Further Development of the Iosipescu Shear Test Method

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ABSTRACT—Recent activities by the present investigators to further develop the Iosipescu-shear-test method for use with composite materials are summarized. Finite-element analyses used to predict the stress states in the specimen are described, with particular emphasis on how they are influenced by the specific test-fixture configuration used. These same analytical tools were also used to predict the influence of specimen notch depth, notch angle, and notch-root radius. The result was a redesign of the original Wyoming version of the Iosipescu-shear-test fixture, and the establishment of guidelines for preparing specimens. These are discussed in some detail. Many references to available literature are included. An attempt has been made to put the work performed to date into perspective, to aid the potential user of the Iosipescu-shear-test method in establishing proper test procedures.

Introduction

Interest in the use of the Iosipescu shear test as a method of determining the shear properties of composite materials is increasing rapidly as more and more research groups become familiar with its utility. An early paper by Iosipescu contains an excellent description of the theory and implementation of the test, although he was primarily interested in isotropic materials. The adaptation of Iosipescu's test method to composite materials was presented by the present authors in Refs. 2 and 3. While these publications do contain brief surveys of available shear-test methods suitable for composite materials, two more recent publications, Lee and Munro and Spigel, are more complete.

The Composite Materials Research Group at the University of Wyoming continues to promote the Iosipescu shear test as being the best general-purpose shear test for composite materials presently available. The original test fixture described in Refs. 2 and 3 has been recently redesigned to make it easier to use and to produce more accurate results. Both the original and the revised configurations have now been evaluated by others, with generally positive results. The overall opinion is that results produced by the original fixture configuration remain valid and can be used with confidence. More than 100 sets of the original fixture drawings were provided by the present investigators, although it is not known how many fixtures were fabricated. The University of Wyoming also fabricated fixtures for approximately 25 industry and university groups; many of these have been extensively used. In addition, to date more than two dozen of the redesigned fixtures have already been provided to other groups. Fixture drawings have been sent to a large number of others. These drawings have also been published in Refs. 6-8. A double-size fixture has also been fabricated.

The Composite Materials Research Group at the University of Wyoming has not actively promoted the Iosipescu shear test for standardization by Committee D-30 of the American Society for Testing and Materials (ASTM) because of our obviously biased opinion of its superior value as a shear-test method for composite materials. It is presumed that if the test method is as valuable as the present investigators suggest, its increasing use by the composites community will promote its standardization. It is clear that its use is increasing rapidly in all sectors of the composite-materials community.

Background

Since Ref. 3 was published by the present authors in EXPERIMENTAL MECHANICS in March 1983, a considerable amount of additional study of the Iosipescu-shear-test method has been conducted at the University of Wyoming, primarily under the sponsorship of the NASA-Langley Research Center. These basic investigations, documented in detail in Refs. 6-8, will be summarized here. In addition, a number of other investigators have also performed equally detailed studies during this same time; these results have also been published in the literature.

In addition to these basic studies, which were performed for the purpose of better understanding the capabilities and current limitations of the Iosipescu shear test, the present authors have also continued to use the test method to generate shear-properties data for a wide range of types of composite materials. These data are presented in detail elsewhere, as will be referenced, and will be introduced here only as appropriate to support the present discussion.

The first-year study under NASA-Langley sponsorship was totally analytical. A newly developed three-dimen-
sional finite-element analysis and associated computer program, WY03D, was used to analyze the stress states in Iosipescu shear specimens of different configurations, simulating loading conditions imposed by the original fixture design. A photograph of this original fixture is shown in Fig. 1. It represents a scaled-down version of a design obtained from T.R. Place of the Aeronutronic Division of Ford Aerospace and Communications Corporation7 as noted in Refs. 2 and 3. The Aeronutronic fixture was configured to test specimens 100-mm (4-in.) long. The fixture shown in Fig. 1 was designed for 50-mm (2-in.) specimens in order to conserve test-specimen material, the shear testing of carbon-carbon composites being the first application at Wyoming.9 As noted in Ref. 6, some deficiencies in the design of the original fixture were discovered as it was used more and more extensively to test a wide range of composite materials and also some isotropic materials. The principal weakness of the original fixture was that it was designed to apply the forces at the inner loading points too close to the center line of the specimen, i.e., too close to the notches. This caused the influence of the concentrated loadings to spread into the gage-section region of the specimen, i.e., that region directly between the notches. While the influence was not major, as shown by the analysis of Ref. 6, it was undesirable. The solution in the redesign was, of course, to move these loading points outward. A second disadvantage of the original fixture design was that it required the use of a specimen having a very precise height dimension. There was no adjustment in the fixture to accommodate variations. This had not been a problem, or even a consideration, for the present investigators since a surface grinder was routinely used to prepare specimens and dimensional precision was easily achieved. Other groups using the original Wyoming fixture did not necessarily prepare specimens in this manner, however, and found the required dimensional tolerances undesirable. The solution, to use adjustable specimen support points, was diagrammed in Ref. 6 and implemented in the second-year study.7 A less significant disadvantage of the original fixture was the relatively small specimen size it utilized. This small size meant that the region of constant shear strain between notches was small, thus making shear strain measurements more difficult than if the specimen had been larger. Also, the small size of the fixture made it more difficult to install a specimen; it was not fully exposed for viewing during a test. The small specimen size had been selected to conserve material; in many test programs this is very important. As a compromise, it was decided to increase the specimen size by 50 percent when redesigning the fixture.

Current Test-Fixture Design

The current (second) version of the Wyoming fixture is shown in Fig. 2. Full details of the design, including complete drawings, are included in Refs. 7 and 8. The specimen is 75-mm (3-in.) long and 19-mm (0.75-in.) high, and can be of any thickness up to 13 mm (0.5 in.). The inner loading points have been moved out to a distance of 6.3 mm (0.25 in.) from the specimen centerline. This distance for the original fixture was 2.5 mm (0.10 in.).

The adjustable wedges and thumbwheels can be seen in Fig. 2. These are designed to accommodate a variation in specimen height of as much as 1 mm (0.04 in.). Of course, by using shims between the wedges and the specimen, other specimen heights can be tested. This has been done a number of times by the present investigators, including the work of Ref. 8. There, interlaminar shear specimens as thin as 6.4 mm (0.25 in.) were successfully tested. This specimen height, only one-third that for which the current fixture is designed, was dictated by the thickness of the graphite fabric/epoxy composite laminate to be tested. Thick spacers were used between the wedges and the specimen to accommodate the thin material. As an alternative, it would have been possible to adhesively bond two or three thicknesses of the plate material together to make a taller interlaminar shear specimen. This was in fact done in the same study,4 in testing laminates only 4.1-mm (0.16-in.) thick. Three layers of this 16-ply fabric composite laminate were bonded together to form an interlaminar shear specimen nominally 13-mm (0.5-in.) thick. The test results were completely satisfactory. This layering technique has been used many times before by the present investigators also; one such example was presented in Ref. 2. If thicker material is available, it is preferable to use it of course.

The entire front face of the specimen remains visible during testing in the current fixture (see Fig. 2). A specimen can be loaded directly from the front. Failure progression can be monitored visually. Also, the left half of the fixture is now fixed to the base, rather than pivoting on a post as in the original design. Only one half of the fixture needs to move to apply the shear loading. The original concept was that the two halves of the fixture would be identical, and therefore interchangeable. With this simplified fabrication, and if one sleeve bushing became worn, the two halves could be interchanged. In the current design, the two fixture halves are still identical, but one half is rigidly attached to the base by means of a spacer block. The other half still moves up and down on a post, but on a recirculating ball bushing rather than a sleeve bushing. Although the ball bushing is marketed as a fixed-diameter bushing, the tightness of fit can be adjusted to minimize the amount of play in the fixture. The right half of the current fixture is also designed to be easily attached to the crosshead of the testing machine via the adapter shown in Fig. 2. Thus the crosshead holds and positions the fixture, making specimen installation much easier than