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INFLUENCE OF IMPREGNATION ON THE THERMAL PROPERTIES OF HEAT-INSULATING FIBROUS MATERIALS

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The thermal-conductivity coefficient and the specific heat of heat-insulating materials impregnated with inorganic binders have been determined experimentally. The influence of the temperature and the degree of impregnation on the thermophysical properties has been revealed.

Unwoven materials (felt) are frequently used as heat-insulating materials or warmth-keeping jackets. The creation and subsequent use of new heat-insulating materials call for thorough investigation of their behavior under service conditions. Such materials possess a number of heat-engineering properties whose knowledge is necessary for correct selection of a structural material and for heat-engineering calculations. The accuracy of the latter largely depends on the correct selection of the values of the thermophysical properties, in particular, the thermal-conductivity coefficient and the specific heat.

The value of the thermal conductivity of heat-insulating materials, among which are fibrous materials, is affected by their density and kind, the size and location of pores, the chemical composition and molecular structure of hard constituents, the emissivity of surfaces bounding the pores, and the kind and pressure of the gas filling the pores [1]. Thermal conductivity usually increases with temperature, but, under service conditions, it is much more greatly affected by an increase in humidity. Sorption humidity and water absorption are very important characteristics on which thermal conductivity depends. The hydrophobization of heat-insulating materials makes it possible to considerably reduce their water absorption, for example, by making additions of inorganic silicon [2].

In the present work, we have investigated the influence of the impregnation of a heat-insulating unwoven material (felt) with solutions of salts of two types on the thermophysical properties of the material. Materials with dissimilar degrees of impregnation (see Table 1) have been considered.

We have determined the thermal-conductivity coefficients in the temperature range 25–125^{o}C and the specific heat in the temperature range 25–175^{o}C. The measurements were carried out in a monotone regime [3] using IT-λ-400 and IT-C-400 meters. The measurement error amounted to 6 to 7%.

Figure 1a shows the temperature dependences of the thermal-conductivity coefficient of fibrous unwoven materials impregnated with composition No. 1 and those of an untreated material. It is seen that the thermal conductivity slightly increases with temperature. The thermal conductivity also increases as the degree of impregnation increases.

It has turned out that the sample's mass is lost in heating of the impregnated felt, since the impregnating composition evaporates. Therefore, we can speak only of the apparent heat capacity and thermal conductivity. Nonetheless, the analysis of experimental data makes it possible to represent a change of state of the fibrous material in heating and to determine the efficiency range of the insulation.

Figure 1b gives the temperature dependences of the apparent specific heat of the same samples. The initial unimpregnated sample has been tested to a temperature of 250^{o}C. It has been noted that the white sample becomes light brown in heating to such a temperature (or even below) and it turns increasingly darker with each subsequent heating, which is attributable to the carbonization of the fibers. In this connection, subsequent experiments with samples 1–6 were carried out only to 175^{o}C. On the temperature dependence $C(t)$ of the untreated felt, we observe a maximum at a temperature of 150^{o}C; this maximum is associated with the evaporation of the moisture adsorbed in the micropores of the fibers. Since this is a bound moisture, it evaporates at higher temperatures than ordinary water. For treated samples this maximum shifts toward higher temperatures; the larger the degree of impregnation, the higher the

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TABLE 1. Samples of Fibrous Material with Dissimilar Degrees of Impregnation

Sample No.	Impregnating composition	Degree of impregnation
1	No. 1	1:2
2	No. 1	1:3
3	No. 1	1:5
4	No. 2	1:2
5	No. 2	1:3
6	No. 2	1:5
7	Without impregnation	

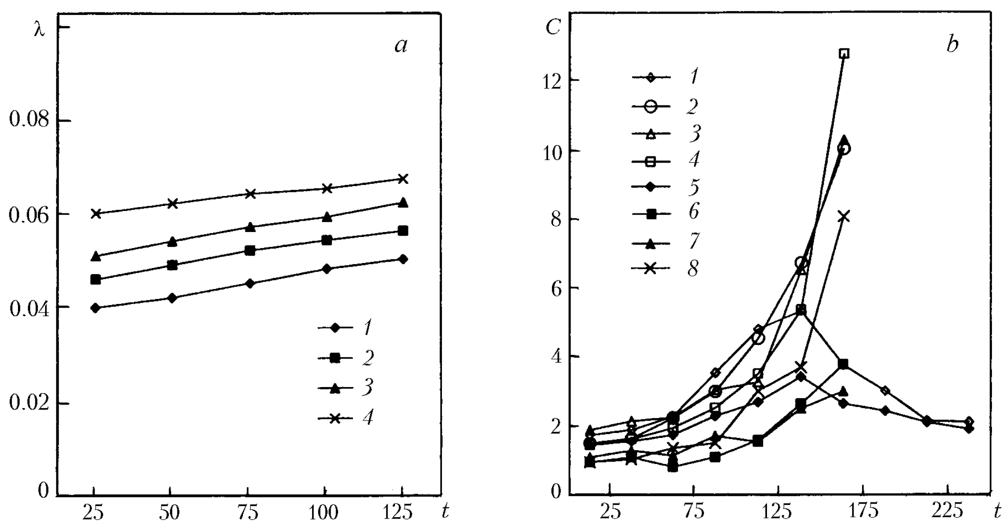

Fig. 1. Temperature dependences of the samples of fibrous material impregnated with composition No. 1: a) thermal-conductivity coefficient [1) sample 7; 2) 1; 3) 2; 4) 3]; b) specific heat [1 and 5) sample 7 after one and four heatings; 2 and 6) 1; 3 and 7) 2; 4 and 8) 3].

apparent heat capacity of a material at the maximum point. At room temperatures and up to 150°C, the specific heat of the felt treated with an impregnating composition is slightly lower than that in the untreated felt.

In heating to such temperatures (175°C), the adsorbed moisture is removed and a decrease in the mass of the sample and accordingly its density is explicitly recorded. The largest removal of mass is observed during the first heating and averages between 22 and 25%. The larger the degree of impregnation, the longer the mass removal. The mass removal for sample 1 with the smallest degree of impregnation ceases even after the second heating, whereas it amounts to 23% for sample 3 with the largest degree of impregnation after the second heating, to 11% after the third heating, and to 6% after the fourth heating; it amounts to about 40% on the whole. Not only is this removal of mass caused by the evaporation of the adsorbed moisture determining the sorption humidity, but it is also caused by the evaporation of the impregnating composition itself. Therefore, after the reheating, the specific heats of all the samples decrease and the maximum on the temperature dependence $C(t)$ is smoothed out (Fig. 1b). Multiple heatings and coolings result in a total smoothing-out of the $C(t)$ curves. The absolute value of the specific heat of the samples impregnated decreases as compared to that of the untreated felt. It is probable that, in multiple heating, we have a complete evaporation of the impregnating composition.

Figure 2a gives the temperature dependences of the coefficient of thermal conductivity of the sample of felt impregnated with composition No. 2. Unlike the samples impregnated with composition No. 1, the thermal conductivity of these samples is virtually independent of the degree of impregnation, except for the sample with a degree of impregnation of 1:2, and somewhat increases with temperature. The curves of the temperature dependences of the specific heat of the samples impregnated with composition No. 2 (Fig. 2b) also have a maximum but at a lower tempera-

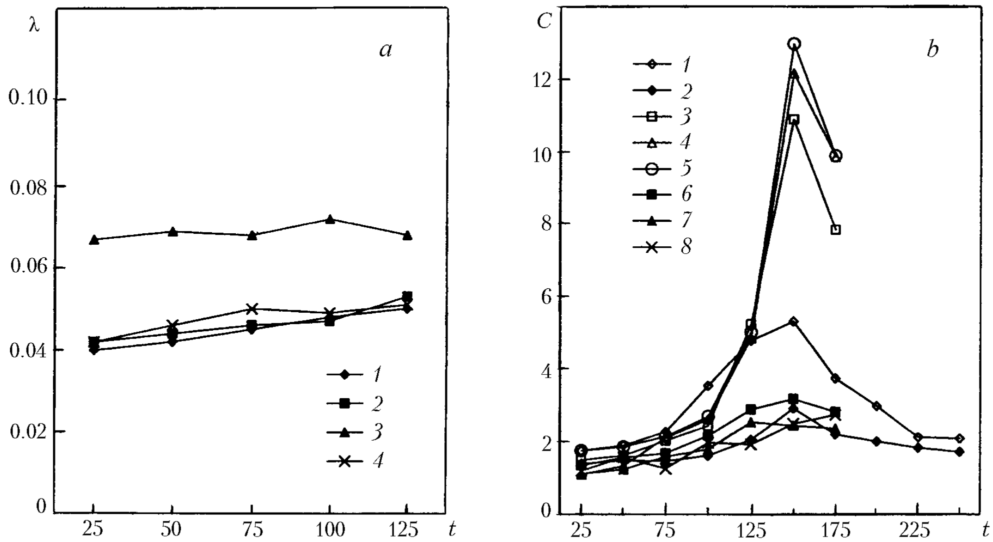

Fig. 2. Temperature dependences of the samples of fibrous material impregnated with composition No. 2: a) thermal-conductivity coefficient [1) sample 7; 2) 4; 3) 5; 4) 6]; b) specific heat [1 and 2) sample 7 after one and four heatings; 3 and 6) 4; 4 and 7) 5; 5 and 8) 6].

TABLE 2. Density ρ and Thermal-Conductivity Coefficient λ at 25^{o}C in Reheatings

Sample No.	ρ			λ		
	ρ_1	ρ_2	ρ_3	λ_1	λ_2	λ_3
1	368	340	269	0.046	0.052	0.055
2	359	304	283	0.051	0.055	0.056
3	311	275	269	0.060	0.063	0.064
4	359	304	269	0.042	0.050	0.053
5	510	359	320	0.067	0.066	0.067
6	528	340	283	0.042	0.050	0.053
7	321	268	240	0.040	0.041	0.043

ture (150^{o}C) than that in the case of the samples impregnated with composition No. 1. This suggests that composition No. 1 includes components which, probably, retain the moisture adsorbed in the fiber for a longer period, keeping it from evaporating. The absolute values of the specific heats turn out to be very close for the same content of impregnating composition Nos. 1 and 2. Reheating reduces the maximum of $C(t)$ in the same manner as in the case of treatment with composition No. 1. Mass removal in reheating is also fairly large and it is the larger, the larger the degree of impregnation (up to 38% in sample 6 after four heatings).

In reheatings, we have an increasing carbonization of the fibers, which also has an effect on the value of the thermal-conductivity coefficient. Table 2 gives the values of the thermal conductivity of the materials under study in reheatings.

A clear tendency toward increase in the thermal-conductivity coefficient in each subsequent heating with decrease in the density of the material is tracked. The reason is, most probably, the increase in both the coefficient of thermal conductivity of the felt fibers themselves in low-temperature pyrolysis and the convective component of the thermal conductivity in heating and mass removal.

Therefore, the impregnation of heat-insulating felt with aqueous solutions of salts substantially affects its thermal properties. However, in utilization of these materials, one must take into account that their structure changes in heating to temperatures above 100^{o}C and the impregnating composition can completely evaporate. The properties which one has attempted to impart to a given material by impregnation can disappear.

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NOTATION

C, specific heat, kJ/(kg·K); *t*, temperature, ^{o}C; λ, thermal-conductivity coefficient, W/(m·K); ρ, density, kg/m^3.

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