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Research of Conditions of Removal of Fire Protection from Building Construction

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Abstract. Fireproof coatings at the time of operation of the building structure is a separate and complex task, covering both the stages of the process protection from moisture, and subsequent fire protection formed during the swelling of the coating. They have been proven to create a layer of material on the surface that prevents moisture from penetrating the wood when the destruction of the coating begins. This makes it possible to determine the effect of flame retardants and the properties of the protective compositions on the process of slowing down the rate of water absorption. The process of moisture transfer by flame retardant coating in the presence of a polymeric shell is simulated, the diffusion and mass transfer dependences are obtained, and the diffusion coefficient is determined, which is $7.08 \cdot 10^{-12}$ m^2/s, which allow to obtain a change in the dynamics of moisture upon washing out of the flame retardant. The results of determining the weight loss of the coating sample during exposure to water indicate the ambiguous effect of the nature of the leaching agent. In particular, this implies the availability of data sufficient for qualitatively conducting the process of inhibition of moisture diffusion and detection on its basis of the moment from which the fall of the coating efficiency begins. Features of slowing down the process of moving the moisture to the material that is treated with flame retardant, are in several aspects. Namely, the use of water-insoluble flame retardants and other components, as well as polymer binder, which are characterized by the formation of polymer shell on the surface of the wood.

1 Introduction

Operational reliability and efficiency of fire protection of wood and wood-based materials (cane) depends on the quality and reactivity fireproof product and the class of conditions of the facility where the materials used [1, 2]. Eventually Fire-retardant bioprotective effectiveness may be reduced because the processes of leaching flame retardant, and so disclosure laws of mass transfer in the flame retardant, flame-protected material is relevant for both science and practice [3, 4].

2 Analysis of Recent Research and Publications

Modern methods include the use of fire protection coatings, intumescent. They are complex systems of organic and inorganic components [5, 6], characterized intumestsentnoyu high resolution. But it said the operation which classes they belong [7]. The effectiveness of fire retardant coatings based on organic substances shown in [8]. Due to the action of flame retardants based on polyphosphoric acids and blowing agents may significantly influence the porous layer pinokoksu.

Describe the behavior intumestsent coatings, one of the objectives of which are experimental data linkage with the existing theoretical models, dedicated work [9]. This allows at least in principle, to estimate the simplification made only in respect of thermal stability, which is regarded Thermal model whose solution polynomials are not associated with physical content.

The mathematical model of changing temperature and moisture fields of fire-proof coatings, based on the laws of conservation of matter and energy. The models immediately predict a specific type of functional dependencies with a set of uncertain coefficients, and the task is to determine the numerical value of these coefficients, which is associated with high inaccuracy [10].

Efficacy component coatings based on organic substances shown in [11], where by the action of flame retardants based on polyphosphoric acids and blowing agents may significantly influence the protective layer pinokoksu. However, it is necessary to investigate the conditions of formation of the barrier for thermal and moisture conductivity and to establish the effective action of the coating with the formation of a protective layer.

Significant increase stability, density and strength of the protective layer is achieved as a result of the directed formation of certain additives which form high-compounds [12]. However, to confirm this process are not relevant physico-chemical data.

Effect of inorganic fillers for fire protective coatings water based shown to be effective, however, cover the swelling mechanism is not specified and is not detected operating conditions covering [13]. The authors of the analytical model shows the fire resistance and thermal degradation pinokoksu porous structure fireproof coating that allows for shape now, but the model does not account for that phase transitions occur when the coating operation in a wet environment [14].

The paper proposes a mathematical model and methodology for numerical study of the kinetics of the state of heat and humidity of a capillary-porous body based on the simultaneous equation of the solution of thermal conductivity and moisture transfer [15]. However, these studies are inherent to inorganic material and cannot be attributed to wood.

Therefore, the modeling of the diffusion process of fire retardant coating for wood, the influence of the components that are part of them, on this process is an unresolved component of ensuring the fire resistance of building structures [16]. This led to the need for research in this area.

3 The Purpose of this Work

The purpose of this work is to establish patterns of diffusion and mass transfer in a flame retardant, flame-protected cane in the presence of the polymer shell.

4 Materials and Methods of Research

Studies of the leaching of the protective agent from the building structure from the cane, fireproofed roofing mortar, were carried out on samples of average sizes up to 10 mm in diameter, 310 mm long, which were tied into a 310×140 mm thick motherboard with a thickness of 10…12 mm and treated with roofing mortar. in the amount of 40.2 g/m^2. Namely, modified roofing impregnating solution "Skela-i" (a mixture of urea 28...30% and phosphoric acids 23...24% and starch 20%), and to increase resistance to water, the samples were covered with polymer mixtures based on polyurethane organic coatings (Fig. 1). The thickness of the flame retardant coating and polymer shell was determined by applying them to a metal plate and after drying was measured by a micrometer.

To obtain the values of the diffusion flame retardant herbal products developed and manufactured special equipment (Fig. 2).

The test sample was fixed in a special cuvette so as to investigate the leaching in one plane at a distance of 25 mm from the end face of the sample and at a depth of 5 mm, and pour 100 cm^3 of distilled water (Fig. 2).

Fig. 1. Model samples of cane for testing

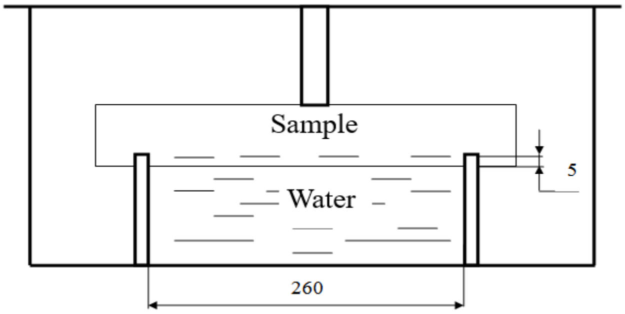

Fig. 2. Device for testing the leaching of flame retardants.

After a certain period of time, stirring the solution with a glass rod, using a pipette, 10 cm3 was selected and the concentration of salt flame retardant in the environment (water) was determined according to DSTU 4479.

5 Modeling of Diffusion Parameters of Fire Retardant Coating

The essence of the layer-by-layer leaching of flame retardants can be explained by the example of the removal of salt flame retardant on the surface of the material in the form of a soluble solid. Moisture gradually penetrates the material and dissolves the salt flame retardant (Fig. 3).

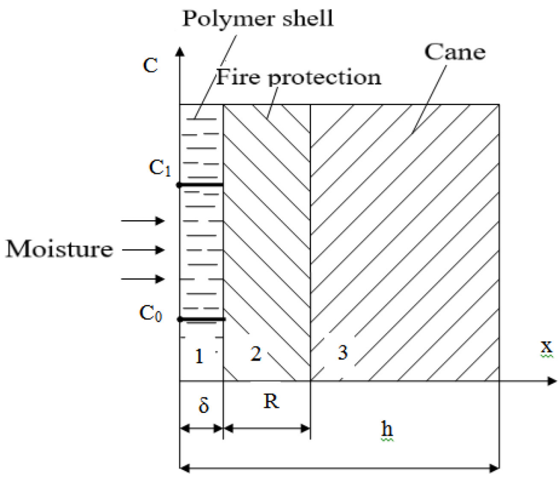

Fig. 3. Scheme of promotion of the phase transformation front in capillary-porous material (wood): 1 – external environment, $x<0$; 2 – flame retardant, $\delta < x \leq$ h, m; 3 – sample material h-R-δ, m

The soluble target component is diffused by the resulting concentration gradient across the layer inside the material that has already dissolved (the spent layer). In this mode of layer-by-layer leaching, the concentration of salt flame retardant in the material remains unchanged and is equal to its concentration in the starting material. In most cases it is possible to assume that the concentration of the component in the solvent at the dissolution front is constant and corresponds to the value of the concentration of saturation (solubility).

As the concentration of salt flame retardant in solution within the waste area is usually accepted small compared to the concentration in the undeveloped area, then the impact of changes in the concentration range from C_0 до C_1 (Fig. 1) on the value of the diffusion coefficient in this area can also take small which gives reason to believe diffusion coefficient constant throughout the process of dissolution of the body surface to its center.

The process of dissolution in most processes is very slow, so the distribution of the concentration of salt flame across the exhaust zone in the first approximation relies on the corresponding stationary distribution and in our case has a stationary profile and is linear [10].

The process of diffusion flame retardant wood in steady approach can be described in equation form:

$$\frac{d^2C}{dx^2} = 0, \tag{1}$$

where is the

C – concentration of salt flame retardant at a distance x from the middle of the sample (thickness).

From the initial and boundary conditions:

$$\text{at } x = \text{R } \tilde{N} = \tilde{N}_o \text{; at } x = \text{R} + \delta \ \tilde{N} = \tilde{N}_1, \tag{2}$$

where is the

R – half the thickness of the fire protection;

δ – half the thickness of the fire protection;

C_0, C_1 – concentration of salt flame retardant inside the sample and in the external environment, respectively.

Double integration of equation (1) is:

$$\tilde{N} = A\,x + B, \tag{3}$$

where is the

A i B – are constant integrations.

From equations (1) and (2), we obtain:

$$\begin{cases} \tilde{N}_i = \grave{A}R + \hat{A} \\ \tilde{N}_1 = \grave{A}(R+\delta) + B \end{cases}. \tag{4}$$

From equation (4), we obtain:

$$A = -\delta^{-1}(C_o - C_1),$$
$$B = \delta^{-1}(C_o(R+\delta) - C_1R).$$

Solution (3) in the form:

$$\tilde{N} = \delta^{-1}(C_o(R+\delta) - C_1R - (C_o - C_1)x). \tag{5}$$

Given that the diffusion flow through the surface covered with film can be submitted as:

$$j = -S \cdot D\frac{dC}{dx}, \tag{6}$$

where is the

S – surface area of the sample, and after substitution (5) in (6), we obtain:

$$j = \frac{S \cdot D(C_o - C_1)}{\delta}. \tag{7}$$

The balance equation of mass transfer through the polymer shell will be:

$$\frac{S \cdot D(C_o - C_1)}{\delta} = V_1 \frac{dC_1}{d\tau}, \tag{8}$$

where is the
τ – time;
V_1 – volume of the environment.

The solution of equation (8) has two unknown quantities C_0 and C_1, for the determination of which the equation of material balance is used:

$$V_o C_o + V_1 C_1 = m, \tag{9}$$

where
V_o – volume of the sample immersed in water;
m – the mass of fire retardant in the sample before starting the experiment.

From equation (9) we find:

$$C_o = C_0^* - \gamma\, C_1, \tag{10}$$

where is the
$C_0^* = \frac{m}{V_o}$ – initial concentration of fire-proof vehicle in the sample;
$\gamma = \frac{V_1}{V_0}$ – volume ratio of the environment and the sample.

Substituting (10) into (8), we obtain a linear differential equation to determine C_1:

$$\frac{dC_1}{d\tau} = \frac{S \cdot D}{\delta \cdot V_1}\left(C_0^* - (1+\gamma)C_1\right) \tag{11}$$

Integration of equation (11) under the condition $\tau = 0$, $C_1 = 0$ gives the value:

$$\ln\left(\frac{C_0^* - (1+\gamma)C_1}{C_0^*}\right) = -\frac{D \cdot (1+\gamma)}{\delta^2 \cdot \gamma}\tau \tag{12}$$

From equation (12) it follows that the concentration of the fire retardant in the external environment varies with $\gamma >> 1$ depending on:

$$C_1 = \frac{C_o^{\ *}}{\gamma}\left(1 - e^{-\frac{D}{\delta^2}\tau}\right). \tag{13}$$

Having made the mathematical transformations of equation (13) in the form:

$$\ln\left(\frac{C_0^*}{C_0^* - \gamma\, C_1}\right) = \frac{D}{\delta^2}\tau\,. \tag{14}$$

The intensity ratio of the mass transfer of salt flame retardant through the polymer film into the external environment is calculated according to:

$$\beta = \frac{D}{\delta}. \tag{15}$$

6 Research Results

The thickness of the flame retardant coating was 10…15 μ, and the polymer shell – corresponded to the value of 20…25 μ. The weight of the flame retardant and polymer shell was 43 g and the volume of the cane sample immersed in water was about 180 cm^3. In the Table 1 shows the concentration of fire retardant coating in the environment (water).

Table 1. Results of experimental determination of the standard fire-proof coatings cane

Sample cane	Washing time interval, minutes									
	5	10	30	60	120	240	360	720	1200	2400
	The content of flame retardant in water, g									
Fire retardant coated with polymer sheath	0	0	0,006	0,012	0,056	0,090	0,15	0,21	0,33	0,44

In Fig. 4 shows the dependency A = $\ln\left(\frac{C_0^*}{C_0^* - \gamma\, C_1}\right)$ from time τ.

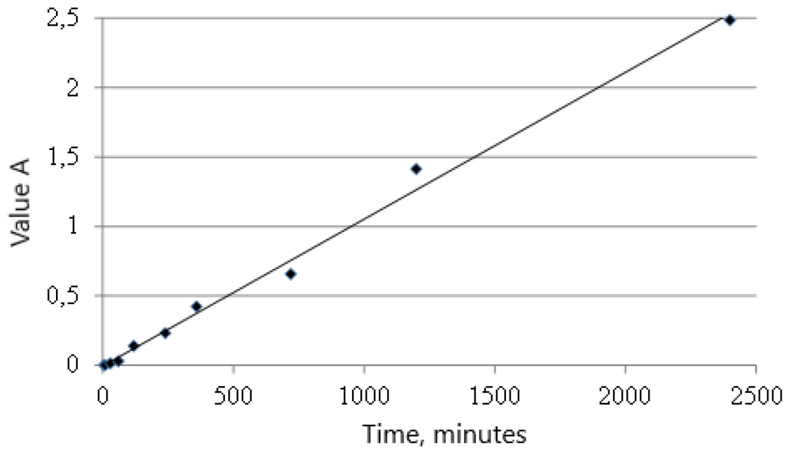

Fig. 4. Dynamics of change of fire retardant in the reed when washed in water

The tangent of the angle $(tg\alpha)$ of inclination of this line gives the coefficient at τ, that is:

$$(tg\alpha) = \frac{D}{\delta^2}\,. \tag{16}$$

Depending on (15) the value of the calculated $(tg\alpha = 0.0177)$ diffusion coefficients is calculated, which is: for the fire-proofed cane – $7.08 \cdot 10^{-12}$ m^2/s and the coefficient of the mass transfer of the fire-extinguishing agent through the polymer film to the external environment (16), which is 0.354 10^{-6} m^2/s, respectively.

7 Conclusions and Perspectives of Further Research

The obtained dependencies allow, on the results of experimental studies, to calculate the diffusion coefficient and mass transfer of the fire retardant from the building structure. The use of polymeric coating "Silol" reduces the process of mass transfer of flame retardant, which greatly increases the life of the fire-proofed cane and allows use on objects with high humidity.

The results of the research will also allow us to purposely solve further problems in the creation of new means and methods of fire protection of organic materials and operating conditions at different sites.

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