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Evaluation of the Fire-Retardant Properties of an Intumescent Organic Binder Composite Material for Shielding Electromagnetic Fields

Sergii Guzii[1, a)], Tetiana Kurska[2, b)], Oleksiy Khodakovskyy[3, c)], Artem Kovalchuk[3, d)] and Anton Chernukha[4,e)]

[1]*V. Bakul Institute for Superhard materials NASU Ukraine, Avtozavodskaya Str., 2, Kyiv, 04074, Ukraine*
[2] *Odessa Polytechnic National University, Shevchenko Ave., 1, Odessa, 65044, Ukraine*
[3]*National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Peremohy Ave., 37, Kyiv, 03056, Ukraine*
[4]*National University of Civil Defense of Ukraine, Chernyshevska Str., 94, Kharkiv, 61023, Ukraine*

[a)] sguziy2@gmail.com
[b)] Corresponding author: tkurskaya67@gmail.com
[c)] dzgeron@ukr.net
[d)] kovalchuk_artem@ukr.net
[e)] an_cher@nuczu.edu.ua

Abstract. This paper investigates the fire properties of a liquid organic component of an intumescent type of material for protection from electromagnetic fields. The flammability group of the organic component of the protective composition was determined depending on the thickness of the film. It is shown that an increase in the film thickness from 1 mm and more even after 16 cycles of accelerated tests provides the first group of flammability. It was found that with a coating thickness of 1 mm, the temperature of the flue gases slightly exceeds the critical value (260 °C) in the range of 86-106 sec and 255-266 sec, the weight loss is 5.2%, which makes it possible to classify the organic component of the protective material as a flame retardant and non-flammable. The paper presents complete data on the fire dependence of the considered water-dispersive binder with a complex of coke-forming agents. It was found that an organic binder of the intumescent type with a film thickness of 1 mm, regardless of the test conditions, is characterized by the first group of flammability.

INTRODUCTION

The most effective method of protecting biological objects from the effects of electric, magnetic and electromagnetic fields is the use of appropriate protective materials and structures made of them. But the manufacture and installation of such structures in many cases involves some difficulties: the complexity of the surface shape, limited space for placing the screen, etc.

The most acceptable is application to the surface of equipment, wall and ceiling structures of the shielding material in liquid form, followed by drying or polymerization. But in this case, difficulties arise associated with ensuring reliable adhesion of the material to the applied surface, degradation of the shielding layer due to the presence of a large amount of shielding substrate and peeling of the protective layer from the surface. Most research in this area is limited to measuring the protective properties of shielding materials, ignoring the functional properties of practical applications. At the same time, ensuring electromagnetic safety for a long time also depends on their fire resistance. The study of this parameter is an urgent scientific and practical task.

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LITERATURE REVIEW AND PROBLEM STATEMENT

In the modern world, along with the rapid development of technical progress, there is an increase in the capacity of various technical devices and electronic devices inside rooms and buildings, as well as an increase in the number of sources of external electromagnetic loads with different radiation frequencies. Much attention is paid to the development of composite materials for protection against electric, magnetic and electromagnetic fields of a wide frequency range. Most of the work is devoted to the development and study of the protective properties of rigid and elastic composites, from which protective structures of the required configuration are made [1–4]. They are not always suitable for cladding surfaces of complex structures. In [5], a paint-and-lacquer coating containing fine graphite is considered. However, only the mechanisms for ensuring the screening of the field have been investigated without obtaining data on the state of the material during its practical use. Work [6] concerns the development of a protective mixture based on nanocarbon.

The results indicate its high protective properties, but it is not shown how it can be used in practice, in particular, depending on the concentration of the protective substance. In studies [7–10], the use of finely dispersed ferrites in a polymer matrix for shielding high-frequency electromagnetic radiation was shown, but the possibility of their deposition on the surface was not shown. In particular, there is no confirmation of their adhesion to the substrate during polymerization, as well as their flammability.

In the review work [11, 12], almost all classes of screening materials were considered, but no attention was paid to compositions on a liquid basis. This is due to the lack of reliable data on the possibility of using such materials in practice, taking into account their adhesion to the surface, methods of application on the surface, and fire properties. Thus, an urgent problem is to study the possibilities of the practical application of liquid fire-retardant materials with a screening filler of different concentrations. The main indicators are the fire-retardant properties of such composites.

MATERIALS AND METHODS

An anionic styrene-acrylic copolymer dispersion was used as an organic binder CHP 506 (CH-Polymers Oy Finland); as a catalyst and coke-forming agent – ammonium polyphosphate (PFA), melamine, pentaerythritol (PER) (Table 1) [13].

The dispersion has the following characteristics: dry residue 48 %, pH = 2, particle size 180 nm, film formation temperature 14 °C, density 1.03 g/cm^3.

Table 1. Characteristics of organic components.

Component	Chemical formula	Melting temperature, ^{o}C	Solubility in water at 25 C, g/100 ml	Density, g/sm^3	Particle size, microns
PFA	$(NH_4PO_3)_n$	312	0.8	1.9	15
M	$C_3H_6N_6$	354	3.2	1.573	40
P	$C(CH_2OH)_4$	215	7.1	1.394	40

Note: PFA – ammonium polyphosphate; P – pentaerythritol; M – melamine

The intumescent organic base was obtained by the technology of water-dispersion paints with the introduction of the necessary technological additives in a laboratory dissolver.

Flammability group was determined according to GOST 12.1.044-1989 [14], EN 13823 + A1: 2014-12 [15], ASTM E119-07 [16]. The study on determining the combustibility group of wood treated with the proposed coating was carried out in accordance with the current normative base. The essence of the test method for the experimental determination of the group of heavy and combustible solids and materials according to the influence of the sample is located in the ceramic tube of the OTM installation, the flame of the burner with the given parameters (the temperature of the gaseous combustion products at the exit from the ceramic tube is 200 ± 5 ^{o}C). In the course of experimental studies, the maximum increase in the temperature of the gaseous combustion products (Δt) and the sample mass loss (Δm) are recorded.

According to test results, materials are classified as:

- heavyweight - $\Delta t < 60$ °C and $\Delta m < 60$ %;
- combustible - $\Delta t \geq 60$ °C or $\Delta m \geq 60$ %.

The critical temperature of flue gases Tcr during the test should not exceed 260 °C.

Accelerated testing of samples with dimensions of 150×60×30 mm was carried out according to the recommendations of Nordic Building & Paint Labs AB (Stubbsundsvagen 17 SE-131 Nacka Sweden) and GOST 9.401-2018 [17] using a simplified procedure. One test cycle included the following: holding in a freezer at a temperature of -18 °C for 8-12 hours, holding in a drying cabinet at a temperature of 50°C – 8-12 hours, soaking in water at a temperature of 20 ± 2 °C – 8-12 hours. The total number of hours in one cycle was 36.

The predicted service life of paint and varnish coatings e in years under operating conditions was calculated by the formula [18]:

$$\tau_{exp} = \frac{k_y \cdot \tau_y}{365}, \text{ sec} \tag{1}$$

where *ky* - acceleration coefficient equal to 46 for conditions U1; *τy* is the duration of accelerated tests (in cycles) until the level of deterioration of decorative and protective properties is reached, namely, a decrease in adhesion no more than point 3 (AZZ) according to GOST 9.407-84 [19], and the area of destruction of the coating should not exceed 15% of the surface of the product.

RESULTS OF THE STUDY

The main purpose of the study is to evaluate the fire-retardant properties of an organic binder of an intumescent type of composite materials for shielding electromagnetic fields.

The amount of protective composition applied per unit surface area depends primarily on the required material thickness, the temperature of the substrate and the environment, as well as the quality of the substrate surface preparation.

In Ukraine, the licensees involved in carrying out fire-retardant works have secretly established a rule, according to which the assessment of the protective effectiveness of special materials, including those for shielding electromagnetic fields, is made after 2 years of operation. Therefore, the research was carried out in 2 stages. At the first stage, the flammability group of the organic binder after its curing was determined; at the second stage, after curing and climatic tests.

As can be seen from Fig. 1, with a coating thickness of 0.5 mm, the flue gas temperature exceeds the critical value in the range of 80-110 sec and 250-265 sec, the weight loss is 5.1 %. With a coating thickness of 1 mm, no excess of the critical temperature was observed on the curve of the temperature change of the flue gases, while the weight loss of the samples was not more than 2.21 %.

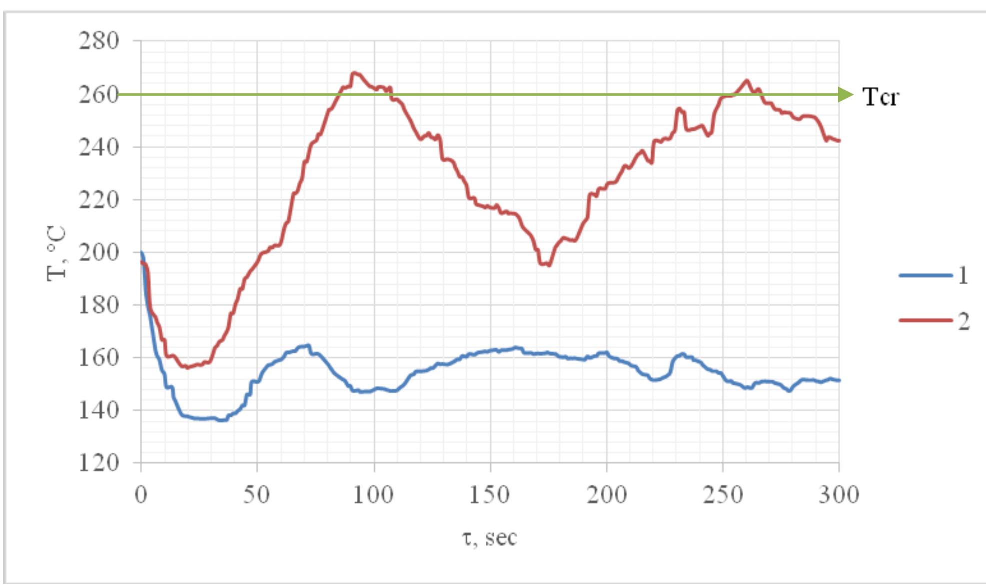

FIGURE 1. Dependence of the flue gas temperature on the test time of an intumescent organic binder of composite materials for shielding electromagnetic fields after curing with a film thickness of 0.5 mm (2) and 1 mm (1).

After 16 cycles of accelerated tests of the organic base of the intumescent type, which corresponds to 2 years of operation of the composite material for shielding electromagnetic fields, it was established: with a coating thickness of 0.5 mm, the flue gas temperature exceeds the critical value in the range of 86-178 sec and 245-295 sec, loss mass is 7.5 %. With a coating thickness of 1 mm, the flue gas temperature exceeds the critical value in the range of 86-106 sec and 255-266 sec, the weight loss is 5.2 % (Fig. 2). After accelerated tests, no destruction of the continuity of the organic coating of the intumescent type was noted.

The appearance of films of an intumescent organic binder of composite materials for protection from electromagnetic fields after accelerated and firing tests is shown in Fig. 3.

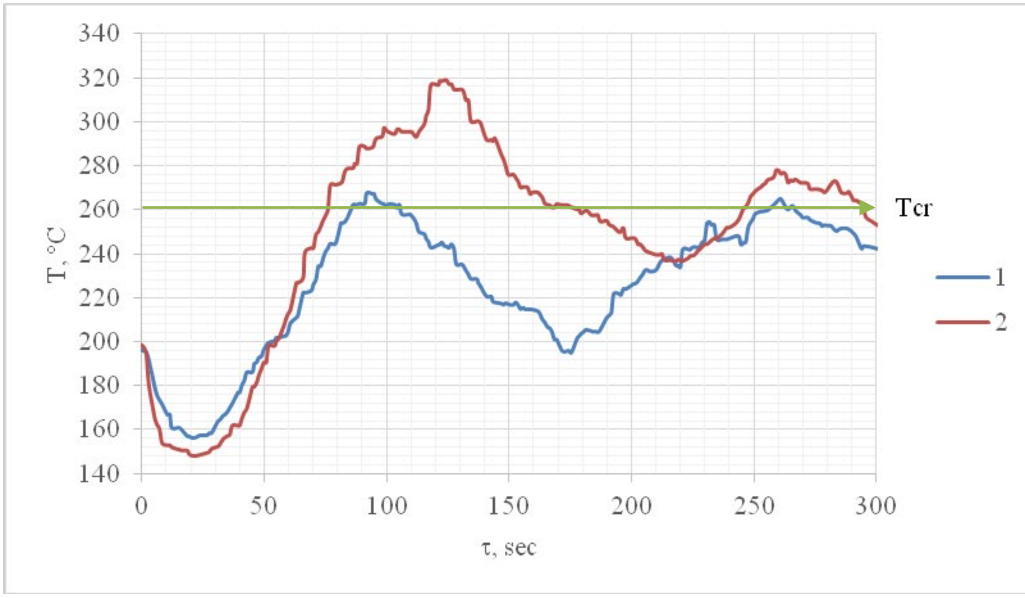

FIGURE 2. Dependence of the flue gas temperature on the test time of an intumescent organic binder of composite materials for shielding electromagnetic fields after curing and accelerated testing with a film thickness of 0.5 mm (2) and 1 mm (1).

FIGURE 3. The appearance of films of an intumescent organic binder of composite materials for protection against electromagnetic fields after accelerated and firing tests with a film thickness of 0.5 mm (2) and 1 mm (1).

Summarizing the results obtained, shown in Fig. 1 – Fig. 3, and according to the requirements of DSTU B V.2.7-19-95 [20] determined the combustibility group of intumescent organic binder, provided that all values of the combustibility parameters match (Table 2).

Table 2. Flammability group of intumescent organic binder.

Flammability parameters	**After natural curing at coating thickness**		**After accelerated tests at coating thickness**	
	δ=0.5 mm	**δ=1 mm**	**δ=0.5 mm**	**δ=1 mm**
Flue gas temperature T, °C	64	38	120	62
Length of damage S_l, %	67	25	100	65
Degree of damage by weight S_m, %	5.1	2.21	7.5	5.2
Self-burning duration t_{sb}, s	4.5	0.5	6.2	3.5
Flammability group of materials	G2	G1	G3	G1

After curing and film formation, the water-dispersion base of the intumescent type of mixtures for shielding electromagnetic fields can be classified as flammable and flammable with a minimum value of the coating film of more than 0.5 mm. After climatic tests corresponding to 2 years of operation, the water-dispersion base of the intrinsic type of mixtures for shielding electromagnetic fields can be classified as non-flammable and flammable with a minimum value of the coating film of more than 1 mm.

As can be seen from the data in Table 2, an organic binder of the intumescent type with a film thickness of 1 mm, regardless of the test conditions, is characterized by the first flammability group.

CONCLUSIONS

The research carried out makes it possible to determine the conditions and methods of using the material for shielding electromagnetic fields, depending on the fire capacity of the organic binder of the intumescent type.

The optimal thicknesses of the film of an organic binder of an intumescent type have been determined, which allow, in the event of a fire, to transfer the material for shielding electromagnetic fields into a flame-retardant and hardly flammable material.

All the main fire properties of an organic binder protective composition were obtained depending on the content of the optimal concentration of coke-forming agents, which will allow optimizing the screening coefficients of electromagnetic fields when they are filled with a Fe-containing agent to ensure the resistance of the coating material under real operating conditions.

It was found that an organic binder of the intumescent type with a film thickness of 1 mm, regardless of the test conditions, is characterized by the first group of flammability.

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