EFFECT OF SURFACE MODIFICATION OF FIBERS
WITH A POLYMER COATING ON THE INTERLAMINAR
SHEAR STRENGTH OF A COMPOSITE
AND THE TRANSLATION OF FIBER STRENGTH
IN AN F-12 ARAMID/EPOXY COMPOSITE VESSEL

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The surface of aramid fibers was modified with a polymer coating — a surface treatment reagent containing epoxy resin. The resulting fibers were examined by using NOL tests, hydroburst tests, and the scanning electron microscopy. The modified fibers had a rougher surface than the untreated ones. The interlaminar shear strength of an aramid-fiber-reinforced epoxy composite was highest when the concentration of polymer coating system was 5%. The translation of fiber strength in an aramid/epoxy composite vessel was improved by 8%. The mechanism of the surface treatment of fibers in improving the mechanical properties of aramid/epoxy composites is discussed.

1. Introduction

Of the new varieties of chemical fibers for industrial use, the para-aramid fibers manufactured in several developed countries — USA, Russia, Netherlands, and Japan — have become very common in the last fifteen years [1]. The F-12 aramid fiber is spun from aromatic polyamides and copolyamides with heterocycles in the chain, which imparts to the fiber a high tensile strength (4.35-4.67 GPa), which is 1.69 times higher than that of Kevlar-49. The F-12 aramid fiber is one of the best candidates for the reinforcement in polymer composites [2] and is widely used in aviation and space engineering [3].

The high-strength and high-modulus F-12 aramid fiber possess a strongly pronounced anisotropy of structure and mechanical properties and has the structure of skin-core morphology type. The microfibrils are oriented along the fiber axis and are rather poorly bonded together in the transverse direction. The high degree of longitudinal orientation of fibrils in the skin inevitably decreases the fiber strength in the transverse direction and, as a consequence, the relatively less dense core of the fiber must have a higher stiffness and lower compliance in this direction than the layer of fibrils highly oriented in the longitudinal direction [4, 5]. The above-mentioned reasons explain why the fibers move apart and slide during the application of a load, which results in a low interlaminar shear strength (ILSS) of composites.
In addition, the surface of the F-12 aramid fiber is chemically inert, which results in their poor adhesion to the resin matrix and in a lower ILSS in F-12 aramid fiber-reinforced epoxy composites, and a lower degree of translation of fiber strength in filament-wound vessels [4, 6]. Therefore, if the F-12 aramid fiber is selected as a reinforcement, its surface modification is necessary in order to influence the skin-core morphology and to improve the adhesion between the fibers and matrices [7]. A better fiber/matrix interfacial adhesion/bond imparts a higher tensile strength, ILSS, delamination resistance, and fatigue and corrosion resistance to polymer composites [8]. In the literature [9], the surface treatment of fibers is considered as one of the best methods, which can “restrict” the fiber and roughen its surface to enlarge the physical interface between the fiber and matrix. This can facilitate the stress transfer at the interface and improve the interfacial properties.

The matrices consistent with F-12 fibers are those of epoxy series widely used in aviation and space engineering. In this study, the F-12 aramid fiber was treated with a reagent able to form a polymer coating on the fiber surface. Specially, the emphasis was on the influence of surface modification of the fiber on the ILSS in aramid/epoxy composites and on the translation of fiber strength in filament-wound vessels.

2. Experimental

The F-12 aramid fibers used in this study were provided by NWPU, China. The basic ingredient of the surface treatment reagent (self-preparation) was one of epoxy resin series, but the matrix was another epoxy resin. They were obtained from the Tian’jin resin factory, China. The amine curing agent came from the Xi’an chemical reagent factory, China.

The F-12 aramid fibers were dried in a vacuum oven at 110°C for 8 h before surface modification.

The epoxy resin used in the surface treatment reagent was heated to 75 ± 2°C in a water boiler and stirred at that temperature for 5 min. Then the amine curing agent was added to the epoxy for reacting over a period of 15 min. Finally, the epoxy resin was poured into acetone according to different concentration ratios.

The fiber surface was treated by using the solution impregnating method. The fiber treatment and the preparation of NOL test samples and Ø150 mm vessels are shown in Fig. 1.

The interfacial adhesion between the aramid fibers and the epoxy resin was characterized by the ILSS of the composite according to GB1461-88.

The percentage translation of aramid fiber strength in filament-wound vessels was obtained from hydroburst tests on a Ø150 mm vessel according to GB6058-85.

The surface morphology of F-12 aramid fibers was investigated by a scanning electron microscope (SEM) Hitachi S-570 operated at 20 kV. The specimens were sputter coated with a thin layer of gold to make them conductive.