Improvement of fire protection of wood board and textile materials for premises with a massive stay of people

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Abstract. In premises with a massive stay of people according to the standards, materials with reduced combustibility should be used. Cellulose containing materials are fire hazardous. The article presents the results of a study of indicators of materials with combustion retardants for rooms with people staying – textile fabrics, chipboards. The effect of flame retardant additives on the weight loss of samples of wood boards under fire exposure was studied. The influence of the type and duration of impregnation to reduce the combustibility and drying temperature of the impregnated textile materials on the time of their flame burning is investigated.

1. Introduction

Objects with a massive stay of people include public buildings and structures in which 50 or more people can simultaneously be (clause 5 of the "Rules of the fire regime in the Russian Federation" approved by Decree of the Government of the Russian Federation of 04.25.2012 No. 390). Such rooms include halls and foyers of spectacular institutions, lecture halls, meeting rooms, etc., the area of the premises is 50 m^2 or more.

From July 1, 2019, Federal Law No. 123 – Federal Law Technical Regulation on Fire Safety Requirements entered into force as amended on December 27, 2018 (No. 538 – Federal Law). The Law establishes requirements for objects of protection (products), including materials used in the design, construction and operation of buildings and structures. Clause 1 of article 52 – Protection of people and property from the effects of dangerous fire factors regulates the use of space-planning solutions and means to limit the spread of fire beyond the outbreak; in paragraph 6 – the use of flame retardants (including flame retardants and fire retardant paints) and building materials (cladding) to increase the limits of fire resistance.

For premises with a massive stay of people from 50 to 300 people, according to the requirements of the Federal Law, materials for walls and ceilings, curtains, curtains, upholstered furniture belong to the fire hazard class KM2, they must be tested for flammability (stove and similar materials) and for flammability (textile materials).

Researchers note that chipboards, like other cellulose-based materials, have an increased fire hazard [1, 2]. The fire hazard of wood-based materials and cellulose-containing textile materials is due to their increased combustibility.

Thermal destruction of the amorphous part of cellulose begins already at a temperature of 150 ... 200 °C. The rate of thermal degradation of cellulose is affected by its supramolecular structure. The amorphous part is more easily degraded than the crystalline one. It should be noted that the linear
structure of macromolecules, the crystalline structure, and numerous hydrogen bonds make cellulose more heat-resistant than hemicelluloses. In the case of low-temperature degradation, the reaction of chain cleavage by glycosidic bonds is accompanied by dehydration reactions (water splitting), and in the presence of oxygen, oxidation reactions. As a result of dehydration, glucopyranose units partially decompose, as evidenced by the formation of CO₂ and low molecular weight volatile aldehydes. At a temperature of about 340 °C, cellulose is completely amorphized with a significant loss in material weight (up to 60 %). Then the transition of the amorphized structure of cellulose to carbonized begins, the coal structure is formed. The structure of thermal decomposition of cellulose is presented in figure 1.

![Figure 1. The thermal decomposition of cellulose.](image)

Cellulose-based textile fabrics are also characterized by increased flammability. The type of materials used is presented in table 1.

| Purpose of textile material | Application area | Type of fibers used |
|----------------------------|------------------|---------------------|
| Decorative draperies, upholstery of furniture, transport seats, curtains, auditoriums | Public buildings and facilities, Linen, cotton, woolen, curtains, wallpapers, carpets | artificial, synthetic, fiber combinations |
| Special protective clothing | Special clothing for metallurgists, car racers, resistant, artificial, synthetic, life guards, etc. | Linen, cotton, wool, heat resistant, artificial, synthetic, fiber combinations |
| Technical fabrics and nonwovens | Heat and sound insulation in public buildings, transport, resistant, artificial, synthetic tents, shelters, filters, etc. | Linen, cotton, wool, heat resistant, artificial, synthetic, fiber combinations |

You can reduce the combustibility of board materials in various ways [2-5]. Technologically most easily implemented methods are the introduction of a flame retardant into the composition and impregnation.

Researchers at Horrocks A.R dealt with fire protection for textile materials [6], Mikryukova O.N. [7], Kirkina L.I. with colleagues [8–10] and other researchers.
At the department of logging and wood processing industries of KSU, research is being conducted in the field of increasing the fire protection of materials for premises with a large stay of people. The aim of the study was to develop the composition for the production of chipboards of the G1 combustibility group. Work to ensure the safety index of the boards must be carried out taking into account the influence of the modifier on the physical and mechanical properties of the material [11]. As an inhibitor of combustion, the addition of alumochromophosphate binder (ACP) CrAl3(H2PO4)8.8 ... 9.6 was used.

Alumochromophosphates are mixed salts of the following structure:

\[
\begin{align*}
\text{O} & \quad \text{CH}_2 \quad \text{NHCONH} \quad \text{CH}_2\text{O} \\
\text{Me} & \quad \text{O} \quad \text{P} \quad \text{O} \quad \text{Me} \\
\text{O} & \quad \\
\end{align*}
\]

where Me – Al, Cr.

According to Sychev M.M., the aluminochromophosphate binder contains mainly the triphosphataluminium complex \([\text{Al}(\text{HP0}_4)_3]^-\) [12].

Indicators aluminochromophosphate binder are presented in table 2.

| Indicator | Indicator value |
|-----------|-----------------|
| Appearance | Dark green viscous liquid |
| Mass fraction of aluminum in terms of \(\text{Al}_2\text{O}_3\), % | 6.5-9.0 |
| Mass fraction of chromium in terms of \(\text{Cr}_2\text{O}_3\), % | 3.5-4.5 |
| Mass fraction of phosphates in terms of \(\text{P}_5\text{O}_9\), % | 35-39 |
| Mass fraction of sulfates in terms of \(\text{SO}_4\), % | 0.5 |
| Mass fraction of formaldehyde, % no more | 0.2 |
| Mass fraction of loss on ignition, % | 47-55 |
| Density, kg/m³ | 1600-1750 |
| Mass fraction of chromium (IV) in terms of \(\text{CrO}_3\), % | is absent |

2. Methods

Control samples of the boards were made on a phenol-formaldehyde binder without the addition of flame retardants, wood chipboards of increased fire protection were made with the addition of alumochromophosphate in the amount of 3 ... 15 % to the outer layers (by weight of absolutely dry shavings), 2 ... 10 % to the inner layer of the board.

For conducting studies on the flammability of textile materials in the laboratory department of logging and wood processing industries of KSU made a stand in accordance with GOST R 50810-95 “Fire safety of textile materials. Decorative fabrics. Flammability test method and classification” (figure 2).

For research, samples of the composition were made: flax 100%; 100% cotton (calico); size 220 × 170 mm. The application of flame retardant was carried out by immersion. The immersion time of textile materials in a container with flame retardants was 15, 30 and 60 minutes. Drying of samples of textile materials was carried out at a temperature of 80 and 100 °C. Used flame retardants of the brands: Rosa, Shield, Senezh, Senezh 2, Vak-S.
3. Results
The results of determining the performance of the boards are presented in table 3.

The dependence of flame burning time on immersion time and drying temperature is shown in figure 3, from flame retardant – in figure 4.

Table 3. Board indicator results.

| Board indicators                                      | The proportion of additives aluminocromophosphate, % * |
|-------------------------------------------------------|-------------------------------------------------------|
|                                                       | 0/0 | 3/2 | 6/4 | 9/6 | 12/8 | 15/10       |
| Static bending strength, MPa                          | 29,6 | 25,5 | 22,9 | 20,5 | 19,8 | 17,0         |
| Weight loss during combustion, %                      | 73,4 | 61,2 | 45,6 | 31,8 | 24,3 | 18,8         |
| Thickness swelling after 24 hours in water, %         | 21,6 | 22,3 | 27,6 | 28,8 | 30,6 | 31,0         |

* Above the line for the outer layers of chipboards, below the line for the inner layer
4. Conclusions
The addition of AHP to the binder for the production of chipboards in an amount of 15 % in the outer layers and 10 % in the inner layer of the boards allows the production of chipboards with a degree of
damage by weight during combustion of less than 20 %, which corresponds to the combustibility

group G1, regulated for materials related to fire hazard class KM2.

No flame burning time:

- for poplin samples when treated with flame retardants Rosa, Senezh at sample drying
  temperatures of 80 °C and 100 °C.
- for flax samples during processing with Rosa flame retardants at a drying temperature of 80 °C;
- for coarse calico samples when treated with flame retardants: Senezh and Shield at a drying
  temperature of 100 °C.

Thus, in a comprehensive study, developments were made that made it possible to obtain board and
textile materials of reduced combustibility for interior decoration of premises with a large stay of
people.

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