THE EFFECT OF TEMPERATURE ON THE LONG-TERM ADHESIVE STRENGTH OF POLYETHYLENE

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Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

Abstract

Full Text

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THE EFFECT OF TEMPERATURE ON THE LONG-TERM ADHESIVE STRENGTH OF POLYETHYLENE

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It was shown earlier ([1,2]) that, under the action of both internal and external stresses, adhesive strength has a time-dependent character and is described by the equation:

$$\tau = Ae^{-\alpha\sigma}, \tag{1}$$

where τ is the time to failure, sec.; A and α are constant coefficients; σ is the breaking stress, kg/cm^2.

The present work establishes that the same regularity is manifested in the destruction of an adhesive bond over a wide temperature interval.

Fig. 1. Temperature-time dependence of the adhesive strength of stabilized polyethylene for various temperatures:
1 –22°; 2–35°; 3–60° and 4–70°.

Fig. 2. Temperature dependence of the long-term adhesive strength of stabilized polyethylene for various loads:
1 –60; 2 –80; 3 –120 and 4 –140 kg/cm^2.

The investigation of the temperature-time dependence of adhesion strength was carried out on a specially designed apparatus with a thermostated chamber, which made it possible to test simultaneously 10 specimens at different temperatures and loads.

As the object of study, stabilized* and unstabilized low-density polyethylene was chosen, making it possible to realize an adhesive type of separation over a wide temperature range. Polyethylene coatings on steel substrates and the bonding of steel rods was obtained by thermal fusion of pressed polyethylene powder at a temperature of 260°.

Figure 1 gives a graphical representation of the dependence $\lg \tau = f(\sigma)$, and Fig. 2—the dependence $\lg \tau = f\left(\frac{1}{T}\right)$ for normal separation of specimens made of stabilized polyethylene. From Fig. 1 it is seen that the temperature–time strength of adhesion in semilogarithmic coordinates has a linear dependence. The temperature dependence of long-term strength (Fig. 2) is described by the equation

$$\tau = \tau_0 e^{U/RT}, \qquad (2)$$

where τ_0 is a constant; U is the activation energy; T is the absolute temperature; R is the gas constant, which indicates the independence of the activation energy from temperature.

Table 1

Activation energy of destruction of the adhesive bond of polyethylene to steel
(kcal/mol)

Material	According to equation (2)	According to equation (3)
Unstabilized polyethylene	36	3–9
Stabilized polyethylene	23.8	3.1

Table 2

Activation energy of cohesive rupture of polymers (kcal/mol)

Material	According to equation (2)	According to equation (3)
Capron fiber	45	0.32–0.6*
Viscose fiber	40	0.45–2*
Polyvinyl chloride fiber	35	0.5–1*
Nitrocellulose	28.6	1.14
Nitrolac	44	5.3

* Activation energy at a higher temperature.

Identical dependences were also obtained for unstabilized polyethylene.

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* Stabilizer —niaz “A” —0.13%, diphenyl-n-phenylenediamine 0.07%, and gas black 0.5%.

Fig. 3. Dependence of the logarithm of adhesive strength on reciprocal temperature: 1 —stabilized polyethylene; 2 —unstabilized polyethylene

Figure 3: Fig. 3. Dependence of the logarithm of adhesive strength on reciprocal temperature: 1 —stabilized polyethylene; 2 —unstabilized polyethylene

Table 1 gives the values of the activation energy of adhesive failure, calculated from the dependences shown in Fig. 2 using equation (2).

Fig. 3. Dependence of the logarithm of adhesive strength on reciprocal temperature: 1 —stabilized polyethylene; 2 —unstabilized polyethylene

From the data in Table 1 it can be seen that for unstabilized polyethylene the value of the activation energy of destruction of the adhesive bond U is equal to 36 kcal/mol, while for stabilized polyethylene it is about 24 kcal/mol; this is apparently connected with the fact that stabilizer additives inhibit oxidative processes at the adhesive-metal (steel) interface.

Table 1 also gives data on the values of the activation energy calculated by the method of Bright (^{3}) and Voyutsky (^{4}), who used the equation

$$P_t = P_0 e^{E/RT}, \tag{3}$$

P_t is the adhesion at temperature; P_0 is a constant; E is the activation energy.

As our data show, the dependence

$$\lg P_t = f\left(\frac{1}{T}\right)$$

(Fig. 3) has a linear character only for stabilized polyethylene (curve 1). For the unstabilized adhesive, a linear dependence is absent (curve 2). For the unstabilized adhesive an increase in activation energy is observed with increasing temperature, which is unlikely (^{5,6}).

The values of the activation energy E, calculated from equation (3), are an order of magnitude smaller than the values calculated from equation (2). As the data given in Table 2 show, the same difference is also observed when comparing the activation energies of cohesive rupture of viscose, polyvinyl chloride, and capron fibers according to the data of Zhurkov (^{7,8}), as well as of nitrocellulose and nitrovarnish films according to data from our laboratory*.

It follows from the above that the use of equation (3) to calculate the activation energies of both cohesive and adhesive failure is not valid. This circumstance is apparently connected with the fact that this equation does not take into account the time (kinetic) dependence of cohesive and adhesive failure.

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* The data were obtained by graduate student G. Grunite.

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