THERMAL PROPERTIES OF POLYSTYRENE WITH FILLERS

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The article describes the results of an experimental investigation of the thermal properties of type A emulsion polystyrene filled with glass fibers.

Type A emulsion polystyrene filled with glass fibers is a typical thermoplastic material. The material is characterized by high mechanical strength, durability, thermal stability, and reliability, which are the basis for many applications of the material in radio engineering and other branches of industry.

The thermal conductivity λ, the thermal diffusivity a, the specific heat c, and the thermal stability are the main thermal parameters of thermoplastic materials.

L. L. Vasil'ev's technique, which makes it possible to determine, on a single sample and in a single experiment, the thermal conductivity, the thermal diffusivity, and the specific heat in the temperature range 273-373°K in temperature steps of 3-5° [1], was used in our studies of the thermal properties λ, a, and c.

Measurements were made on cylindrical samples with the dimensions $l = 120$ mm and d = 40 mm. The samples were obtained by press-forming with a hydraulic P-483 press under a pressure of $1.76 \cdot 10^7$ N/m^2. The conditions of press-forming were as follows: the mold was heated to 448-453°K, a pressure of $3.6 \cdot 10^2$ was used for molding, and the mold was thereafter cooled to 318°K.

Type A emulsion polystyrene was mixed with glass fibers in a laboratory-type ball mill. The required homogeneity of the mixture was obtained after $6.0 \cdot 10^3$-$7.2 \cdot 10^3$ sec.

Type A emulsion polystyrene is obtained by emulsion polymerization of styrene. Potassium persulfate was used as initiator. The properties of type A emulsion polystyrene at 293°K are as follows: $\lambda = 0.093$-0.14 W/m·deg; $c = 1.34 \cdot 10^3$ J/kg·deg; thermal stability, according to Martens [2], 353°K, and $\rho = 1.05$-1.08 g/cm^3.

The glass fiber consists of fluffy, 8-10 mm long glass filaments which were obtained from No. 2 glass cloth by cutting 10 × 10 mm squares and grinding the squares in a laboratory-type ball mill. The glass fiber has the following properties at T = 293°K: $\lambda = 1.09$ W/m·deg, $c = 0.67 \cdot 10^3$ J/kg·deg, $a = 4.44 \cdot 10^{-7}$ m^2/sec; and $\rho = 2.5$ g/cm^3 [3].

The thermal stability of polystyrene with filler was determined with the technique corresponding to GOST 9551-60.

The experimentally obtained temperature dependencies of λ, a, and c of type A emulsion polystyrene with filler are shown in Fig. 1a, b. The dependencies λ(T) and a(T) are linearly decreasing for both compositions of thermoplastic compounds, whereas the function c(T) monotonically increases. When a thermoplast consisting of polystyrene with 10% glass fibers reaches the temperature T ≈ 334°K, λ and c increase sharply but drop off at higher temperatures. A similar behavior is observed at the temperature T ≈ 337°K in the case of a polystyrene thermoplast with 20% glass fibers.

We are of the opinion that the maxima and minima on the curves indicate phase transitions in the polymer of the polystyrene-filler composition. Softening of the polymer is the reason for the transitions. Softening changes the polymer structure from a relatively ordered configuration (in the solid state) to a disordered (amorphous) structure of the softened material. This, in turn, leads to a sharp change in the thermal parameters λ, c, and a.

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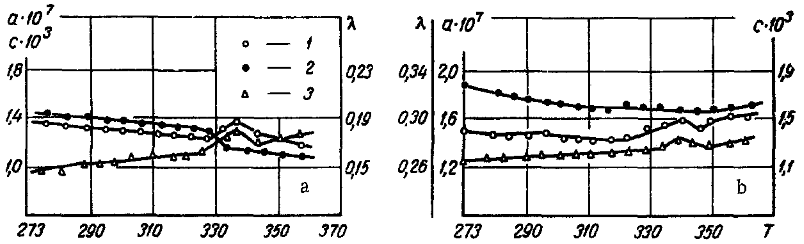

Fig. 1. Temperature dependencies λ(T), a(T), and c(T) of a thermoplast consisting of Mark A polystyrene with a) 10% glass fibers and b) 20% glass fibers (T expressed in °K): 1) heat conductivity; 2) thermal diffusivity; 3) specific heat.

Similar changes in the thermal properties were observed by other researchers [4-6].

The absence of a sharp minimum on the a(T) curve (Fig. 1b) seems to be a consequence of the increasing percentage concentration of the filler in the polymer and from the slightly irregular distribution of the filler in the mixture. The errors which were made in the experiment and in the calculation of the thermal characteristics were less than 5-7%.

The thermal stability of the mixture depends upon the amount of filler introduced. When 10% glass fibers are added to polystyrene, the thermal stability according to Martens is 374.4°K, whereas a stability of 381.3°K is reached at 20% glass fibers, and a stability of 387.3°K at 40%.

The thermal stability of a polymer is generally defined as the temperature at which a sample becomes deformed by continuous load application, the deformation reaching a certain value. The deformation of the mixture is the sum of the deformations of polystyrene and glass fiber. The overall deformation decreases with increasing concentration of the filler in the mixture, because the rigid filler takes up a large fraction of the load. This means that the thermal stability of the mixture increases with increasing percentage concentration of the glass fibers.

LITERATURE CITED

1. L. L. Vasil'ev, Inzh.-Fiz. Zh., No. 5 (1964).
2. M. Yu. Katsnel'son and G. A. Balaev, Plastics [in Russian], Moscow (1965).
3. A. V. Lykov, Theoretical Principles of Constructional Thermophysics [in Russian], Izd. AN BSSR, Minsk (1961).
4. A. N. Karasev, Plasticheskie Massy, No. 1 (1967).
5. V. S. Shifrina and N. N. Samosatskii, Polyethylene [in Russian], Goskhimizdat, Moscow (1961).
6. L. L. Vasil'ev and Yu. E. Fraiman, Thermal Properties of Poor Heat Conductors [in Russian], Nauka i Tekhnika, Minsk (1967).