EFFECT OF THE MORPHOLOGY OF THE ORGANIC FIBERS ON THE MECHANICAL BEHAVIOR OF COMPOSITES*

V. E. Yudin*, T. E. Sukhanova*,
M. É. Vylegzhanina*, V. K. Lavrent'ev*,
G. M. Mikhailov*, Z. G. Oprits**,
B. A. Zaitsev*, E. N. Popova*,
and A. A. Mikhailov*

Scanning electron microscopy and x-ray diffraction analysis are used to study the morphology of several aramid and polyimide fibers developed in Russia and to determine their strain-strength characteristics. It is shown that the supermolecular structure of the fiber in large part determines the character of its interaction with the matrix and behavior during failure of the fiber composite (FCP). In the case of aramid fibers, composite failure is accompanied by intensive fibrillation leading to lamination on a microscopic scale and a deterioration in the service characteristics of the composite. The stability of the investigated polyimide fibers against fibrillation and microlamination, in combination with good heat resistance, makes them promising as reinforcing materials for FCPs.

INTRODUCTION

Along with carbon fibers, organic fibers are presently the most promising materials for use as reinforcing fillers in fiber composites (FCPs). The best-known organic fibers are the aramid fibers Kevlar (made by the U.S. firm DuPont) and tvaron (made by the Dutch company Akzo Nobel) [1, 2], as well as the fibers armos, SVM, and terlon produced commercially in Russia [3, 4]. Organic fibers are the equal of carbon fibers and in some instances even superior to them with respect to their specific mechanical properties in tension [1] and are thus finding wide use in FCPs in which the material is loaded primarily along the direction of reinforcement [5]. The most FCPs are those based on organic fibers loaded in shear or across the reinforcement direction [6-8]. Organic fibers are inferior to carbon fibers in terms of their transverse and shear mechanical characteristics, which is probably one of the main factors impeding their broader application in FCPs.

Polyimide fibers are of particular interest [4, 9, 10], since they are more heat-resistant than aramid fibers while having similar mechanical characteristics. However, the structural organization of polyimide fibers is not yet well understood, and more detailed analysis is needed to establish their mechanical behavior in composites [11].

Some researchers believe that one reason for the low transverse and shear characteristics of unidirectionally reinforced FCPs based on organic fibers may be the tendency of aramid-type fibers such as Kevlar [2] or similar fibers such as PBZT and PBZO [12] to undergo fibrillation. Efforts are being made to improve these characteristics by increasing adhesive interaction between the matrix and the fibers through plasma treatment or other types of treatment of the fiber surface [13, 14]. Good adhesion is required for the creation of high shear stresses at the boundary of the phases without their separation, which in turn assures that the applied load will be transmitted to the fibers [13, 14]. However, if the fibers have a low compressive strength (as Kevlar and tvaron fibers do), low values of mechanical strength may be seen in FCPs under certain conditions even in the event of good adhesion to the matrix [2, 3].

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The goal of the present investigation is to study the effect of the chemical and supermolecular structure of certain organic fibers developed in Russia on a commercial or trial-commercial scale on the strength properties of composites composed of these fibers and a polymer matrix of rolivsan MV-1 [15, 16].

EXPERIMENTAL PART

Materials

Fibers. We are examining the structure and mechanical characteristics of aramid and polyimide fibers. Elur carbon fibers were chosen to compare the behavior of these two types of fibers in a composite. The aramid and polyimide fibers that will be studied were developed in Russia, and some of them are produced on a commercial or trial-commercial scale.

The chemical structure of the investigated fibers is as follows:

* aramid fibers
  SVM

\[
\text{SVM} = \frac{\text{NH}}{\text{NH}} - \frac{\text{NC}}{\text{CO}} - \frac{\text{NH}}{\text{CO}} \quad n
\]

* polyimide fibers
  arimid T

\[
\text{arimid T} = \frac{\text{C}}{\text{C}} - \frac{\text{C}}{\text{O}} - \frac{\text{N}}{\text{H}} - \frac{\text{N}}{\text{C}} - \frac{\text{NH}}{\text{C}} - \frac{\text{O}}{\text{O}} - \frac{\text{O}}{\text{O}} - \frac{\text{N}}{\text{C}} - \frac{\text{N}}{\text{H}} - \frac{\text{C}}{\text{C}} - \frac{\text{C}}{\text{O}} \quad n
\]

* arimid VM (developed by the "Khimvolokno" Scientific-Industrial Association in Mytishchi)

\[
\text{arimid VM} = \frac{\text{N}}{\text{C}} - \frac{\text{C}}{\text{O}} - \frac{\text{N}}{\text{C}} - \frac{\text{N}}{\text{C}} - \frac{\text{NH}}{\text{C}} - \frac{\text{O}}{\text{O}} - \frac{\text{O}}{\text{O}} - \frac{\text{N}}{\text{C}} - \frac{\text{N}}{\text{H}} - \frac{\text{C}}{\text{C}} - \frac{\text{C}}{\text{O}} \quad n
\]

* Tvim (developed by "Khimvolokno") — an analog of arimid VM with respect to chemical structure but subjected to a high degree of elongation during processing

* Ivisan (developed by the Institute of High-Molecular-Weight Compounds (of the Russian Academy of Sciences) in St. Petersburg)

\[
\text{Ivisan} = \frac{\text{N}}{\text{C}} - \frac{\text{C}}{\text{O}} - \frac{\text{N}}{\text{C}} - \frac{\text{N}}{\text{C}} - \frac{\text{NH}}{\text{C}} - \frac{\text{O}}{\text{O}} - \frac{\text{O}}{\text{O}} - \frac{\text{N}}{\text{C}} - \frac{\text{N}}{\text{H}} - \frac{\text{C}}{\text{C}} - \frac{\text{C}}{\text{O}} \quad n
\]