Journal of Engineering Physics and Thermophysics, Vol. 72, No. 2, 1999

EXPERIMENTAL EVALUATION OF THE CRACK RESISTANCE OF GLASS-FILLED POLYAMIDE UNDER COLD CLIMATIC CONDITIONS

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UDC 678.067.5.017

We show that a correct evaluation of the effect of various factors of a cold climate on the crack resistance of a material is not possible without account for the dependence of the coefficient K_{Ic} on the effective rate of loading of a specimen that has a notch–crack.

In order to evaluate the operational reliability of a structural material in a cold climate it is necessary to investigate the effect of its most aggressive factors on the indices of the crack resistance of the material. We investigated the separate and joint effect of the following characteristic factors of a cold climate: low temperatures, moisture, temperature drops.

As the object of investigation we selected PA6-211DS glass-reinforced plastic, which is a polyamide binder-based composite randomly reinforced with short fibers. Specimens of the material were cut out of slabs (sheets) produced by injection molding in the form of bars measuring 40 × 25 × 10 mm. Then, notches of different depths (a = 10, 14, and 18 mm) were made on these bars by the technique of [1], and the bars were tested for tension according to the scheme of a double cantilever beam (DCB) [2]. All the specimens had notches on their sides to stabilize the motion of the front of a crack ($B_N/B = 0.75$) [2]. Mechanical tests were run on an "Instron-1195" machine at a speed of the loader arm of 0.5 mm/min and two temperatures: T = 213 and 293 K.

Saturation of the specimens with moisture to a steady-state level ($W = 6.5\%$) was done by the technique of [3, 4]. To accelerate the process of diffusion, the temperature of the distilled water was maintained at the level of T = 333 K. Some of the initial and impregnated specimens were subjected to thermocycling for 2 h at 213 K and then for 2 h at 293 K.

The crack-resistance factor K_{1c} was determined by the following formula [2] using results of mechanical tests of the initial PA6-211DS specimens and spesimens that had been damaged by various climatic factors:

$$K_{1c} = \frac{1}{0.2\dfrac{B_N}{B} + 0.8}\sqrt{\left(\frac{12P_c^2a^2}{B_N B H^3}\left(1 + 1.32\frac{H}{a} + 0.542\frac{H^2}{a^2}\right)\right)}.$$

Experimental results on the influence of factors of a cold climate on the crack resistance of PA6-211DS composite are given in Table 1.

To carry out a correct analysis of the experimental data, we took account of the change in the actual rate of loading of the material near the tip of the notch–crack. The rate of loading dK_1/dt was calculated by differentiating the above expression. Here the rate of loading dP/dt was determined on the linear stretches of the $P-t$ load diagrams of initial and "damaged" specimens with cracks of various lengths.

The most interesting consequence of the dependence $K_{1c} - dK_1/dt$ (see Fig. 1) is the existence of two regions (intervals) for the rate of loading of the tip of a crack in each of which a directly opposite dependence of the crack-resistance factor on the temperature of testing is observed: embrittlement of the material upon reduction

Institute of Nonmetallic Materials, Russian Academy of Sciences, Yakutsk Science Center. Translated from Inzenerno-Fizicheskii Zhurnal, Vol. 72, No. 2, pp. 251-252, March-April, 1999. Original article submitted December 31, 1997.

TABLE 1. Effect of Factors of the Ambient on the Crack Resistance K_{1c} of Polyamide Glass-Reinforced Plastic

T_{test}, K	$a = 10$ mm				$a = 14$ mm		$a = 18$ mm
	dry state	moisture	thermocycling	moisture + thermocycling	dry state	moisture	dry state
293	6.14	4.03	5.83	5.83	6.03	3.85	5.08
213	4.14	4.45	4.09	4.09	4.2	4.52	4.44

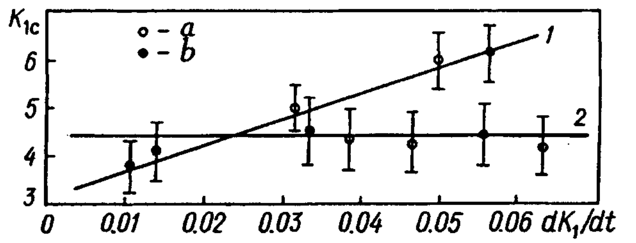

Fig. 1. Crack resistance of PA6-211DS versus the rate of loading of the tip of a crack: 1, 2) temperature of the tests $T = 293$ and 213 K, respectively; a) dry specimens, b) impregnated specimens.

of the temperature in the case of "rapid" loading and an increase in the fracture toughness in the case of "slow" loading.

As follows from the data given, the second most important climatic factor is moisture. The substantial decrease in the crack resistance of impregnated specimens at $T = 293$ K compared to the initial ones (the dry state) is due, in our opinion, to a decrease in the modulus of elasticity and a corresponding decrease in the "effective" rate of loading of the tip of the crack, which is indirectly confirmed by the dependence $K_{1c} - dK_1/dt$ for the initial specimens (straight line 1 in Fig. 1).

As regards the effect of thermocycling, it is insignificant at $N = 10$ for both specimens in the initial (dry) state and impregnated specimens. Probably, to reveal the influence of thermocycling action on PA6-211DS material, it is necessary to increase substantially the number of thermal cycles.

NOTATION

a, length of the notch, m; B, thickness of the initial cross section, m; B_N, thickness of the notched cross section, m; H, half-width of the specimen, m; K_1, stress intensity factor, MPa·m$^{1/2}$; P, current value of the force in stretching the specimen, N; t, current value of the time in stretching the specimen, sec; P_c, force in fracture of the specimen, N; K_{1c}, critical stress intensity factor, MPa·m$^{1/2}$; dK_1/dt, "effective" rate of loading of the material near the tip of the notch–crack, MPa·m$^{1/2}$·sec^{-1}; W, amount of moisture in the specimen, %; N, number of thermal cycles.

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