CARBON FIBER FOR STRUCTURAL PURPOSES BASED ON ALIPHATIC POLYAMIDE

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Polyamide PA 6,6 is an engineering polymer, a products whereof are used in mechanical engineering, shipbuilding, aerospace engineering, automotive engineering, food industry, electrical engineering to replace bronze and non-ferrous metals to work under conditions of increased mechanical loading.

Aliphatic polyamide PA-6,6 is characterized by high mechanical strength, hardness, stiffness and toughness, good fatigue strength, radiation resistance, ease of processing. Among commercially produced polymers, it ranks second by production volume and is widely used to produce artificial fibers [1].

For the purpose of obtaining a new polymeric composite for structural purposes, PA-6.6 was reinforced with carbon fiber (CF) in an amount of 40 wt.%. A preliminary study of the effect of carbon fiber production processing conditions showed that the optimal property package was shown by samples obtained by compression molding at the temperature of 513 K. At the initial stage of the research, a package of thermal and thermophysical studies of the original polymer and the carbon plastics (CP) based PA-6.6.

One of the good practices for predicting the material behavior at high temperatures is the thermogravimetric analysis method. It is known [2] that the thermal resistance is determined by the temperature threshold when the thermal or thermo-oxidative breakdown of material begins, which is accompanied by the release of volatile products. As a result, the test sample weight loss takes place, which is the basis of thermogravimetric analysis.

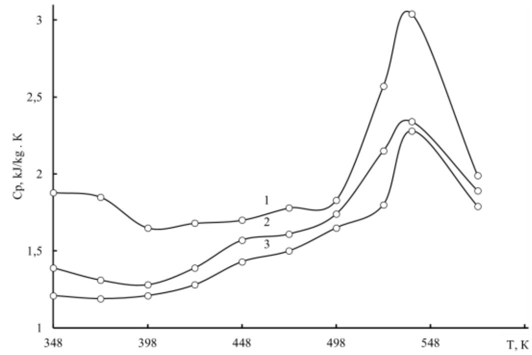
The data of thermogravimetric analysis (Table 1) showed that the reinforcement of PA-6.6 carbon fiber can significantly increase its thermal resistance: the temperature corresponding to 30 and 40% weight loss of samples for CP was 23 and 44 degrees higher than for PA-6.6.

Table 1. Thermal resistance of polyamide and carbon plastic based PA-6.6

Material	Temperature, K	
	T_{30}	T_{40}
PA-6,6	678	723
PA-6,6 + 40 % CF	701	767

Note: T_{30}, T_{40} – temperatures of 30 and 40% of the weight loss of samples, K

The study of the pressing temperature effect on the CP thermos-physical properties showed that in the entire studied temperature range (323-573K), the specific thermal capacity of samples increased with an increase in molding temperature (Fig.1a).



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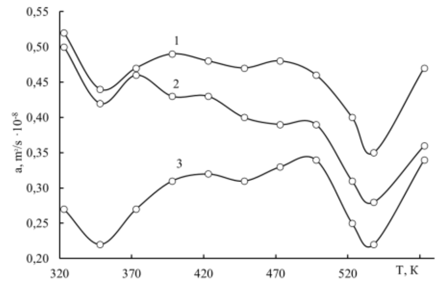

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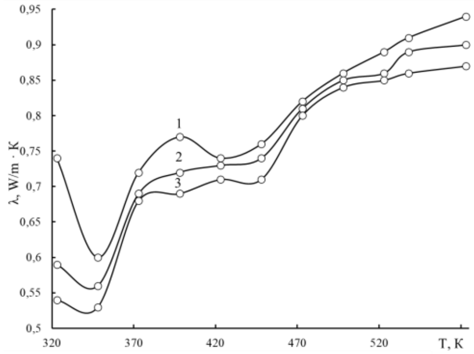


c

Fig. 1. Temperature dependences of specific thermal capacity (a), thermal conductivity coefficients (b) and thermal conductivity (c) of carbon plastic based on PA-6.6 on the molding temperature: 1 – 523 K; 2 – 518 K, 3 – 513 K

The comparative analysis of CP thermal capacity molded at 513 and 528 K shows that at 323-573 K it increased by 8-29%. On all temperature curves at the temperature of 548 K, a surge in thermal capacity corresponding to the CP softening point is clearly manifested. Attention is drawn to the fact that in the range of high temperatures (more than 548 K), the increase in the specific thermal capacity of CP samples with the increase of the molding temperature is manifested to a far lesser extent. The samples obtained by compression molding at 513 K shown a specific thermal capacity over the entire tested temperature range within 1.1-18 kJ/kg · K and high values of the thermal conductivity coefficient (0.74-0.94 W/ m · K).

Calculation of the linear expansion thermal coefficient (LETC) according to the curves of the specimen relative elongation against the temperature (Table. 2), showed that this feature grows with increasing temperature, and the CF glass-transition temperature is 516 K. A comparative analysis of the LETC calculation data of the original polymer and the CP in the temperature range of 298-323 K showed that the reinforcement of aliphatic polyamide of the CF allows reducing this indicator by 6 times.

Table 2. Thermal coefficient of linear expansion
of carbon plastic based on PA-6.6

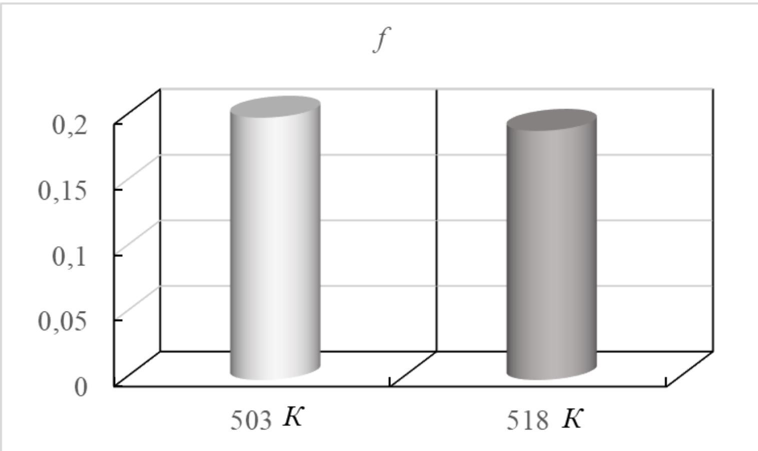
Temperature range, K									$T_{gt.}$, K
298-323	298-348	298-373	298-398	298-423	298-448	298-473	298-498	298-523	
15,1	23,0	22,8	28,8	30,2	31,5	32,3	33,2	33,7	516

T_{gt} – temperature glass-transition, K

Carbon fiber processed at 513 K, in addition to improved thermos-physical properties, showed high stress-related properties and tribological performance (Table 3, Fig. 2).

Table 3. Thermos-physical and tribological properties
of carbon plastic based on PA-6.6

Modulus of elasticity in compression, MPa	Failure stress in compression, MPa	Rockwell hardness number, HR_{α}	Friction coefficient	Linear wear intensity, $I_h \cdot 10^{-9}$
2750	110	87,6	0,18	0,16



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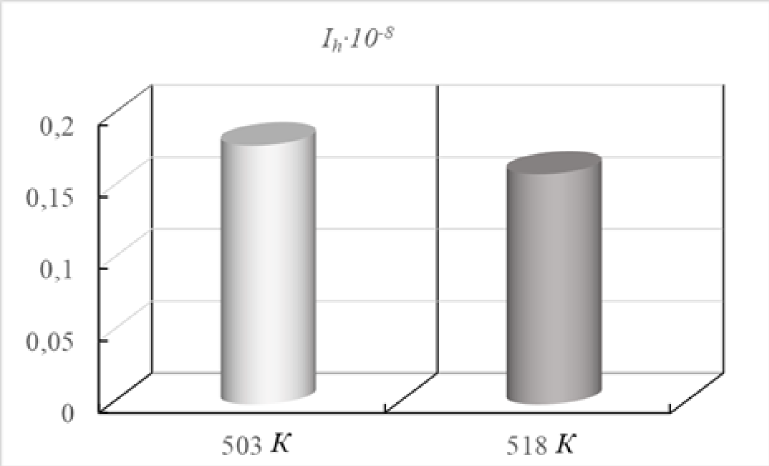

b

Fig. 2. Effect of processing temperature on friction coefficient (a) and intensity of linear wear (b) of carbon plastic based on PA-6.6

Thus, the research data indicate that the optimal property package was shown by the plastic obtained at a molding temperature of 513 K. The developed carbon plastic has a high thermal conductivity, low values of LETC and friction coefficient, as well as good wear resistance, which will allow it to be recommended for use as a material for structural purposes.

References

1. Katsnelson M.Yu., Balaev G.A. Plastic masses. Properties and application: Guidebook. L.: Khimiya. 1978. 384 p.
2. Korshak V.V. Thermally-resistant polymer. Moscow: Nauka. 1969. P. 25.