DETERMINATION OF IN-PLANE SHEAR CHARACTERISTICS OF COMPOSITE MATERIALS WITH [±45°] LAYUP

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The shear characteristics of a composite with a [±45°] layer layup are measured experimentally by different methods. Investigations were conducted on flat and tubular specimens. The strength and shear modulus were determined by the rail method, the losipescu method, and by applying torsion to thin-wall tubes; only the shear modulus was determined by applying torsion to square plates. Determination of the shear modulus yields quantitatively comparable results, and, at the same time, the scatter of the shear-strength values of the specimens is significant. Maximum strength is achieved on the tubular specimens. The cause of the lower strength values of the flat specimens can be explained by secondary stresses and strains in their effective sections. The influence exerted by the geometry of the specimens on their strength is investigated for specimens tested by the rail and losipescu methods. It is shown that it is possible to increase the strength appreciably by varying the specimen's geometry.

The majority of existing methods of shear testing were developed for composites having planes of weak shear strength [1], i.e., planes in which the properties of the material are determined primarily by the properties of the matrix. These methods do not guarantee in-plane failure of specimens with a [±45°] layer layup, where the properties of the material depend not only on the matrix, but also on the properties of the fibers. Other methods are required to test these composite materials, whose shear strengths exceed the interlayer strength by several times.

The torsion testing of thin-wall tubular rods is the most reliable method of determining the shear properties in the plane of reinforcement layup, since the tangential stresses are distributed uniformly around the circumference and over the length of the specimen, and the shear strain is essentially constant throughout the thickness of the wall. Unfortunately, this method is very costly, due to the complexity of specimen fabrication and the need for special testing equipment. Moreover, the procedure used to prepare the tubular and flat specimens may differ appreciably. Therefore, a number of alternative methods of determining shear characteristics, which employ simpler flat specimens, have also been proposed [1].

In our study, we investigate the rail and losipescu methods for determination of the strength and shear modulus of flat specimens, and the method of applying torsion to a square plate to determine the shear modulus alone.

For the shear testing of flat specimens, it is necessary to provide for a stress state of pure shear in the effective section, for which a tangential stress that is constant in magnitude acts in the effective section and there are no secondary stresses and strains. The deformation characteristics, especially the shear modulus in the linearly elastic region of deformation, are readily determined by various methods. This is associated with the fact that for all test methods, it is possible to isolate on the specimens a zone with a uniform stress-strain state, which is rather close to pure shear, where the measurements are taken. Moreover, the shear modulus was determined well in advance of specimen failure.

It is by far more complex to measure the strength properties. The fact is that regions with a disturbed stress state (zones adjacent to notches, zones of contact between metal components used for reinforcement and the transmission of forces onto the specimen, and edge-effect zones) surround the zone with a uniform stress state of pure shear. The stress state in these zones is normally of greater risk to material strength than a uniform stress state in the effective zone of the specimen. The basic purpose of the development of a method for shear testing is therefore the selection of specimen geometry and a means of applying load in order to minimize the effect of these zones on bearing capacity. It is particularly necessary to focus
Fig. 1. Schematic diagram of flat shear-test specimens: a) rail method (H = 70 mm, b = 40 mm, t = 3.5-4.0 mm; S is variable parameter); b) Iosipescu method (H = 20 mm, L = 80 mm, t = 3.5-4.0 mm; R and S are variable parameters); c) method of applying torsion to square plate (L = 80 mm, t = 3.5-4.0 mm).

Fig. 2. Schematic diagram of tubular specimen: D = 37 mm; d = 29 mm.

Fig. 3. Coordinate system used in testing flat specimens.

major attention on the method of transmitting load to the specimen in cases of high material shear strength. Since a composite with a [±45°] layup possesses the highest shear strength, the area through which the load is transmitted onto the specimen was increased as compared with the area of the effective section.

The extent to which the stress state deviates from one of pure shear is determined by the length-to-width ratio of the effective section when the rail method is used [2, 3], and by the shape of the notch (depth, angle, and the radius at the tip of the notch) and by the means of load application when the Iosipescu method is used [4-6]. As one would expect, moreover, the degree of deviation also depends heavily on the degree of anisotropy of the elastic properties of the material under investigation and the orientation of the axes of loading with respect to the axes of anisotropy. All this prevents us from formulating universal recommendations concerning the selection of geometric shape, and the conditions under which the specimen is affixed and the load is applied to the latter. When the structure of the material under investigation is altered, this selection, in essence, must be made again; this significantly complicates the acquisition of reliable results with respect to shear strength.