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THE STUDY OF THERMOPHYSICAL CHARACTERISTICS OF CARBON PLASTICS BASED ON ALIPHATIC POLYAMIDE

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In recent decades, there has been a consistent tendency to replace traditional materials with polymer composite materials. This is due, on the one hand, to the fact that by choosing the correct composition of a polymer composite, it is possible to obtain a combination of required properties of final products, and on the other hand, to the fact that the process technology of manufacturing products from polymer composites is more economical as compared with the production of metal products.

One of the promising polymer binders for the purposes of creating the new polymer composites for structural purposes is aliphatic polyamide PA-6. The specified thermoplastic polymer is characterized by high mechanical strength and chemical resistance, good wear resistance and the ability to work in friction units without lubrication. It is widely used to replace non-ferrous metals (bronze, steel) in mechanical engineering, while maintaining its operability to temperatures up to +140 °C [1-5].

The key disadvantages of PA-6 include the unstable friction factor, as well as the high contact temperature that develops during operation of a movable joint in dry friction mode, which is caused by the low conductivity of a polymer. While in operation of PA-6 products, it is required to oversee the overheating of its products, since insufficient heat removal from the friction zone can lead to their cracking and destruction. Therefore, for the stable operation of a friction unit, the quite substantial is to ensure an increase in its thermophysical characteristics.

For the purpose of creating new polymer composites with improved thermal and physical characteristics, aliphatic PA-6 was reinforced with Ural-24H carbon fiber (CF) in an amount of 5-30% by weight.

The study of the effect of the filler content on the thermal conductivity of the original polymer made it clear that with an increase in the CF content, this thermophysical factor increases by an average of almost 40% in the studied temperature range, which is probably explained by higher values of the conductivity of the reinforcing fiber compared with the original polymer (Table 1).

Table 1

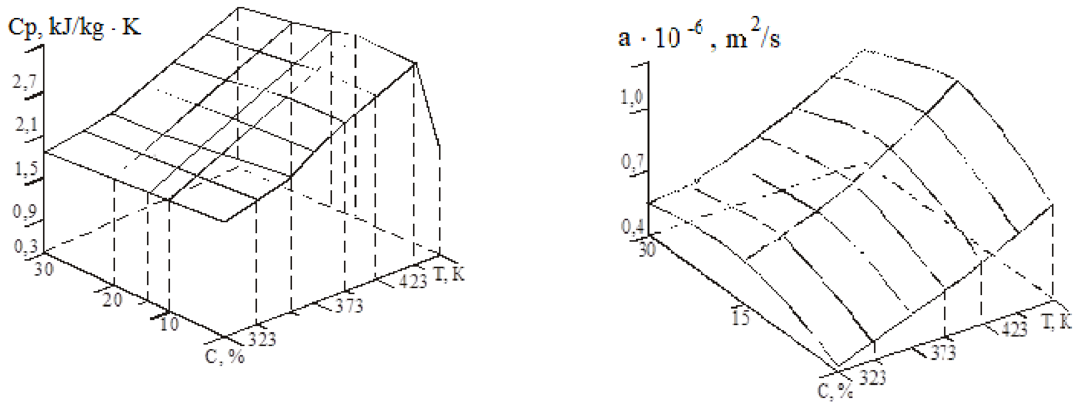
Thermal conductivity coefficient of carbon plastics based on PA-6

Content of fibers, wt.%	Temperature, K			
	323	373	423	473
–	0.27	0.29	0.30	0.31
5	0.30	0.31	0.32	0.34
10	0.34	0.36	0.39	0.39
20	0.38	0.40	0.42	0.44
30	0.44	0.46	0.48	0.49

[авторська розробка]

An analysis of the temperature dependence of the specific heat capacity (C_p) of the carbon plastics (CP) based on PA-6 indicates its monotonous increase (Fig. 1a). In the zone characterizing the CF transition from a glass-like to a highly elastic state, a characteristic jump in heat capacity (ΔC_p) was noted. The determination of the ΔC_p value in the phase transition zone made it clear that with an increase in the CF content in the polyamide matrix, it decreased from 0.38 (for PA-6) to 0.16-0.24 (for CP), which is apparently due to a limitation of the molecular mobility of polymeric chains at the interface of polymer matrix and fiber filler and the transition of a certain portion of the polymer macromolecules into the boundary layers.

Therefore, the jump value in the phase transition zone was affected, on the one hand, by a decrease in the mobility of polymer macromolecules that passed into the boundary layers, and, on the other hand, by the transformation of the globular supramolecular binder structure into a spherulitic one.



a b

Fig. 1. **Temperature dependence of specific heat capacity (a) and the temperature conductivity factor (b) of carbon fibers based on PA-6**

According to the known dependence [6], the effective portion of "excluded" binder macromolecules transferred into the boundary layers and the thickness of the boundary layers was calculated (Table 2):

$$[(\Delta r + r)/r]^3 - 1 = \nu \cdot \Phi/(1 - \Phi),$$

where: $\nu = 1 - \Delta C_{p,н}/\Delta C_p$ *– is the portion of polymer macromolecules that have transferred into the boundary layers;* $\Delta C_{p.н.}$ *– is the specific heat capacity jump of the filled polymer;* ΔC_p *is the specific heat capacity jump of the unfilled polymer;* Φ *– is the volume content of the filler.*

Table 2

The effect of carbon fiber content on the thermophysical properties

Feature	Carbon fiber content, wt.%		
	5	10	30
The portion of macromolecules transferred into the boundary layers	0.37	0.39	0.58
Thickness of the boundary layers, Å	0.14	0.18	0.70

[авторська розробка]

Data from the table 2 testified that the thickness of the boundary layers of the CP were in the range of 0.14-0.70 Å and with an increase in the CF content from 5 to 30 wt.%, they increased 5-fold. In general, an increase in the CF content in the polyamide matrix led to a decrease in its specific heat capacity by 7-18%.

The temperature conductivity factor (Fig. 1b) characterizes the rate of temperature change in the body during heat transfer. The higher the temperature conductivity coefficient, the faster the temperature equalization takes place in the heated body. Therefore, it is important to note that in the entire temperature range under study, with an increase in the CF content, this feature increased by 1.1-1.3 times compared with the initial polymer matrix.

The study revealed that the maximum improvement in the thermophysical properties of CP is observed in the area of low temperatures. In particular, analyzing the concentration dependences of thermophysical properties at a temperature of 323 K, it is worth noting the reinforcement of the original binder by CF in an amount of 30 wt.% reduces the heat capacity by 17%, and increases the heat- and temperature conductivity factors by 1.3-1.4 times (Fig. 2).

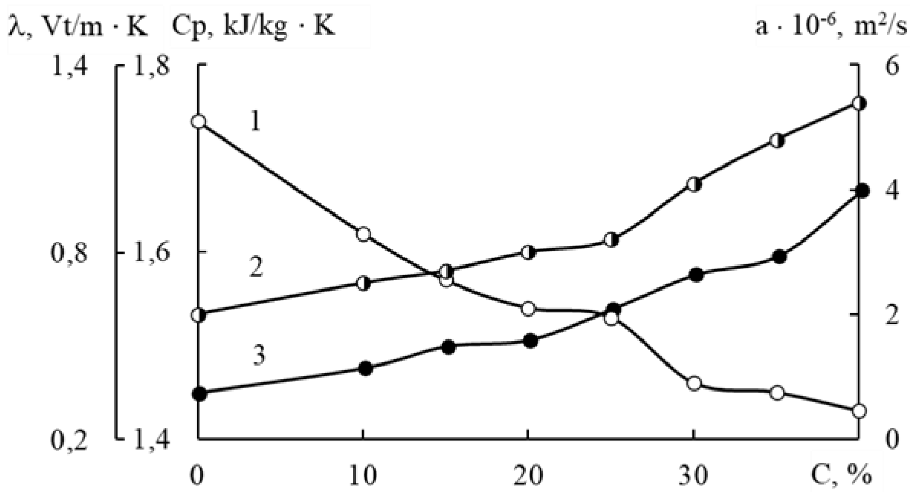


Fig. 2. **Effect of carbon fiber content on specific heat capacity (1), temperature- (2) and thermal conductivity (3) factors of PA-6**

Moreover, an increase in Vicat softening point was observed for the obtained plastics: if for PA-6 it was equal to 474 K, then for CP containing 10, 20, and 30 wt.% it was 478, 482, and 485 K, respectively.

Therefore, the conducted set of studies provide evidence of a significant improvement in the thermophysical properties of PA-6 due to its reinforcement with Ural-24H CF, which made it possible to recommend the developed CP as structural materials for operation at elevated temperature conditions.

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