Justification of the conditions of application of fire protective coating for wood

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Abstract. Thus, experimental studies have established that an untreated sample of wood ignited under thermal action, the flame spread over the entire surface, which led to its combustion with a mass loss of more than 60 %, and the temperature of flue gases increased by more than 500 ºC in 60 s of testing. The use of an intumescent coating under the influence of temperature leads to the formation of a foam coke layer and inhibition of heat transfer of high-temperature flame to the material and a decrease in mass loss to 6.6 g/(m^2·s) and a temperature of less than 160 ºC. During the study of the flame spread index, it was found that when the flame acted on untreated wood samples for 21 s, their ignition occurred, the temperature was 367 °C and intensive flame spread over the surface, the flame spread index was 43.5. During the tests of fire-protected wood samples, the following values were obtained, namely, the wood sample treated with an inorganic coating caught fire for 890 s, the flame spread over the surface occurred only to the first section, the maximum temperature of flue gases was 82 °C for a time greater than 2.5 times, and the flame spread index decreased by 6.5 times. For a sample of wood treated with a fire-retardant intumescent coating, the wood did not ignite, the flame spread index was 0. Thus, there is reason to argue about the possibility of directed regulation of fire protection processes in wood by using fire-retardant coatings capable of forming a protective layer on the surface of the material that slows down the rate of wood burning.

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INTRODUCTION

A significant number of fires occur in the residential sector, public and industrial buildings, and transport, where wood and wood-polymer materials present in the form of products and their ignition are the main cause of fire. Given the fact that wood and products made from them (timber, plywood, fiberboard, chipboard, and others) are the main conductors of flame spread, fire safety imposes increasingly high requirements on both the effectiveness of fire retardants and the quality of fire-resistant materials [1-3]. The main requirements for fire protection of wood and wood-polymer materials are to provide them with the ability to resist fire and not spread the flame along the surface by changing the direction of material decomposition towards the formation of non-combustible gases and a difficult-to-burn coke residue, as well as inhibiting oxidation in the gas and condensed phases [4, 5].

It is known that under the influence of temperature, wood decomposition products burn, and the introduction of flame retardants into the material reduces the amount of formation of flammable volatile products, inhibits gas-phase flame reactions, eliminates flameless combustion of the carbonized residue and reduces the rate of mass loss. The use of coatings allows you to slow down the heating of the material due to the formation of a protective layer and maintain its functions in the event of a fire for a given period of time. That the fires that occurred in recent years have shown an increase in dangerous fire factors, in particular, high temperature. Since recently the range of participation in fires of various synthetic materials, hydrocarbons, capable of high heat release during combustion, has expanded [6-8].

Therefore, establishing the mechanism of operation of fire-retardant coatings for wood at elevated temperatures, studying the rate of wood burning and the effect of the coating on this process is an unresolved component of ensuring fire resistance. And, accordingly, determines the need for such research.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

In the study [9], different amounts of boric acid (BA, 1.25, 2.5, 3.75 and 5.0 wt. %) were used to enhance the performance of an intumescent fire retardant (IFR) system consisting of ammonium polyphosphate (APP) and pentaerythritol (PER) in polypropylene (PP) including 2 wt. % montmorillonite nanoclay (MMT). At the same time, metaboric acid and boron oxide, which were formed during the decomposition of BC, appeared in the melt bonding and combustion processes, respectively. Large-scale experimental studies were conducted to investigate the effects of BA/boron oxide and MMT combinations on the properties of PP/IFR. The fire resistance of the composites was investigated by UL 94, limiting oxygen index (LOI) and cone calorimetry tests. The thermal properties were determined by thermogravimetric analysis, differential scanning calorimetry and thermal conductivity measurements. In addition, the mechanical properties of the composites were investigated. The experimental results showed that although the addition of 1.25 and 2.5 wt. % BC with 2 wt. % MMT significantly improved the thermal and fire resistance of the PP composites, the addition of 3.75 and 5.0 wt. % BC caused antagonistic effects and deteriorated the fire resistance of the composites. The sample with the addition of 2.5 wt. % BC achieved the best fire resistance. The LOI value was increased from 18 to 31% with a UL 94 V-0 rating. In addition, the peak heat release rate was reduced from 668.6 to 150.0 kW/m2, and the total heat release value was reduced from 247.9 to 98.4 MJ/m^2. At the same time, the thermal conductivity was increased from 0.22 to 0.28 W/m·K. In addition, CO, CO_2 and smoke production were significantly reduced compared to PP. NO formation was reduced by replacing BA. At the same time, despite a slight decrease in tensile strength, flexural strength increased significantly with the addition of BA and MMT.

In [10], a new strategy for coatings that protect steel structures from fire while improving mechanical properties is considered. The aim of this study was to show that fly ash additive can be a partial replacement for other conventional additives while still having a fire protection effect. To study the effectiveness of fly ash additives, we tried to combine them with nano-additives. In particular, we study the synergy of fly ash with multi-walled carbon nanotube additives to strengthen the coating system: Epikote 240 epoxy/ammonium polyphosphate (APP)/pentaerythritol (PER) and melamine. The fly ash content was investigated: 10 wt. % with 0.5, 1 and 1.5 wt. % multi-walled carbon nanotubes (MWNTs). The results prove that the synergy between fly ash and multi-walled carbon nanotubes enhances the fire resistance and enhances the protection of steel structures of the building. When using 10 wt. % fly ash and 1 wt. % MWCNTS, the coating can be considered as a fire-retardant material with a fire resistance of UL 94V-0 and a limiting oxygen index of 27.2%.

In a study [11], ammonium polyphosphate (APP) and aluminum hydroxide (ALH) with different mass contents were used as flame retardants (FR) on plant-based polymer-reinforced materials (FFRP). Thermogravimetric analysis (TGA), limited oxygen index (LOI), and horizontal and vertical Underwriters Laboratories (UL)-94 tests were performed to evaluate the effectiveness of these FR treatments. Flat tensile tests were performed to evaluate the effect of FR treatment on the mechanical properties of FFRP composites. For both flame retardants, the results showed that the thermal decomposition temperature and LOI values of the composites increased with increasing FR content. According to the UL-94 vertical test, FFRP composites with 20% and 30% APP (i.e., by mass content of the epoxy polymer matrix) self-extinguished within 30 and 10 s after flame removal without any flammable droplets, respectively. However, tensile mechanical tests showed that the APP-treated FFRP composites reduced their elastic modulus and strength by 24% and 18%, respectively. Scanning electron microscopy (SEM) for morphological investigation showed effective coating of the FR material, which improved the fire resistance of the treated composites.

To improve the fire retardant properties of wood plywood, as reported in [12], intumescent fire retardant coatings were prepared using melamine, borate, pentaerythritol and urea as the main components and vein rock as a modified additive. The fire resistance of the samples was characterized by cone calorimeter, scanning electron microscope, X-ray diffraction and thermogravimetric analysis. In addition, the effect of vein rock content on the properties of the prepared coatings was studied in the study. The results show that doping vein rock in intumescent fire retardant coatings can improve the fire retardant effect of the coatings. In particular, when the mass fraction of vein rock was 8 wt. %, the exothermic reaction rate, total smoke generation and total exothermic amount of the coating were significantly reduced. In addition, the addition of void rock contributed to the formation of a continuous and dense carbon layer structure during the coating combustion process, resulting in the formation of a molten substance that effectively isolated oxygen and heat, thus enhancing the fire-retardant and thermal insulation properties of the coating. The results of this study provide valuable information on the development of fire-retardant coating formulations for wood plywood.

Decarbonization has prompted the construction industry to rediscover biological but inherently combustible materials such as wood [13]. To avoid fire safety risks, the reaction of wood to fire can be effectively reduced by flame retardant coatings or impregnation. Using a combination of simultaneous thermal analysis, microscale combustion calorimetry and cone calorimetry, vacuum pressure impregnated plywood (boron-free, phosphorus-based) was tested against plywood coated with a thin layer of water-based flame retardant coating (melamine-free, phosphorus-based). Comparing the peak heat release rate (pHRR) and total heat release (THR) of the three plywood samples, the impregnated plywood was the lowest and the coated plywood was the lowest (pHRR -34% and -20%, THR -45% and -21%, respectively) relative to the untreated plywood. In contrast, the coating layer delayed sustained combustion for longer than impregnated wood and delayed burn-through, which is crucial for the rate of fire development. A better understanding of the flammability assessment of fire-protected wood was obtained using cone calorimeter data supported by microscale analysis. The results challenge a simple flammability rating based on total heat release and highlight the need for further development of a methodology for comparing different fire protection strategies for wood.

In [14], we report a novel phosphonated thermoset material consisting of networked phosphonate esters containing both P–C and P–O bonds. Using a simple one-pot, two-step synthetic methodology, the oxirane groups of the epoxy resin were partially reacted with varying amounts of a reactive bis-H-phosphonate monomer and cured with a cycloaliphatic hardener to yield multifunctional thermosets with up to 8% phosphorus (P) content. Although 2.5% P was sufficient to achieve good flame resistance, a concentration of > 5% P was required to achieve material recyclability and recyclability. These phosphonated thermosets exhibit high Tg (94 °C…140 °C) and good thermal stability. The flame retardant properties of the thermoset with 2.5% P by cone calorimetry showed an effective reduction in the maximum heat release rate (pHRR, 75%) and a significant suppression of the total smoke production (TSP, 72.5%), which was attributed to the gas and condensation phases. action of the phosphonate moieties. This thermoset material was investigated as a transparent fireproof coating on wood, where a swelling fireproofing mechanism was observed. The phosphonated thermoset material with a higher phosphorus content (6%) demonstrated excellent damage repair ability and thermomechanical reworkability due to network rearrangement induced by transesterification. This thermoset material was used to fabricate a flax fiber reinforced composite to demonstrate its future application as a polymer matrix for composite materials.

The behavior of intumescent paints for the protection of wood pretreated with phosphate or silicate-based flame retardants was investigated [15]. In addition, the effect of intumescent paint on aging under several conditions was investigated. A conical calorimeter was used to measure the response to thermal reactions and char development. Pretreatment showed improved fire resistance of samples with intumescent coatings. The effects depend on the moisture content and uniformity of the pretreatment. Experiments also showed differences in fire resistance depending on the aging method. Ultraviolet aging preserved the thermal insulation properties, while samples immersed in acid experienced a sharp decrease in fire resistance. The latter aging test increased the pore size of the char, which led to a decrease in the expansion coefficient and a decrease in the thermal insulation characteristics of the intumescent material.

To improve the fire resistance of wood plywood, as reported in [16], an intumescent fire retardant coating (IFRC) was prepared using APP-PER urea as the main system formula and pyrophyllite as a modified additive. The fire retardant, hydrophobic and mechanical properties of the samples were characterized by cone calorimeter, static angle machine, scanning electron microscopy, X-ray diffractometer and tensile machine, and the effect of pyrophyllite content on the coatings was studied. The results show that adding an appropriate amount of pyrophyllite to the intumescent fire retardant coatings improves the fire retardant effect of the coatings. The fire resistance growth index (FGI) is reduced by 47%, the fire resistance index (FPI) is increased by 89%, and the fire resistance index (FRI) is increased by 2.5 times at a mass fraction of pyrophyllite powder of 2%. The addition of pyrophyllite powder promotes the formation of a continuous and dense carbon layer structure during combustion, forms a molten substance that can effectively isolate oxygen and heat entering the base material, and further improves the fire retardant and thermal insulation properties of the coating. With a mass fraction of pyrophyllite of 2%, the hydrophobic properties of the coating and the mechanical properties of wood plywood after combustion are the best, and the water contact angle increases by 8°, the tensile strength increases by 45%, and the elongation at break also increases by up to 8.5 times. The research results can be used as a reference for the development of intumescent fire retardant coatings for wood plywood.

The study [17] aims to develop an optimal approach to the synthesis of flame retardant coatings by comparing different methods based on the settings involved for applications related to the protection of materials such as wood and polymer during fire exposure. The focus is on the development of intumescent coatings with uniform carbon thickness using different materials, formulations and synthesis methods, as well as developing an understanding of key process parameters. The formulation is based on ammonium polyphosphate (APP) and other flame retardant additives and fillers, in which epoxy resin is used as a binder. The effect of flame retardant additives and fillers is characterized by thermogravimetric analysis (TGA), oxygen index test, smoke density test and flammability test. TGA showed that the addition of graphite as a filler increases the maximum degradation temperature. It was found that the combination of graphite, flame retardant additives and fillers provides the best flame retardant properties with good adhesion, no dripping, as well as good expansion of the carbon layer and good thermal stability.

Fire retardants and coatings, as described in [18], which are intumescent, effectively reduce various parameters of the reaction to fire of wood, such as ignitability, heat release, burning rate and flame spread. These parameters are relevant for the classification of materials in terms of reaction to fire according to European or international standards. Most products improve wood, which is usually classified as class D-s2, d0, to the European class B-s2, d0 according to EN 13501. This article discusses the development of the char limit and the temperature profile of Norway spruce (Picea abies L.) coated with transparent and pigmented intumescent coatings compared to uncoated wood as a reference material. The tests were conducted using a cone calorimeter according to ISO 5660 with a heat release rate of 50 kW/m^2 and an adapted ISO 834 test curve. The results show that intumescent coatings on wood significantly reduce the charring rate and substrate temperature and protect the wood from ignition compared to the uncoated reference material.

Therefore, establishing the parameters for inhibiting the burning of fire-resistant materials and the influence of the components that make up their composition on this process is an unresolved component of ensuring the fire resistance of wooden building structures. This has necessitated the need for research in this area.

THE PURPOSE OF THIS WORK

The purpose of this work is to identify the patterns of combustion of wood samples and establish the parameters for suppressing the burning process during fire protection.

MATERIALS AND METHODS OF RESEARCH

To determine the flammability of wood, samples of straight-ply pine wood measuring 150×60×30 mm, with a density of 450…470 kg/m^3 were used, which were treated with fire-retardant coatings (Fig. 1):

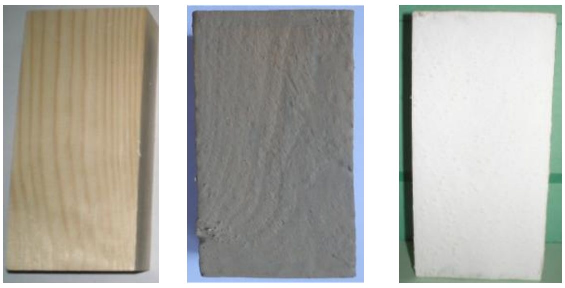
– fire-retardant reactive fire-retardant intumescent coating (“FIREWALL-WOOD”);

– inorganic coating based on aluminosilicate binders.

The compositions were applied in layers to the surface of wood samples with a consumption of: inorganic coating in the amount of 440 g/m^2 and reactive in the amount of 270 g/m^2. After drying to constant mass, tests were carried out on both treated and untreated wood samples.

To conduct the study, a device for determining the flammability group of materials was used (Fig. 2).

The essence of the test method for experimentally determining the group of difficult-to-burn and combustible solid substances and materials is to expose a sample located in the ceramic tube of the OTM installation to a burner flame with specified parameters (the temperature of gaseous combustion products at the outlet of the ceramic tube is 200 °C ± 5 °C).



a b c

Fig. 1. Model samples of fire-retardant wood: a – untreated; b – treated with a fire-retardant coating based on aluminosilicate binders; c – treated with a fire-retardant intumescent coating (“FIREWALL-WOOD”)

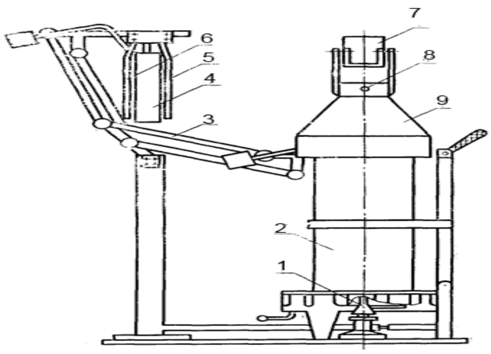


Fig. 2. Installation for determining the flammability of wood: 1 – gas burner; 2 – ceramic box; 3 – sample feeding device; 4 – sample; 5, 6 – sample holder; 7 – mirror; 8 – thermoelectric converter; 9 – upper umbrella nozzle

During experimental studies, the maximum increase in the temperature of gaseous combustion products (Δt) and the loss of sample mass (Δm) are recorded. According to the test results, materials are classified as:

– hardly flammable – Δt < 60 °C and Δm < 60%;

– flammable – Δt ≥ 60 °C or Δm ≥ 60%.

Combustible materials are divided depending on the time (τ) of reaching the maximum temperature of gaseous combustion products into:

– low-flammability – τ > 240 s;

– medium-flammability – 30 s ≤ τ ≤ 240 s;

– highly flammable – τ < 30 s.

A device was used to determine the surface flame spread index (Fig. 3).

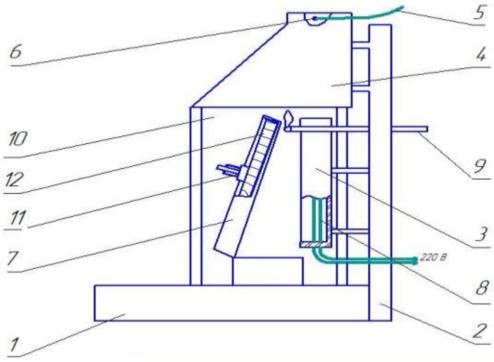


Fig. 3. Device for determining the flame spread index: 1 – housing; 2 – stand; 3 – radiation panel; 4 – exhaust hood; 5 – thermocouple; 6 – thermocouple junction; 7 – sample holder; 8 – electric heater; 9 – burner; 10 – side screen; 11 – clamp; 12 – sample

The essence of determining the flame spread index of solid building materials, which includes the effect on the sample by infrared radiation from gas burners and ignition by ignition flames, as well as determining the thermal coefficient of the installation, measuring the maximum temperature of combustion products and the time of its achievement, the time of ignition and passage of the flame front through the surface areas, the length of the burnt part of the sample, is that the sample is exposed to the heat flux of an electric radiation panel and the ignition of the upper edge of the sample by a burner, and the value of the dimensionless flame spread index is calculated by the coefficient I:

$$I = \sqrt{\frac{q \cdot Q}{W} \cdot \frac{T_{\max} - T_0}{T_1 - T_0} \cdot \frac{\tau_{\max} - \tau_0}{\tau_0} \cdot \left[1 + \frac{60 \cdot l_{\text{г}}}{l} \cdot \sum_{i=1}^{n} \frac{1}{\tau_i}\right]}, \quad (1)$$

where q – specific heat of combustion of propane gas (23630), kJ·l^{-1}; Q – gas flow rate of the pilot burner (0.003), l·s^{-1}; W – power of the electric radiation panel, 0.75 kW; T_0 – ambient temperature, °C; T_1 – initial temperature of flue gases, °C; T_{max} – maximum temperature of flue gases, °C; τ_0 – time of ignition of the sample, s; $\tau_{\max}$ – time of reaching the maximum temperature of flue gases, s; τ_i – time of passage of the flame front of the control sections, s; l – length of the sample, mm; $l_{\text{г}}$ – length of damage to the sample, mm.

To determine the flame spread index, turn on the temperature recording device, light the gas burner 9 and adjust the gas flow rate so that the height of the flame tongues is (11 ± 2) mm. Turn on the electric radiation panel 3 and the temperature recording device and determine the initial temperature of the flue gases using a thermocouple 5. The material sample 12 prepared for testing is installed in the holder 7, fixed with a clamp 11 and brought to the radiation panel 3. During the test, the following are determined: the time from the start of the test to the moment the flame front passes the zero mark, the time the flame front passes the i-th section of the sample surface, the distance the flame front has spread, the maximum temperature of the flue gases and the time it is reached. The test continues until the flame stops spreading over the sample surface or when 600 s is reached in the absence of sample ignition.

RESEARCH RESULTS

The results of studies on determining the mass loss of samples (Δm, %) and the increase in the maximum temperature of gaseous combustion products (Δt, °C) of untreated wood and fire-protected wood are shown in Fig. 4, 5.

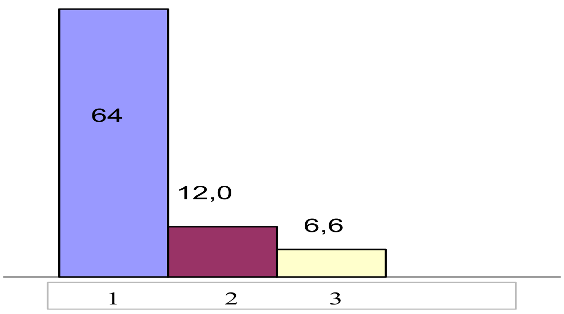


Fig. 4. Results of mass loss of samples Δm: 1 – untreated; 2 – treated with a fire-retardant coating based on aluminosilicate binders; 3 – treated with a fire-retardant intumescent coating (“FIREWALL-WOOD”)

Experimental studies have confirmed that an untreated wood sample ignited under thermal action, the flame spread over the entire surface, which led to its combustion with a mass loss of more than 60%, and the temperature of the flue gases increased by 500 ºC in 60 s of the test. When treating wood with an inorganic coating, a heat-resistant ceramic film is formed on the surface of the wood, which reduces the mass loss process by 5.3 times, the temperature of the flue gases reached a value of more than 200 ºC. The use of an intumescent coating under the influence of temperature leads to the formation of a foam coke layer and inhibition of heat transfer of a high-temperature flame to the material and a decrease in mass loss to 6.6 g/(m^2·s) and a temperature of less than 160 ºC.

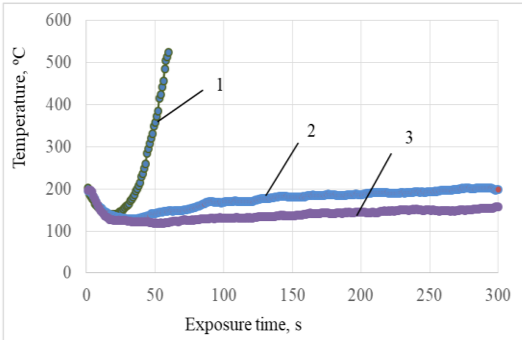


Fig. 5. Dynamics of the increase in the temperature of flue gases during tests of wood: 1 – untreated; 2 – treated with a fire-retardant coating based on aluminosilicate binders; 3 – treated with a fire-retardant intumescent coating (“FIREWALL-WOOD”)

To determine the flame spread index, tests were conducted on untreated wood samples. When exposed to flame for 21 s, untreated wood samples ignited, the temperature was 367 °C and the flame spread intensively over the surface (Fig. 6), the flame spread index was 43.5. Then, tests were conducted on samples treated with fire retardant coatings.

During testing of fire-retardant wood samples, it was found that the sample caught fire in 890 s, the flame spread over the surface occurred only to the first section, the maximum temperature of the flue gases was 82 ºC for a time greater than 2.5 times, and the flame spread index decreased by 6.5 times (see table). For the sample of wood treated with a fire-retardant intumescent coating ("FIREWALL-WOOD"), the wood did not ignite, the flame spread index was 0.

a b

Fig. 6. Appearance of samples during testing: a – unprotected wood; b – protected by coating

The ignition of wood under the thermal action of a high-temperature flame, as indicated by the results of the studies (Fig. 4, 5), occurs through its decomposition and is characterized by the loss of mass of the sample and the spread of the flame over the surface. In contrast, for a protected sample, due to the action of flame retardants, the processes of ignition and flame spread are significantly slowed down. This mechanism of the protective agent is primarily due to the decomposition of flame retardants under the influence of temperature with the absorption of heat and the release of non-combustible gases, a change in the direction of the decomposition of the material towards the formation of a difficult-to-burn coke residue. When wood is treated with an inorganic coating, a heat-resistant ceramic film is formed on the surface of the wood, which reduces the burning rate. But with increasing temperature, thermal conductivity increases to a critical temperature and the wood sample decomposes, which is confirmed by an increase in mass loss. The use of an intumescent coating under the influence of temperature leads to the formation of a foam coke layer and inhibition of heat transfer of high-temperature flame to the material and a decrease in the burning rate. In addition, the processes of decomposition of the coating occur with the release of gases and the formation of a heat-protective foam coke layer on the surface of the wood.

In contrast to the results of the studies of the authors of works [9-12], the obtained data on the influence of protective agents on the process of heat transfer to the material and changes in fire-retardant properties allow us to state the following:

– the main regulator of the process is not only the formation of a heat-shielding layer of coke, but also the decomposition of flame retardants with the release of non-combustible gases. In particular, nitrogen, carbon dioxide, which interact with the flame and inhibit the oxidation process in the gas and condensed phase;

– a significant impact on the process of protecting a combustible material when using a fire-retardant coating is carried out in the direction of reactions in the pre-flame region towards the formation of soot-like products on the surface of a natural combustible material.

Such results can be considered appropriate from a practical point of view, because they allow a reasonable approach to determining the necessary formulation of a fire retardant. Treatment with an intumescent coating more effectively counteracts high temperatures, which is what should be the main focus when developing a coating formulation for wood. From a theoretical point of view, they allow us to state the mechanism of fire protection processes, which are certain advantages of this study. The results of determining the mass loss of fire-protected wood indicate an ambiguous influence of the nature of the protection agent on changing the parameters of combustion and flame suppression. In particular, this assumes the availability of data sufficient for high-quality conduct of the combustion process and the identification on its basis of the moment of time at which the suppression process begins, which is new and unexplored. Such identification will allow us to investigate the transformation of the wood surface under the action of fire protection towards coke formation and flame inhibition and to identify those variables that significantly affect the beginning of this process.

CONCLUSIONS

Thus, experimental studies have established that an untreated wood sample ignited under thermal action, the flame spread over the entire surface, which led to its combustion with a mass loss of more than 60%, and the temperature of the flue gases increased by more than 500 ºC in 60 s of the test. When treating wood with an inorganic coating, a heat-resistant ceramic film is formed on the surface of the wood, which reduces the mass loss process by 5.3 times, the temperature of the flue gases reached a value of more than 200 ºC. The use of an intumescent coating under the influence of temperature leads to the formation of a foam coke layer and inhibition of heat transfer of a high-temperature flame to the material and a decrease in mass loss to 6.6 g/(m^2·s) and a temperature of less than 160 ºC.

During the study of the flame spread index, it was found that when a flame was applied to untreated wood samples for 21 s, their ignition occurred, the temperature was 367 °C and the flame spread intensively over the surface, the flame spread index was 43.5. During the tests of fire-protected wood samples, the following values were obtained, namely, a wood sample treated with an inorganic coating ignited for 890 s, the flame spread over the surface occurred only to the first section, the maximum temperature of the flue gases was 82 ºC for a time greater than 2.5 times, and the flame spread index decreased by 6.5 times. For a wood sample treated with a fire-retardant intumescent coating, the wood did not ignite, the flame spread index was 0.

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Обґрунтування умов застосування вогнезахисного покриття для деревини

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Анотація. Експериментальними дослідженнями встановлено, що необроблений зразок деревини під термічною дією зайнявся, полум'я поширилося по всій поверхні, що призвело до його згорання з втратою маси понад 60 %, а температура димових газів збільшилася понад 500 ºС за 60 с випробування. При обробленні деревини неорганічним покриттям на поверхні деревини утворюється термостійка керамічна плівка, яка знижує процес втрати маси у 5,3 рази, температура димових газів досягла значення понад 200 ºС. Застосування спучуючого покриття під дією температурного впливу приводить до утворення шару пінококсу та гальмування теплопередачі високотемпературного полум’я до матеріалу і зниження втрати маси до 6,6 г/(м^2·с) та температури менше 160 ºС. Під час дослідження індексу поширення полум’я було встановлено, що при дії полум’я на необроблені зразки деревини на 21 с відбувалось їх займання, температура становила 367 °С та інтенсивне поширення полум'я поверхнею, індекс поширення полум'я склав 43,5. Під час випробувань зразків вогнезахищеної деревини було отримані наступні значення, а саме, зразок деревини оброблений неорганічним покриттям зайнявся на 890 с, поширення полум'я поверхнею відбулося тільки на першу ділянку, максимальна температура димових газів становила 82 °С за час більший понад 2,5 рази, а індекс поширення полум'я знизився у 6,5 рази. Для зразка деревини обробленої вогнезахисним спучуючим покриттям займання деревини не відбулося, індекс поширення полум'я склав 0. Таким чином, є підстави стверджувати про можливість спрямованого регулювання процесів вогнезахисту деревини шляхом застосування вогнезахисних покриттів, здатних утворювати на поверхні матеріалу захисний шар, який гальмує швидкість вигорання деревини.

Ключові слова: захисні засоби, вогнестійкість, втрата маси, покриття, оброблення поверхні, вигорання деревини, ефективність захисту.