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THERMODYNAMIC STUDY OF FIRE-PROTECTIVE MATERIAL

Chernukha Anton, PhD,
Chernukha Andrii,
Kovalov Pavlo, PhD, Associate Professor,
Savchenko Alexander, PhD, Senior Researcher,
National University of Civil Defence of Ukraine

Currently, natural building materials such as wood are still used. The use of such building structures is possible with the provision of fire safety measures.

An important component of the study of a chemical system [1, 2] is the calculation of thermodynamic characteristics [3, 4]. Thermodynamic studies are widely used to study various kinds of systems, including silicate ones. Thus, when obtaining the temperature dependence of the change in the Gibbs energy (onwards ΔG) of the system under study, one can judge the possibility of a chemical reaction proceeding in the forward or reverse direction in the investigated temperature range. At temperatures that correspond to positive ΔG values, a forward reaction is impossible. While studying a material based on a xerogel using chemical thermodynamics, we can determine the possibility of a particular process, the energy effect, theoretically predict the possibility of processes occurring when the coating is heated. The chemical process that takes place in the coating material when heated is described using the equation:

$$H_4SiO_4 + Na_2CO_3 \leftrightarrow Na_2SiO_3 + CO_2\uparrow + 2H_2O\uparrow \qquad (1)$$

The calculation of ΔG was carried out for the reaction of chemical transformation in a hard coating upon heating, using the thermodynamic characteristics of substances. In this case, it was taken into account that when the xerogel is heated, the carbonate decomposes with the release of a gaseous component, which contributes to an increase in the volume of the coating.

An increase in temperature during a fire leads to the initiation of processes that reduce the temperature of the surface of the structure. Thermodynamic calculations make it possible to estimate the probability of these processes occurring when the temperature changes. Calculation of ΔG for chemical reaction (1) for the temperature range was carried out according to the method. The values of ΔG for the investigated temperature range (Table 1).

Table 1. Gibbs energy of the reaction with increasing temperature

T, [K]	298	373	473	573	673	773	873	973	1073
ΔG, [kJ·mol^{-1}]	61.1	32.9	-1.54	-33.4	-63.1	-91.0	-117.0	-141.0	-164.0

Plotting the temperature dependence of the ΔG process during heating, it can be noted that at temperatures above 470 K, the substances in the coating can react with each other with the release of gas, which contributes to the swelling of the coating and an increase in its fire retardant properties. The calculation method carried out a thermodynamic study of the processes occurring under the influence of high. It was found that at a temperature of the onset of thermal destruction of wood ~ 200 °C and higher, it becomes possible for the processes of swelling of the coating to occur. Petrography showed the presence of a vitreous substance consisting of small vitrified particles with a size of 3–5 µm, combined into porous aggregates up to 40–50 µm in size. The pore diameter in the aggregates is 5–10 µm. The pores between the aggregates are 60–80 µm in size. Rarer are individual large pores 150–300 µm in size.

Shows a cut of the coating after exposure to heat. Under a microscope, it can be seen

that the pores present in the coating are subdivided into three groups according to their size: small, regular spherical in size up to 3–5 microns, medium and large. Apparently, the formation of the smallest pores is associated with the release of carbon dioxide during the reaction with silicic acid and potassium carbonate. This reaction proceeds rather slowly due to the limited amount of silicic acid released during the hydrolysis of sodium silicate; therefore, a pronounced coalescence of gas bubbles in the gel mixture is not observed. The average pore size is apparently formed when physical water is removed from the mixture, which is located in the voids between large gel globules. Large pores are formed due to the coalescence of medium-sized pores during heat treatment. As seen in, the swelling of the material does not lead to its destruction. Vitrified silica gel particles form a dense bonding layer with a wood surface without chips. The introduction of vermiculite and asbestos into the gel does not violate the integrity of the coating.

It can be concluded that the sequential passage of these reactions ensures controlled gas evolution during heat treatment of the mixture and thereby ensures swelling and material integrity. Coating samples $70 \times 70 \times 3$ [mm^3] were placed in a muffle furnace under normal conditions. When the muffle furnace was turned on, the heating rate was 20 °C·min^{-1}. The samples were removed from the muffle furnace with an increase in temperature by every 50 °C. It was found that material swelling occurs in the temperature range 150–250 °C.

A significant decrease in the swelling coefficient for a material at a low heating intensity has been experimentally proven. It can be seen from the given dependence that the Gibbs energy decreases with increasing temperature. The swelling coefficient of the material was experimentally established at a low heating intensity of more than 7.

It has been established that the material can swell, both under the influence of flame and when the temperature rises at a low speed. Swelling coefficient K_{sw}. at the same time it reaches 8. The temperature range of swelling is 150–250 °C, which is confirmed by thermodynamic calculations and experimentally. The temperature at which the material begins to swell is lower than the temperature of thermal destruction of wood.

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