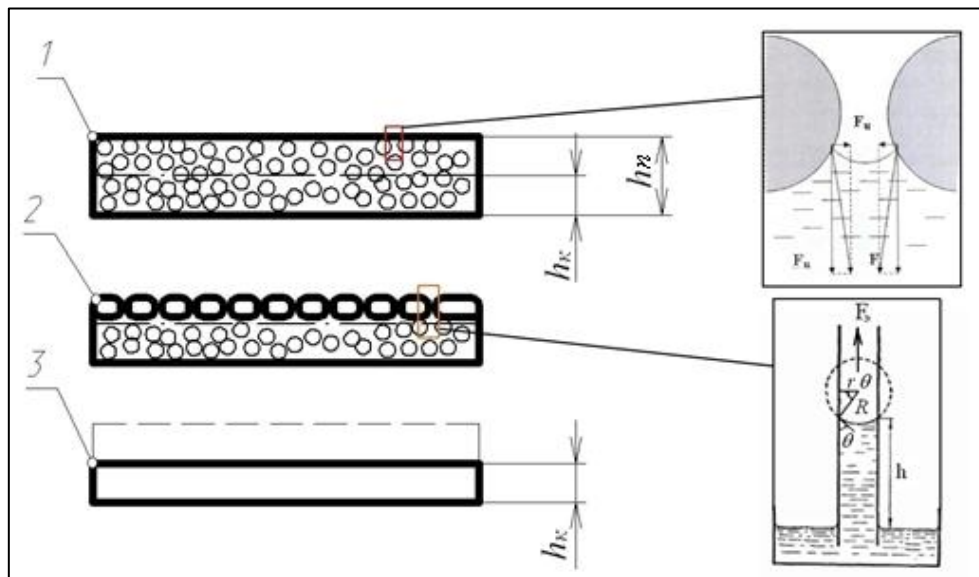
Then the change in energy  $\Delta W$  in the curable paintwork coatings layer can be defined as the energy of the film-forming layer (total energy minus the energy of the solvent layer).



**Figure 2.** Conditional representation of a system consisting of an electric effluvial aeroionization and a sample of a substrate with applied coatings in the form of capacitors (on the right is a series circuit of capacitors): 1 - aeroion emitter, 2 - paintwork coatings, 3 - substrate (wood), 4 - grounding base,  $h$  - the distance between the surface of the coating and the radiator,  $h_1$  is the thickness of the coating ( $h_k$  is the initial thickness of the paintwork layer before drying,  $h_k$  is the thickness of paintwork final after film formation)

Suppose that the electric force  $F_e$  acting on the solvent in a thin layer of curable paint and varnish products is greater than gravity  $F_t$ , this facilitates the movement of the solvent through the layer of paintwork coatings formed to the surface and more intensive evaporation from the open surface.

The second stage of the film formation process of paint and varnish products formed by water-dispersion paint is the syneresis (compression) of the intermediate gel in which the solvent is removed from the drying film and the capillary phenomena occur, during which the solvent rises in the capillaries formed between the compressing particles of the dispersed phase. It can be said that the effect of the electric effluvial aeroionization electric field affects the ordering and compaction of particles of the dispersed phase, and also has an effect on reducing the wetting angle of the solvent, due to the message of the electric charge and, as a result, its rising to the surface by capillaries formed between the dispersed particles sticking together phases (Figure 3).



**Figure 3.** Film formation in the layer of liquid paintwork with aeroionization: 1 - gel formation and evaporation of the solvent from the open surface; 2 - gel compaction with the formation of microcapillaries; 3 - hardened paintwork;  $h_n$  - the initial thickness of the paintwork;  $h_k$  - the final thickness of the paintwork

The height of the liquid or solvent paint coating in the capillary is characterized by the formula of Jurin:

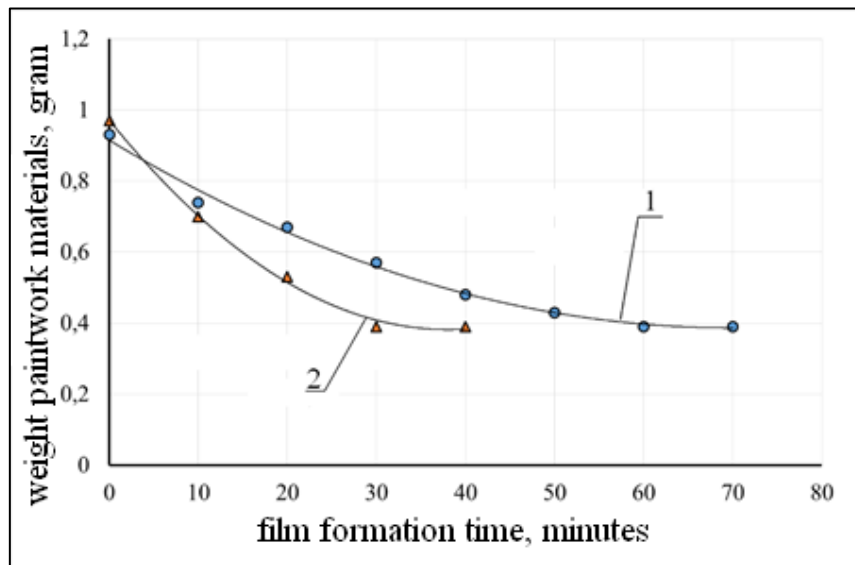
$$h = \frac{2\sigma\cos\theta}{\rho r g} \quad (4)$$

Therefore, it is influenced by the radius of the capillary  $r$  and the wetting angle  $\theta$  by the liquid of the capillary walls [11].

As a result of the study of the film formation kinetics of wood varnish coating with water-dispersion varnish during aeroionization, the experiment was carried out with the following operational parameters: Voltage applied to the electric effluent radiator  $U = 24$  kV; current in the supply circuit of the ionizer  $I = 0.5$  A; the step between the electrodes of the emitter is 0.04 m. The kinetics of film formation of paintwork on wood during aeroionization is shown in Figure 4, and the process of water-dispersion lacquer weight loss can be mathematically represented as regression equations, the adequacy of which is confirmed by the approximation reliability value  $R^2=0,9$ .

$$y_1 = 0.0001x^2 - 0.0015x + 0.91, \quad (5)$$

$$y_2 = 0.0004x^2 - 0.0031x + 0.97. \quad (6)$$



**Figure 4.** Kinetics of mass loss paintwork in the process of film formation on wood: 1 - in vivo  $y_1$ ; 2 - with aeroionization  $y_2$

The kinetics of evaporation of the solvent from the paintwork coatings in the process of its film formation on a wood substrate is shown in Figure 5.

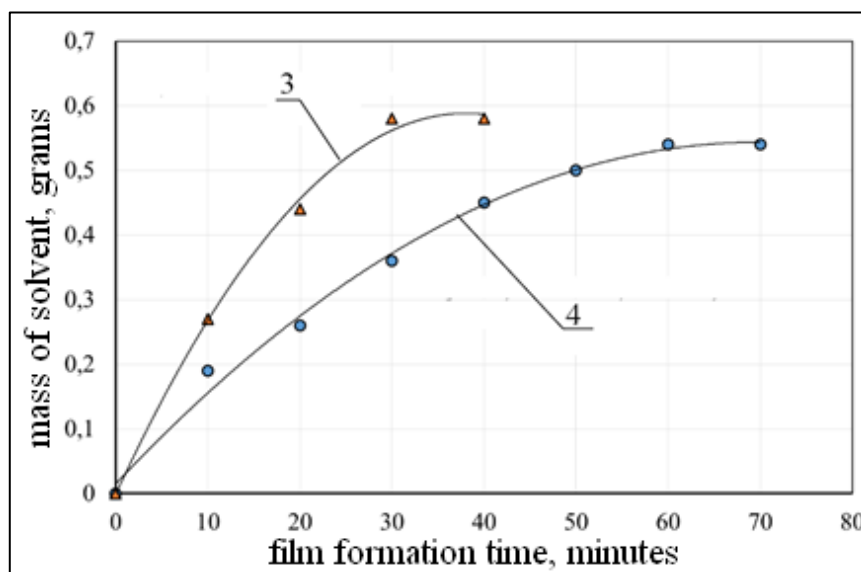
The process of the solvent mass loss from the paintwork material can be mathematically represented as regression equations, the adequacy of which is confirmed by the confidence value of the approximation  $R^2=0.9$

$$y_3 = 0.0004x^2 - 0.031x + 0.0014 \quad (7)$$

$$y_4 = 0.0001x^2 - 0.0015x + 0.015 \quad (8)$$

In the process of film formation on the wood surface of a varnish film, its transition to a solid state occurs, the solvent moves from the depth of the layer to the surface, followed by evaporation of the solvent and the thickness of paintwork material decreases.

The process of film formation of water-dispersion lacquers proceeds in three stages and is a sol-gel transition and subsequent spontaneous compression of the resulting intermediate gel to a state of monolithic foam. The last stage - globules merge during film formation occurs under the influence of many active forces: the capillary pressure of the liquid, the surface tension at the polymer – water interface, the intermolecular interaction, the gravity forces of the particles. The fundamental role is given to capillary, or interparticle pressure. Film formation occurs when the capillary pressure in the system exceeds the resistance to deformation of the polymer particles (globules).



**Figure 5.** Kinetics of change in the mass of the solvent evaporated from the paintwork coatings layer in the process of film formation: 3 - with aeroionization  $y_3$ ; 4 - in natural conditions  $y_4$

According to research data on the evaporation of moisture from a water surface and from a wood surface [12], there is always a thin layer of air above the free surface of water that is saturated with moisture. If to ensure the movement or circulation of air at such a surface, the thickness of the saturated air layer decreases and facilitates the transfer of water vapor from the surface to the surrounding air. If you create additional air circulation at the surface, then the evaporation rate will increase, therefore the air circulation rate is one of the important factors affecting the evaporation rate from the free surface. The movement and velocity of air circulation usually occurs in a direction parallel to the surface of evaporation. The air flow is perpendicular to the surface of evaporation, it allows to increase by a factor of 2 the evaporation coefficient, which was verified by the All-Union Thermal Engineering Institute.

#### 4. Conclusion

Film formation is accelerated due to the message of opposite charge to the boundary layers of the contacting materials, which causes the acceleration of the process of moving the solvent from the paintwork coatings layer to the surface due to capillary and electroosmotic forces. The results of the study of the film formation kinetics of paintwork with air ionization, show a reduction of time by 50% in comparison with the natural conditions of curing. Aeroionization allows you to create a directional flow of air along the lines of the force field from the paintwork surface to the radiator, which leads to increased electrification of water molecules at the border with air, translating them into an excited state that accelerates the evaporation of the solvent from the surface of the coatings, which is confirmed by practical experiments. The results obtained reflect the effectiveness of aeroionization, and the regression equations allow us to adequately describe the kinetics of film formation.

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