

Anisotropy of a Fiber Structure and the Frictional Wear of Composites on the Basis of Polyarylate

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ABSTRACT: An influence of the anisotropy of surface structure of short fibers on an interfacial layer structure in polymer composites is studied. In its turn, mentioned changes of structure cause an essential variation of frictional wear for these materials. In this aspect, the existence of a hydrogen bonds polymer-filler plays an impor-

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Key words: composite; polyether; short fibers; structure; surface

INTRODUCTION

A reinforcement of polymers by oriented fibers has several specific features in comparison with a reinforcement by mineral fillers.¹ In a earlier study,² a supposition is made that the fibrillar structure of a fiber surface results in the more frictional stability in comparison with an isotropic structure of analogous fibers. Besides, Burya et al.,² by the methods of IR-spectroscopy, demonstrated the existence of hydrogen bonds on the interface of fibers ugle and vniivlon with polyarylate (PAr), which are used as matrix polymers. The existence of these bonds assumes anisotropy of PAr macromolecules on the interface, which also influence on the frictional stability of composite. Such “copy” of the main features of fiber surface by interfacial layers of polymer is well-illustrated by PArterlon system. This fiber has crystalline structure that causes the PAr crystallization up to crystallinity degree of ~ 0.20 ,² whereas amorphous ugle and vniivlon do not give this effect. Therefore, the purpose of this work is to study the influence of surface anisotropy of the fibers iglen and vniivlon on the frictional wear of composites on the basis of PAr filled by these fibers.

EXPERIMENTAL

The composites on the basis of PAr of trade mark DV-102 with content of ugle and vniivlon 5, 15, 25,

and 35 wt % are used. The density of ugle is equal to 1240 kg/m^3 and of vniivlon is equal to 1100 kg/m^3 .² Composites are produced by “dry” method, which includes a blending of components in a rotating electromagnetic field, with the help of nonequaxial ferromagnetic particles.³ Tribological properties of composites are studied on the disc-shaped apparatus of friction, according to the method described earlier.⁴ As a contrbody material, steel 45 is used, quenched up to HRC 45–48, with surface roughness $R_a = 0.32 \text{ }\mu\text{m}$. The experiments were carried out after the final attrition of samples to a constant friction coefficient. The intensity of linear wear is calculated as described earlier.⁵

The X-ray structural analysis is made using apparatus DRON-3, according to the method of Bragg-Brentano in angles interval $2Q = 10\text{--}70^\circ$ (Cu-radiation intensity is made on the points with introduction in to computer memory).⁶

RESULTS AND DISCUSSION

In Figure 1, diffraction X-ray curves for PAr, ugle, and carboplastics on the basis of PAr with various volume content of ugle φ_f are shown. At the increase of φ_f , the decrease of intensity I_r of carboplastics amorphous halo and its displacement in the direction of more scattering angles $2Q$ are observed. The change of diffraction curves assumes an increase of a relative part of local-order regions (clusters) φ_{cl} in polymer matrix structure and a decrease of interchain distance at the increase of φ_f .⁷ It is necessary to mention that, in the considered case, the generalized definition of clusters is adopted: these are structure parts that made from the segments with “freezing” molecular mobility.⁷ Besides, on the densification of polymer matrix

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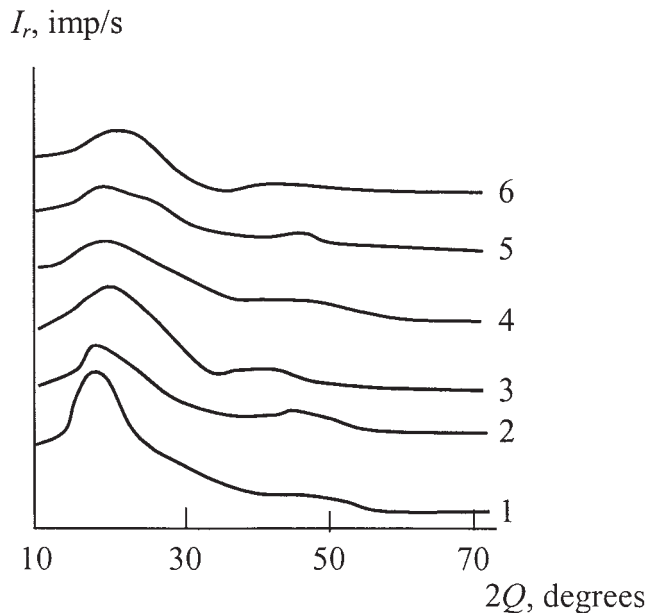


Figure 1 The diffraction X-ray curves for polyarylate (1), composites on the basis of polyarylate with volume content of uglen 0.038 (2), 0.114 (3), 0.195(4), 0.282 (5), and uglen (6).

structure at increase φ_f , the measurements of composites density ρ point out that the experimental value ρ is more than the additive value and this difference being increased at the increase of φ_f .² Between the parameters I_r and φ_{cl} , the following relationship⁷ is obtained:

$$\varphi_{cl}^{-1} = CI_r \quad (1)$$

where C is constant.

The estimation of the value C for studied composites can be made by the following method. For initial PAr, the value φ_{cl} can be determined from the following percolation relationship⁷:

$$\varphi_{cl} = 0.03(T_g - T)^{0.55} \quad (2)$$

where T_g and T are glass transition temperature and testing temperature, accordingly. For PAr, $T_g = 468$ K² and $T = 293$ K. Then, the value C is defined as a reciprocal of product of calculated value φ_{cl} and experimental magnitude I_r , for PAr, by the above-mentioned method.

On the basis of this, it can be assumed that the polymer matrix structure densification (the estimations according to the eq. (1) gave an increase in φ_{cl} from 0.514 for initial PAr up to 0.887 for composite PAr-uglen with volume content of uglen equal to 0.282) is determined by the anisotropy of PAr macromolecules in the interfacial layer polymer-filler, which is due to the existence of a structure anisotropy of fiber surface and hydrogen bonds between uglen and PAr.²

On the contrary, the drawing of PAr macromolecule on the surface of a filler fiber is assumed, and the degree of this drawing can be estimated with the help of fractal dimension D of a chain part between its fixation points (crosslinks, clusters, sites of hydrogen bonds, etc.).⁸ The value D is varied in the limits $1.0 < D \leq 2.0$, where $D = 1.0$ assumes full drawing of a chain part and molecular mobility loss, and $D = 2.0$ assumes maximum possible mobility of this part, which is typical for devitrificated polymers.⁹ The value D can be determined according to the following equation⁹:

$$\frac{2}{\varphi_{cl}} = C_{\infty}^D \quad (3)$$

where C_{∞} is the characteristic ratio, which is an index of a static flexibility of a polymer chain.¹⁰ For PAr, C_{∞} is equal to 2.3.¹¹

In Figure 2, the dependence of fractal dimension D of chain part on volume content of fibers φ_f for composites PAr-uglen and PAr-vniivlon, according to the eq. (3), is shown. As it should be expected, a decrease in D at an increase in φ_f is observed, which assumes a process of chain PAr drawing on fibers surface (fibrilization). At $\varphi_f \approx 0.25$, the asymptotic value $D \approx 1.05$ is reached, which assumes practically full loss of molecular mobility for chains of PAr. It is necessary to point out that, for the studied composites, a minimal value of linear wear intensity I is reached approximately at $\varphi_f \approx 0.20$ – 0.22 .²

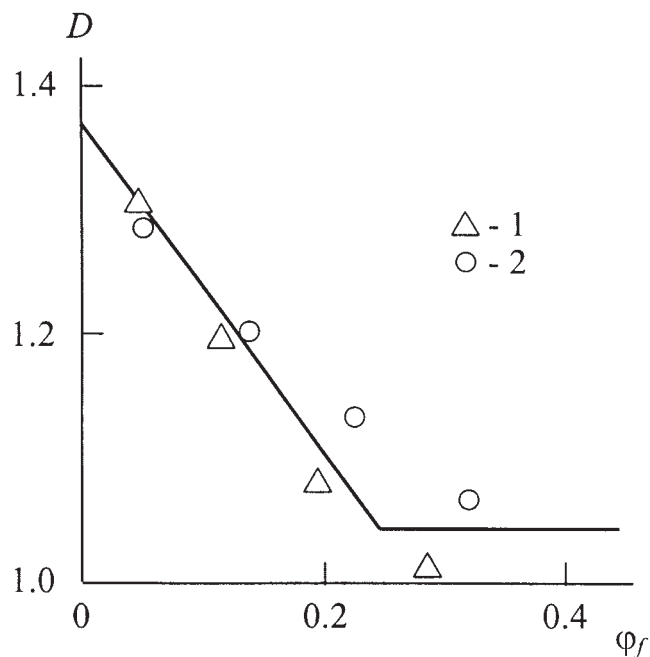


Figure 2 The dependence of fractal dimension D of chain part on volume content of fibers φ_f for composites PAr-uglen (1) and PAr-vniivlon (2).

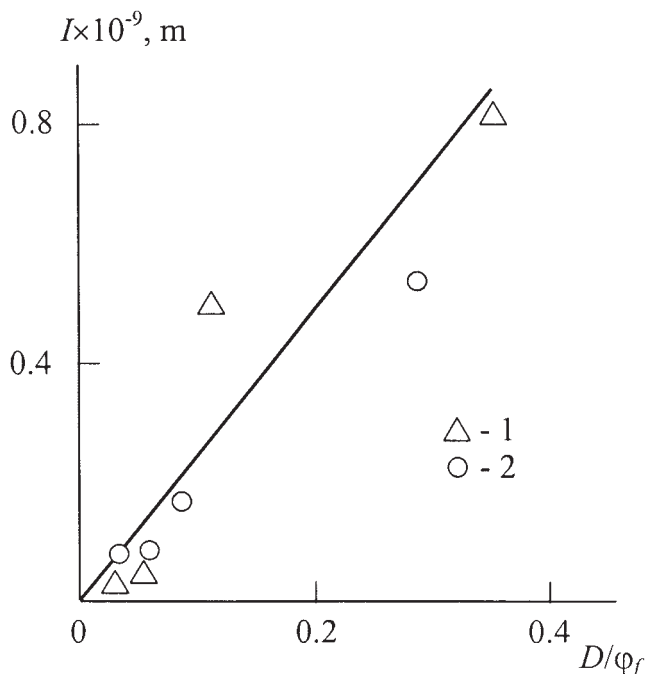


Figure 3 The dependence of linear wear intensity I on the value of ratio (D/φ_f) for composites PAR-uglen (1) and PAR-vniivlon (2).

Other factor that is influenced on the polymer fibrilization on the fibers surface is the area of their summary surface, which is proportional to value φ_f —the more the area is, the more is the article sites concentration, which are able to form hydrogen bonds polymer–filler. On the basis of this, it should be expected that the decrease in D and an increase in φ_f bring to a reduction in I . In Figure 3, the dependence I on the value of ratio D/φ_f is shown, which is approximated well enough by linear correlation passing through the

origin of coordinates. Such course of dependence $I(D/\varphi_f)$ shows that the frictional wear intensity decreases at the increase of hydrogen bonds number and drawing degree (fibrillization) of polymeric chain on the surface of anisotropic fibers in the polymer composites.

CONCLUSIONS

Thus, the results of the present study have shown the influence of the anisotropy of the surface structure of short fibers on an interfacial layer structure in polymer composites. The earlier-discussed changes in the surface structure cause the essential variation of frictional wear for these materials. In this aspect, the existence of hydrogen bonds polymer–filler plays an important role.

References

1. Lipatov, Yu. S. *Polymer Reinforcement*; Chemtec Publishers: Toronto, 1995; p 256.
2. Burya, A. I.; Tchigvintseva, O. P.; Sutchilina-Sokolenko, S. P. *Polyarylates. Synthesis, Properties, Composite Materials*. (Russ.); Dnepropetrovsk: Nauka i osvita, 2001; p 152.
3. Fomitchev, A. I.; Burya, A. I.; Gubnikov, M. G. *Electron. obrabotka materialov* 1978, 26.
4. Burya, A. I. *Trenie i iznos* 1998, 19(5), 671.
5. A methods of calculated estimation of wear-proofing of friction surfaces of mashines details. (Russ.). Moscow, Izd. Standartov 1979, p 156.
6. Kozlov, G. V.; Beloshenko, V. A.; Kuznetsov E. N.; Lipatov, Yu. S. *Doklady NAN Ukrainy* 1994, 126.
7. Kozlov, G. V.; Zaikov, G. E. *Structure of the Polymer Amorphous State*; Brill Academic Publishers: Leiden, 2004; p 465.
8. Kozlov, G. V.; Novikov, V. U. *Synergetics and Fractal Analysis of Cross-Linked Polymers* (Russ.); Klassika: Moscow, 1998; p 112.
9. Kozlov, G. V. Novikov, V. U. *Uspekhi Fizich. Nauk* 2001, 171(7), 717.
10. Budtov, V. P. *A Physical Chemistry of Polymer Solutions*; Sanct-Peterburg: Khimiya, 1992; p 384.
11. Aharoni, S. M. *Macromolecules* 1983, 16, 1722.