Fire and biological protection of paper and corrugated board with an impregnating composition

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Abstract. The issue of fire protection of cellulosic materials has been studied in the works of domestic and foreign scientists. However, there are still a number of unresolved problems in this area: modern means are not effective enough, the treated products are unaesthetic, do not meet performance indicators, and do not resist biodegradation. It has been established that volatile mixtures of pyrolysis products differ significantly in the content of combustible gases. Thus, for the treated samples, the amount of methane decreases by 30 times, hydrogen – by 25...30 times, carbon monoxide – by 35...40 times, and the amount of non-combustible gases increases: carbon dioxide - by 1.2...2 times, nitrogen – by 1.4...5 times. Studies on determining the smoke-forming capacity of untreated and treated paper samples showed an 8-fold decrease in the smoke-forming coefficient for treated paper samples and their transition from the group of materials with high smoke-forming capacity (untreated samples) to the group of materials with moderate smoke-forming capacity. Tests were conducted to determine the flammability of corrugated cardboard samples used for packaging various materials, including combustibles: untreated samples are classified as flammable materials, and treated samples are classified as flammable materials with a 42.38 kg/m^3 absorption of the impregnating composition in terms of anhydrous substance.

Studies have been conducted on the fire and biological protection of paper and products made of it with an impregnating composition that can effectively protect against fire and biological degradation without compromising the aesthetic

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and operational characteristics of these materials, taking into account modern environmental requirements. To determine the flame retardant effect of the impregnating composition, thermal destruction of untreated and treated paper samples was performed. In the course of the study, volatile products of thermal degradation were collected and their gas chromatographic analysis was carried out.

Keywords: flame retardant, paper, corrugated board, impregnating composition, flammability.

INTRODUCTION

Today, paper and paper products traditionally remain one of the most common materials for packaging. Due to their high flammability, the fire load of facilities is increasing. There is a tendency to increase the number of fires caused by paper ignition and the number of fatalities [1].

The use of highly combustible and flammable materials in everyday life and in industry is one of the main areas of fire prevention.

In this regard, Ukraine adopted the regulatory document DBN V.1.1-7-2002, which provides for the protection of people on evacuation routes from the effects of fire hazards. In buildings of all fire resistance levels, except for buildings of the V fire resistance level, it is not allowed to use building materials with a high fire hazard on evacuation routes. The treatment of materials with fire protection agents significantly affects the spread of flames and significantly reduces smoke generation and heat generation. Paper and paper products are also widely used for packaging various materials, including combustibles. The fire protection of such paper eliminates the possibility of paper ignition from low-calorie ignition sources.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

As a result of fire protection treatment of paper and paper products, the possibility of their ignition from low-calorie ignition sources is excluded, such materials are converted into a highly flammable state, which allows to limit the spread of flame, but at the same time, some fire protection agents increase the smoke-forming ability and toxicity of combustion products [2].

The issues of fire protection of cellulosic materials have been studied in the works of domestic and foreign scientists. However, there are still a number of unresolved problems in this area: modern means are not effective enough, the treated products are unaesthetic, do not meet performance indicators, and do not resist biological destruction.

This is the reason for the relevance of scientific research aimed at determining the conditions for protecting paper and paper products from fire and biological degradation using an impregnating composition based on inorganic and organic substances, and at developing regulatory documents that regulate the technical requirements for these substances, test methods and technologies for their use, which will help reduce the fire hazard of facilities, taking into account modern environmental requirements [3 – 4].

The following types of paper (or product) treatment with fire and bioprotection agents are known:

– surface or bulk treatment with the formation of a fire retardant layer on the surface;

– adding water-insoluble flame retardants to the paper pulp to form covalent bonds between the flame retardant and the paper fiber molecule.

The treatment process involves the impregnation of paper and paper products with aqueous solutions of flame retardant salts (flame retardants). The impregnation method is used for fire and biological protection of paper, the products of which are used in rooms with certain air humidity indicators [5].

The technology and methods of impregnation with various fire retardants are similar. What may differ are the consumption rates to ensure a given level of fire and bioprotection, the frequency of fire and bioprotection treatments, and the duration and temperature of drying. The frequency of fire and bioprotection treatment should be reflected in the regulatory and technical

documentation for fireproof paper.

When choosing consumption rates, type and technology of fire and bioprotective agent application specified in the technological regulations for the fire retardant, it is necessary to take into account the main characteristics of the paper product: chemical composition, structure, thickness, surface density, etc.

THE PURPOSE OF THIS WORK

The purpose of this work is to study the fire protection of paper and corrugated board by impregnating composition.

MATERIALS AND METHODS OF RESEARCH

To impregnate paper with a flame retardant (fire retardant) using the immersion method, it must be kept in the solution for 2…3 minutes until it is completely saturated, and excess solution is allowed to drain off the paper. The impregnated paper is dried in the air using a fan or in drying chambers.

To solve the complex problem of combining the fire and biological protection properties of paper with its performance characteristics, an impregnating composition was developed that includes modified starch (FSG-1K), which helps to increase the strength of wrapping paper [6 – 8].

RESEARCH RESULTS

The study of the effectiveness of fire protection of paper and paper products treated with an impregnating composition based on urea phosphate with polyhexa-methylene guanidine phosphate with the addition of starch (FSG-1K) was carried out in accordance with the requirements of [8]. The results of the study are shown in Table 1.

In accordance with [7], the treated paper samples are classified as flammable material.

In order to substantiate the fire protection effect of the developed impregnating composition, we studied the flammability parameters of paper at specified levels of exposure to the surface of samples of heat flow and flame from an ignition source according to [8].

It was found that under the influence of a heat flux with a critical surface density of 20 kW/m^2, untreated paper samples ignited. The treated samples did not ignite at a surface heat flux density of 50 kW/m^2 for 900 seconds.

Table 1. Results of studies to determine flammability in accordance with DSTU 4155 [8]

Fire and explosion hazard index according to [8]	Paper sample treated with flame retardant composition	
Type of test	Test from the surface	Test from the edge
Duration of residual flame burning, s	missing	missing
Material burnout	does not burn out	does not burn out
Propagation of surface flash more than 100 mm from the ignition point	does not apply	
Average length of the toughened section, mm	54,9	46,4
Average weight of samples before testing, g	7,07	7,20
Average weight of samples after testing, g	6,99	6,95

To determine the fire retardant effect of the impregnating composition, thermal destruction of untreated and treated paper samples was performed. In the course of the study, volatile products of thermal degradation were collected and analyzed by gas chromatography.

It was found that the volatile mixtures of pyrolysis products differ significantly in the content of combustible gases. Thus, for the treated samples, the amount of methane decreases by 30 times, hydrogen – by 25...30 times, carbon monoxide – by 35...40 times, and the amount of non-combustible gases increases: carbon dioxide – by 1.2...2 times, nitrogen – by 1.4...5 times.

Studies to determine the smoke-forming ability of untreated and treated paper samples

were conducted according to [8-9]. The studies showed an 8-fold decrease in the smoke generation factor for the treated paper samples and their transition from the group of materials with high smoke generation (untreated samples) to the group of materials with moderate smoke generation.

Studies to determine the biostability of paper were conducted in accordance with [10] by determining the biological resistance to the effects of forest soil microflora affected by fungal cultures. It was found that the impregnating composition increases the level of biostability of treated paper samples (compared to untreated ones) by 19 times in terms of biodegradation according to [10].

To test the performance of the packaging paper, we measured its resistance to compression. A paper sample treated with an impregnating composition containing starch has a much better indicator.

Tests were conducted to determine the flammability of corrugated cardboard samples in accordance with [10] used for packaging various materials, including combustibles: untreated samples are classified as flammable materials, and treated samples are classified as flammable materials with a 42.38 kg/m^3 absorption of the impregnating composition in terms of anhydrous substance (Fig. 1 – 4).

Fig. 1. An untreated corrugated cardboard sample during the test

Fig. 2. Unprocessed corrugated cardboard sample after the test

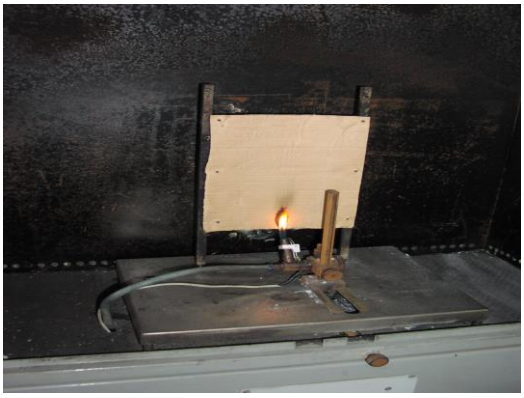

Fig. 3. Processed corrugated cardboard sample during the test

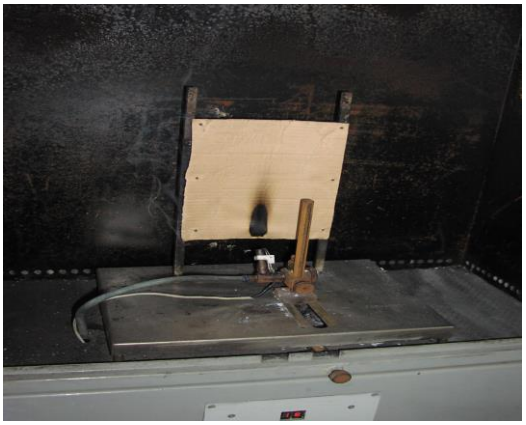

Fig. 4. Unprocessed corrugated cardboard sample after the test

CONCLUSIONS

Thus, a study was conducted on the fire and bioprotection of paper and products made of it with an impregnating composition that can effectively protect against fire and biological degradation without compromising the aesthetic and performance characteristics of

these materials, taking into account modern environmental requirements.

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Вогнебіозахист паперу та гофрокартону просочувальною композицією

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Анотація. Питання вогнезахисту целюлозних матеріалів досліджувались у роботах вітчизняних та закордонних вчених. Однак, у цій сфері ще існує ряд невирішених проблем: сучасні засоби недостатньо ефективні, оброблені вироби неестетичні, не відповідають експлуатаційним показникам, не протистоять біоруйнуванню. Встановлено, що леткі суміші продуктів піролізу суттєво відрізняються за вмістом горючих газів. Так, для оброблених зразків кількість метану зменшується в 30 разів, водню – в 25…30 разів, оксиду вуглецю – в 35…40 разів та збільшується кількість негорючих газів: діоксиду вуглецю – в 1,2…2 рази, азоту – в 1,4…5 разів. Дослідження з визначення димоутворювальної здатності необроблених та оброблених зразків паперу показали зменшення в 8 разів коефіцієнта димоутворення для оброблених зразків паперу та їх перехід з групи матеріалів з високою димоутворювальною здатністю (необроблені зразки) до групи матеріалів з помірною димоутворювальною здатністю. Проведено випробування з визначення займистості зразків гофрокартону, що використовуються для пакування різних матеріалів, в тому числі і горючих: необроблені зразки відносяться до горючих легкозаймистих матеріалів, а оброблені – до горючих важкозаймистих матеріалів за умови поглинання просочувальної композиції в перерахунку на безводну речовину 42,38 кг/м^3. Для визначення вогнезахисної дії просочувальної композиції проведено термодеструкцію необроблених та оброблених зразків паперу. В процесі дослідження були зібрані леткі продукти термодеструкції та проведено їх газохроматографічний аналіз. Проведено дослідження щодо вогне- і біозахисту паперу та виробів з нього просочувальною композицією, яка здатна ефективно захищати від загоряння та біологічного руйнування, не погіршуючи естетичні та експлуатаційні показники цих матеріалів з урахуванням сучасних екологічних вимог.

Ключові слова: вогнебіозахист, папір, гофрокартон, просочувальна композиція, займистість.