UDC 614.84

A. Chernukha, *PhD, Associate Professor, Associate Professor of Department (ORCID 0000-0002-0365-3205)*
P. Kovalov, *PhD, Associate Professor, Head of Department (ORCID 0000-0002-2817-5393)*
O. Bezuglov, *PhD, Associate Professor, Associate Professor of Department (ORCID 0000-0002-8619-9174)*
R. Meleshchenko, *DSc, Professor, Associate Professor of Department (ORCID 0000-0001-5411-2030)*
O. Cherkashyn, *PhD, Deputy Head of Department (ORCID 0000-0003-3383-7803)*
O. Khmelyk, *Deputy Head of Course (ORCID 0000-0001-8933-4135)*
National University of Civil Defence of Ukraine, Kharkiv, Ukraine

INVESTIGATION OF ASH WOOD DURING TREATMENT WITH FIRE-PROTECTIVE AGENT DSA

Experimental studies of fire-retardant efficacy of DSA for ash wood have been carried out. The dependence of fire-retardant efficiency on the mass of dry agent is obtained, which is important when treating ash wood with DSA. The influence of wood characteristics of different species on the effectiveness of fire-retardant impregnating agents on the example of ash and DSA has been studied. It is established that the standard method of research of fire protection efficiency using only pine cannot provide fair data on the effectiveness of the tool to other wood species. Yes, according to the instructions of the test agent, 3 applications are required, but for ash to achieve the first group of fire-retardant effectiveness required 6 applications. The obtained dependence of the weight loss of the treated wood sample on the amount of fire-retardant composition in standard tests provides the possibility of engineering, economic and other calculations when performing work on fire protection. The standard method of research of fire-retardant efficiency with use of pine exclusively is checked. It is determined that standard test methods cannot be objective when processing species other than pine. Especially useful for the study is the dependence of the weight loss of the treated wood sample on the amount of fire-retardant composition in standard tests, the influence of wood of different species on the effectiveness of fire-retardant impregnating agents such as ash and DSA. The standard method of research of fire-retardant efficiency with use of pine exclusively is checked. Can it be used in the case of ash wood processing. Thus, according to the instructions of the tested tool, 3 applications are required. Ash wood has a higher specific weight than pine, so to make a sufficient amount of active substance is a more difficult task.

Keywords: fire protection, fire protection efficiency, fire protection coating, impregnation, experimental researches

1. Introduction

One way of fire protection is impregnation. Under the local influence of a short-term ignition source, fire-retardant coatings complicate the burning of wooden structures, facilitate fire extinguishing, and in some cases exclude the possibility of its occurrence.

In most fire retardants, their effectiveness depends on the number of treatments, application to the protected surface. The manufacturer determines the number of treatments with a flame retardant to achieve a certain group of flame retardant performance based on certification tests. For the DSA, this number reaches 3.Pine wood is used in certification tests. Different species of wood have different properties for burning, impregnation, thermal destruction. Thus, ensuring the normative fire resistance of wooden structures is an urgent problem.

2. Analysis of recent research and publications

Fire protection of wood by impregnation is carried out by two methods - the method of surface application [1], the problem of processing different types of wood is not sufficiently disclosed, and the method of deep impregnation [2], impregnation with various fire retardants is not considered. When using fire-retardant impregnating agents, the number of treatments to achieve the first group of fire-retardant efficiency is 3-4 [3], this is determined for pine wood, which cannot be used for other wood species. The method of deep impregnation should be used for pre-treatment of source wood or wood products of small size [4],

the possibility of using the method at the stage of operation of the object is not considered. The method of surface treatment is used for the treatment of building structures as before installation [5], the possibility of restoring fire protection in case of its loss during operation is not considered. Although the method of deep impregnation provides a higher level of fire protection [6], but it is much more time consuming than the method of surface impregnation. Surface impregnation [7], requires additional study depending on the species of wood.

The wood processed by impregnating structures keeps the invoice that does it in demand in cases when high requirements to decorative characteristics of products of wood are put forward. Substances that reduce the flammability of wood as a result of its introduction are called flame retardants. The effect of flame retardants on the process of burning wood is explained by the following mechanisms:

– substances introduced into wood absorb heat for their heating and thermal decomposition;

– gaseous non-combustible products of thermal decomposition of flame retardants dilute combustible gases in the space above the wood;

– as a result of thermal destruction of flame retardants inhibitors of the reactions proceeding in a zone of burning over a wood surface are formed;

– flame retardants change the mechanism of thermal destruction reactions of wood towards the formation of non-combustible gaseous products (CO_2, H_2O) and porous surface carbonized layer [8], loss of load-bearing capacity of the structure due to active, catalytic charring of carbonized layer;

– method of preventing heterogeneous combustion reaction by isolating the surface of the carbon layer from oxygen in the air [9], which is not effective enough.

The use of inorganic substances for fire protection, obtaining an effective coating [10] has a high efficiency of fire protection, but requires a comprehensive test of performance, both at the stage of use and during thermal exposure to the protected surface.

Thus, the unsolved part of this problem is to ensure the normative fire resistance of wooden structures made of ash wood with the help of flame retardant DSA.

3. The purpose and objectives of the study

The aim of the work is to study the possibility of using flame retardant DSA for the treatment of ash wood.

To achieve the goal it is necessary to solve the following tasks:

– experimentally determine the effectiveness of DSA flame retardants for different amounts of ash wood treatments;

– to obtain the dependence of the effectiveness of the flame retardant DSA on the amount of dry composition.

4. The results of experimental determination of fire-retardant effectiveness of the tool

For this purpose, experimental studies were conducted. Test method GOST 16363-98 "Flame retardants for wood. Methods for determining the flame retardant properties" establishes the classification method and the method of accelerated tests to determine the group of flame retardant effectiveness of the tool.

The essence of the accelerated test method is the effect of the burner flame with the specified parameters (temperature of gaseous combustion products at the outlet of the ceramic pipe is 200 (C ± 5 ° C) like wood with fire-retardant coating or impregnation, which is placed in the ceramic pipe OTM, in conditions conducive to heat accumulation, and determination of weight loss by this sample of wood after fire tests [10].

Test equipment and measuring instruments:

– the tests were performed on the basis of the OTM device, the umbrella of which is located 40 (± 2) mm above the ceramic box;

– microprocessor module «TRITON 6000»;

– computer based on AMD processor, pro-software Windows, Termosoft;

– drying of the samples was performed in an oven SNOL-3, 5.3, 5.3, 5 – I1 (TC 16-681.032-84).

The tests are performed on three samples. The sample is kept in the burner flame for 2 minutes. After 2 minutes, the gas supply is stopped and the sample is left in the device to cool to room temperature. The cooled sample of wood is removed from the ceramic box and weighed.

The weight loss of the sample P_i in percent is calculated by the formula:

$$P_i = \frac{(m_1 - m_2) \cdot 100}{m_1}, \% \quad (1)$$

where: m_1 – the mass of the sample before the test, g; m_2 – the mass of the sample after testing, g.

The arithmetic mean of the three tests is taken as the result of the tests.

Depending on the amount of loss of mass of the samples, determined by the classification method of testing, fire-retardant coating or impregnating agent belong to the following groups of fire-retardant efficiency (tab. 1)

Tab. 1. Classification of fire protection efficiency groups according to GOST 16363-98

Weight loss, %	Fire protection efficiency groups
Not more than 9	I
More than 9, but less than 25	II

Types of samples studied - ash wood treated with DSA from 4 to 6 times.

In the study of these samples, we selected the average values given in the test reports, so for each type of sample, the test parameters are given as the arithmetic mean of the three tests.

Data from the study of samples of ash-DSA are shown in tab. 2.

Tab. 2. Weight loss and consumption of dry composition depending on the number of treatments for ash wood treated with DSA

Number of treatments	Sample weight, g			The cost of the working solution for example, g	Consumption of working solution, kg / m^2	Consumption of dry composition, kg / m^2	The cost of dry composition such as, g	Loss of sample mass (Pi) after testing, %
	Before processing (m)	Before the test (m1)	After the tests (m2)					
4	229,1	231,6	169,3	6,3	0,206	0,084	2,6	26,9
5	221,9	225,0	184,8	7,5	0,246	0,101	3,1	17,9
6	231,0	234,6	216,7	8,8	0,288	0,118	3,6	7,6

From the graphs shown in Figure 1 we see that the percentage of loss of mass of the sample is significantly reduced with the introduction of more dry mixture of flame retardant, but the minimum number of impregnations to achieve the first group of flame retardant efficiency is 6.

The number of treatments is of great importance for the effective practical use of the tool. The price of processing, quantity of a warehouse, time of carrying out works depends on this characteristic.

5. Obtaining the dependence of the effectiveness of the flame retardant on the amount of dry composition.

When calculating the actual cost of fire-retardant composition to achieve the required degree of fire-retardant efficiency, the dependence of the percentage weight loss of the sample in standard tests is constructed.

Expression (2) expresses the percentage of weight loss by a sample of ash wood in standard tests depending on the mass of dry matter spent on sample processing. The reliability of the approximation $R^2 = 1$.

$$P_i = -2249{,}1 \cdot m_{cc}^{\ 2} - 113{,}32 \cdot m_{cc} + 52{,}289\ ,\ \% \qquad (2)$$

where P_i – loss of sample mass, %; m_{cc} – mass of dry composition, g.

The number of treatments is of great importance for the effective practical use of the tool. The price of processing, quantity of a warehouse, time of carrying out works depends on this characteristic.

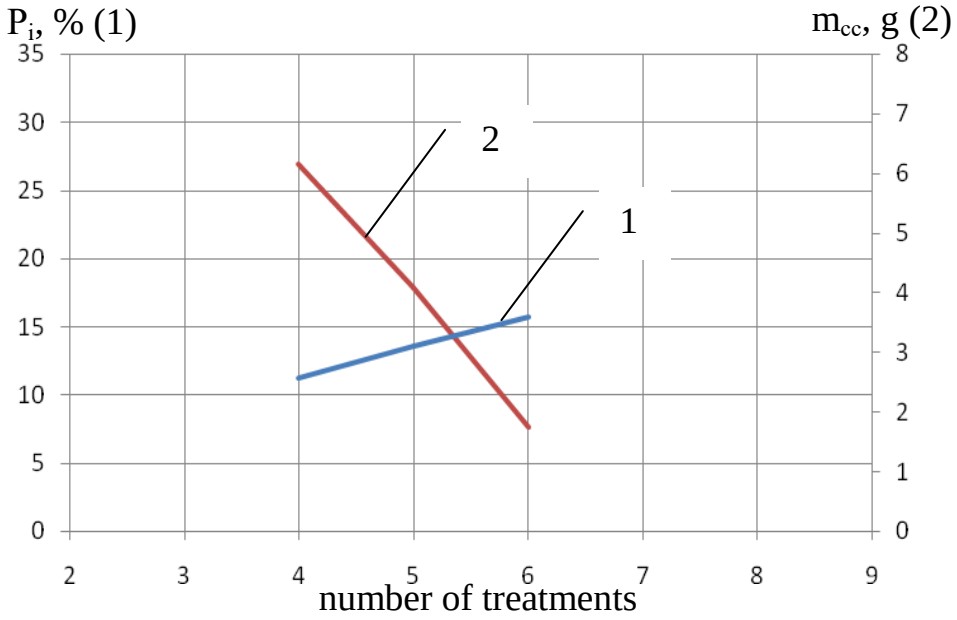

Fig. 1. Loss of mass and consumption of dry composition depending on the number of treatments for ash treated SJA: 1 – weight loss; 2 – consumption of dry composition

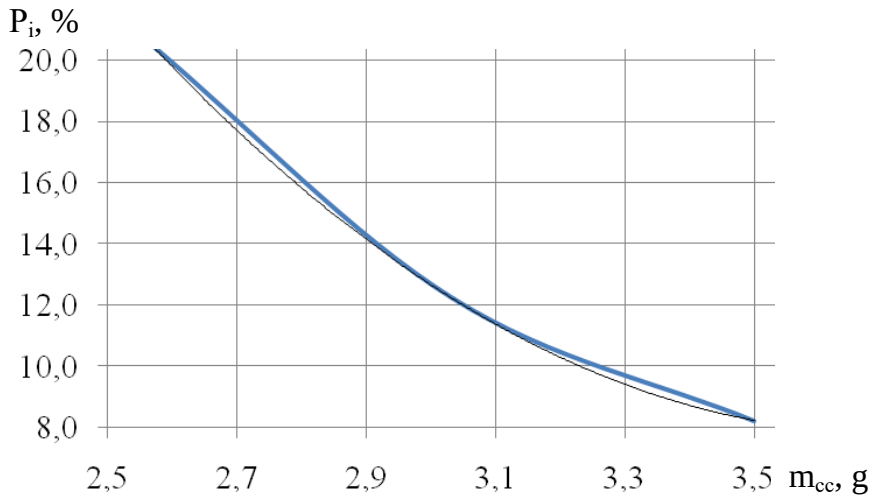

Fig. 2. Loss of mass of the sample depending on the consumption of dry composition

But when calculating the required amount of material for processing it is necessary to calculate the weight of the dry agent.

6. Discussion of the results of the study of fire retardants

The results are explained by the fact that after analyzing the existing methods of fire protection, certification methods. it was found that to determine the effectiveness of fire protection means used pine wood, not a specific species. When establishing the fire-retardant effectiveness of the agent for ash wood. it was found that the number of treatments according to the instructions is not enough to obtain the first group of fire-retardant effectiveness. When determining the fire-retardant efficiency, the weight loss and dry composition consumption depending on the number of treatments for ash wood were studied. The results of the study are presented in table 2 on three samples for each number of treatments. The results of the study are graphically presented in Fig. 1.

The peculiarity of the proposed study is to determine the fire protection efficiency directly for the species of wood used. After performing a study of the fire-retardant effectiveness of the DSA provided for in the norms on the example of ash wood treatment, you can analyze the fire protection of other wood species. Preliminary research has already provided the fire-retardant characteristics of the main fire-retardants for some wood species. Wood species with a high specific weight have poor permeability, which requires more treatments to achieve the first group of fire-retardant efficiency according to GOST 16363. The dependence of the loss of mass of the treated wood sample on the amount of fire-retardant composition in standard tests provides the possibility of engineering, economic and other calculations when performing work on fire protection. The standard method of research of fire-retardant efficiency with use exclusively of pine is checked. It is determined that standard test methods cannot be objective when processing species other than pine. The data obtained in this work are necessary to assess the treatment of ash wood, calculate the amount of dry agent and the number of treatments to achieve the first group of fire-retardant efficiency.

The disadvantages of this study are the attachment to the wood species, rather than determining the characteristics. Parameters, features of the material inherent in its effective, predictable, standardized fire protection.

Further development of work consists in more detailed research of quantitative characteristics of the processed material, definition of influence of these parameters on

fire-retardant processing and fire-retardant efficiency of means. Providing recommendations and methods of applying fire retardants depending on the characteristics of the wood being treated.

7. Conclusions

1. The fire-retardant efficiency of the means at different number of treatments is determined. The influence of wood features on the effectiveness of fire-retardant impregnating agents on the example of ash and DSA has been studied. The dependence of fire-retardant efficiency of the product on the number of treatments has been studied. It is established that the standard method of research of fire protection efficiency using only pine cannot provide fair data on the effectiveness of the tool to other wood species. Yes, according to the instructions of the test agent. 3 applications are required, but for ash to achieve the first group of fire-retardant effectiveness required 6 applications.

2. The dependence of fire protection efficiency on the amount of dry fire protection agent is obtained, which is of practical importance for the actual calculation of the required amount of DSA on the surface area to be protected. It is determined that when performing the normative treatment in the amount of 3 applications. the weight loss of the sample exceeds 16 %, which does not satisfy even the second group of fire-retardant efficiency, formally such wood is not considered fire-retardant. The actual amount of fire protection composition to obtain sufficient fire protection is much higher than the norm. Thus, according to the instructions, about 0.2 kg of dry composition is consumed per 1 m^2 of protected surface, and to achieve weight loss after testing less than 9 %. it is necessary to spend about 0.3 kg per 1 m^2 of surface. Thus, to obtain the first group of fire-retardant effectiveness for ash wood requires 3 times, more dry agent than provided by the instructions.

References

1. Chernukha, A. A., Kireyev, A. A., Bondarenko, S. N., Kirichenko, A. D. (2009). Issledovaniye ognezashchitnoy effektivnosti pokrytiy na osnove kserogelevoy kompozitsii. Pozhezhna bezpeka, 26, 166–171. Retrieved from http://repositsc.nuczu.edu.ua/handle/123456789/4551

2. Kireev, A., Tregubov, D., Safronov, S., Saveliev, D. (2020). Study insulating and cooling properties of the material on the basis of crushed foam glass and determination of its extinguishing characteristics with the attitude to alcohols. Materials Science Forum, 1006 MSF, 62–69. doi: 10.4028/www.scientific.net/MSF.1006.62

3. Dadashov, I., Loboichenko, V., Kireev, A. (2018). Analysis of the ecological characteristics of environment friendly fire fighting chemicals used in extinguishing oil products. Pollution Research. 37/1. 63–77. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85062144705&partnerID=40&md5=36a1aa2ad65f6325a5bac590a1deb977

4. Dadashov, I., Kireev, A., Kirichenko, I., Kovalev, A., Sharshanov, A. (2018). Simulation of the insulating properties of two-layer material. Functional Materials, 25/4, 774–779. doi: 10.15407/fm25.04.774

5. Skorodumova, O., Tarakhno, O., Chebotaryova, O., Hapon, Y., Emen, F. M. (2020). Formation of fire retardant properties in elastic silica coatings for textile materials. Materials Science Forum, 1006 MSF, 25–31. doi: 10.4028/www.scientific.net/MSF.1006.25

6. Chernukha, A., Kovaliov, P., Ponomarenko, S., Yeriomenko, V. (2017). Research of fireproof properties of fabric for Fireproof rescue stretchers. Problemy

nadzvychaynykh sytuatsiy, 25, 149–152. Retrieved from http://repositsc.nuczu.edu.ua/handle/123456789/2706

7. Babrauskas, V., Williamson, R. (1980). The historical basis of fire resistance testing. Fire Technology, II, 304–314. Retrieved from https://link.springer.com/article/10.1007/BF01998390

8. Brinker, C. Y., Keefer, K. D., Schaefer, D. W. (1982). Sol-gel transition in simple silicates. J. Non–Cryst. Solids, 48(1), 47–64. doi: 10.1016/0022-3093(82)90245-9

9. Chernukha, A., Teslenko, A., Kovaliov, P., Bezuglov, O. (2020). Mathematical Modeling of Fire-Proof Efficiency of Coatings Based on Silicate Composition. Materials Science Forum, 1006, 70–75. doi: 10.4028/www.scientific.net/MSF.1006.70

10. Chopenko, N., Muravlev, V., Skorodumova, O. (2018). Technology of molding masses for architectural and artistic ceramics using low-aluminate clays. International Journal of Engineering and Technology (UAE), 7(3), 587–590. Retrieved from https://www.sciencepubco.com/index.php/ijet/article/view/14595/5944

А. А. Чернуха, *к.т.н., доцент, доц. каф.*
П. А. Ковальов, *к.т.н., доцент, нач. каф.*
О. Є. Безуглов, *к.т.н., доцент, доц. каф.*
Р. Г. Мелещенко, *д.т.н., професор, доц. каф.*
О. В. Черкашин, *к.пед.н., заст. нач. каф.*
О. В. Хмелюк, *заст. нач. курсу*
Національний університет цивільного захисту України, Україна, Харків

ДОСЛІДЖЕННЯ ДЕРЕВИНИ ЯСЕНЮ ПРИ ОБРОБЦІ ВОГНЕЗАХИСНИМ ЗАСОБОМ ДСА

Проведено експериментальні дослідження вогнезахисної ефективності засобу ДСА для деревини ясеню. Отримано залежність вогнезахисної ефективності від маси сухого засобу, що нанесено, що важливо при обробці засобом ДСА деревини ясеню. Досліджений вплив особливостей деревини різних порід на ефективність вогнезахисних просочувальних засобів на прикладі ясеню та засобу ДСА. Встановлено, що стандартний метод досліджень вогнезахисної ефективності з використанням виключно сосни не може надати справедливі дані, щодо ефективності засобу до інших порід деревини. Так, згідно інструкції засобу, що випробуваний, необхідно 3 нанесення, але для ясеню для досягнення І-ої групи вогнезахисної ефективності знадобилось 6 нанесень. Отримана залежність втрати маси обробленого зразка деревини від кількості вогнезахисного складу при стандартних випробуваннях надає можливість інженерного, економічного та інших розрахунків при виконанні робіт щодо вогнезахисту. Перевірено стандартний метод досліджень вогнезахисної ефективності з використанням виключно сосни. Визначено, що стандартні методи випробувань не можуть бути об'єктивними при обробці інших порід крім сосни. Особливо корисною для дослідження є залежність втрати маси обробленого зразка деревини від кількості вогнезахисного складу при стандартних випробуваннях, вплив особливостей деревини різних порід на ефективність вогнезахисних просочувальних засобів на прикладі ясеню та засобу ДСА. Перевірено стандартний метод досліджень вогнезахисної ефективності з використанням виключно сосни. Чи може він використовуватися у випадку обробки деревини ясеню. Так, згідно інструкції засобу, що випробуваний, необхідно 3 нанесення. Ясень має більшу питому вагу ніж сосна, тому внести достатню кількість діючої речовини більш складна задача.

Ключові слова: вогнезахист, вогнезахисна ефективність, вогнезахисне покриття, просочування, експериментальні дослідження

Література

1. Чернуха А. А., Киреев А. А., Бондаренко С. Н., Кириченко А. Д. Исследование огнезащитной эффективности покрытий на основе ксерогелевой композиции. Пожежна безпека. 2009. № 26. С. 166–171. URL: http://repositsc.nuczu.edu.ua/handle/123456789/4551

2. Kireev A., Tregubov D., Safronov S., Saveliev D. Study insulating and cooling properties of the material on the basis of crushed foam glass and determination of its extinguishing characteristics with the attitude to alcohols. Materials Science Forum, 1006 MSF. 2020. 62–69. doi: 10.4028/www.scientific.net/MSF.1006.62

3. Dadashov I., Loboichenko V., Kireev A. Analysis of the ecological characteristics of environment friendly fire fighting chemicals used in extinguishing oil products. Pollution Research. № 37/1. 2018. С. 63–77. URL: https://www.scopus.com/inward/record.uri?eid=2-s2.0-85062144705&partnerID=40&md5=36a1aa2ad65f6325a5bac590a1deb977

4. Dadashov I., Kireev A., Kirichenko I., Kovalev A., Sharshanov A. Simulation of the insulating properties of two-layer material / Functional Materials. № 25/4. 2018. С. 774–779. doi: 10.15407/fm25.04.774

5. Skorodumova O., Tarakhno O., Chebotaryova O., Hapon Y. Formation of fire retardant properties in elastic silica coatings for textile materials. Materials Science Forum, 1006 MSF. 2020. С. 25–31. doi: 10.4028/www.scientific.net/MSF.1006.25

6. Chernukha A., Kovaliov P., Ponomarenko S., Yeriomenko V. Research of fireproof properties of fabric for Fireproof rescue stretchers. Проблеми надзвичайних ситуацій. № 25. 2017. С. 149–152. URL: http://repositsc.nuczu.edu.ua/handle/123456789/2706

7. Babrauskas V., Williamson R. The historical basis of fire resistance testing. Fire Technology. II. 1980. 304–314. URL: https://link.springer.com/article/10.1007/BF01998390

8. Brinker C. Y., Keefer K. D., Schaefer D. W. Sol-gel transition in simple silicates. J. Non–Cryst. Solids. № 48(1). 1982. С. 47–64. doi: 10.1016/0022-3093(82)90245-9

9. Chernukha A., Teslenko A., Kovaliov P., Bezuglov O. Mathematical Modeling of Fire-Proof Efficiency of Coatings Based on Silicate Composition. Materials Science Forum. 1006. 2020. С. 70–75. doi: 10.4028/www.scientific.net/MSF.1006.70

10. Chopenko N., Muravlev V., Skorodumova O. Technology of molding masses for architectural and artistic ceramics using low-aluminate clays. International Journal of Engineering and Technology(UAE). № 7(3). 2018. С. 587–590. URL: https://www.sciencepubco.com/index.php/ijet/article/view/14595/5944

Надійшла до редколегії: 30.09.2021
Прийнята до друку: 16.11.2021

