ON THE USE OF IOSIPESCU SHEAR TEST FOR CHARACTERIZING SOME COMPOSITE MATERIALS

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Abstract: The test methods that were proposed, for studying the shear properties of composite materials, are numerous, but varied and controversial. As a consequence, there is no method globally accepted at this aim. Nevertheless, one can accept that some methods are considered more suitable for nonhomogeneous and nonisotropic materials.
In that meaning, the test method that was created by professor Iosipescu is one of the main shear tests, at this moment, and as a result it was adopted as a ASTM Standard test method.
This paper presents some experimental results, obtained by applying that method on some carbon/epoxy fiber reinforced composites.

Keywords: composite materials, Iosipescu shear test, shear properties.

1. INTRODUCTION

The experimental test methods for studying the shear properties of composite materials are very numerous [Ref. 6], and are using various loading types and different principles of data analyse and interpretation. Among them, there are some more frequently used methods, thanks mainly to their reliability, stability and repeatability of experimental results. One can consider (see Ref. 1) that at this moment the Iosipescu shear test is the most largely accepted method, mainly on the base of its approaching of the pure shear stress state into the specimen.

2. EXPERIMENTAL METHOD

In principle, the test consists [Ref. 4] in an anti-symmetric load of a double-notched prismatic specimen, in order to obtain a pure shear stress state into its middle transversal section.

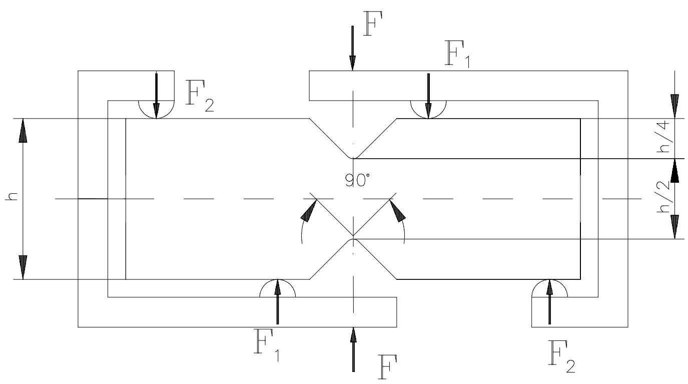

Fig. 1. The pure shear-testing model developed by N. Iosipescu.

Although the test was firstly introduced for metals, it was then developed in order to be applied on composite materials [Ref. 7] and a variety of fixtures were proposed, during the past three decades [Ref. 8], for increasing the reliability of experimental results . One of the earlier type of fixture, dedicated to composites, was developed at the Wyoming University (see Fig. 2), and was then adopted into the ASTM Standard [Ref.9], as a shear test applied to double-notched Iosipescu specimen. Lately, another variant, more stable than Wyoming fixture, was developed, at the Idaho University, by Connant and Oddom [Ref. 2].

In order to establish the shear strain state parameters in the specimen, some strain gages have to be mounted into the transversal section corresponding to the V-notches of the specimen For an accurate measurement of shear strain, special strain gage rosettes were introduced [Ref. 3]. Two types of it, having the grid oriented at ±45° in respect of notches axis, as currently produced by MicroMeasurements (Vishay), are presented in Fig. 3.

Fig. 2. The Wyoming shear test fixture

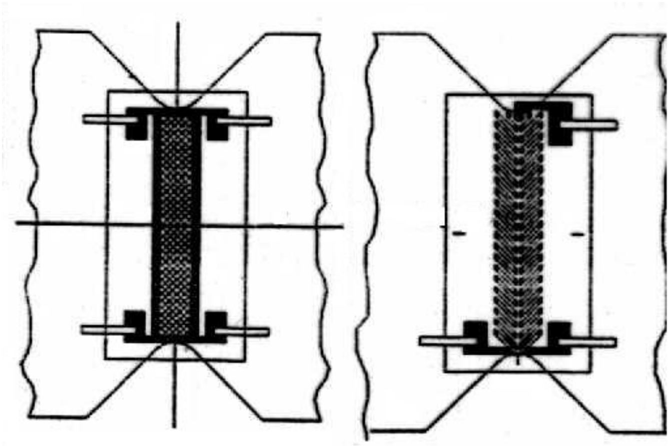

Fig. 3. Strain gages for Iosipescu specimen.

3. MATERIALS AND EXPERIMENTAL DEVICES

In this paper, an Iosipescu shear test is described. The experiments are done according to ASTM Standard D 5379 [Ref. 9], in order to evaluate the shear modulus of the studied composite. A modified Idaho University fixture (Fig. 4) is used, together with a double-side shear gage instrumentation of the double-notched composite specimens. It is important to note that the fixture was designed and realized [Ref. 5] at the Technical University Iasi, and it was utilized for numerous shear tests, during the entire past decade, with very stable and reliable results.

The studied composite is based on an epoxy resin, with unidirectional carbon fibre as reinforcement, in 68% volume content. The specimens are cut from a plate, 3.3mm in thickness, having 24 plies. The gage area of the specimen is:

$$A=3,3\text{mm} \cdot 10,7\text{mm}=35,31\text{mm}^2.$$

The shear gages are produced by Micro Measurements (Vishay) and are on type

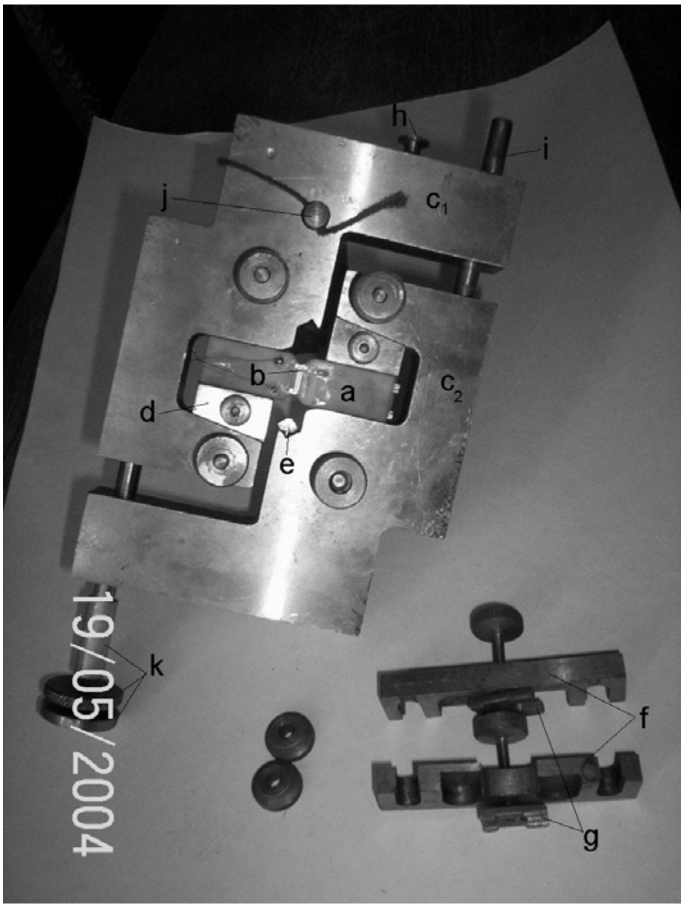

Fig. 4. Iosipescu shear test fixture, made at the Technical University Iaşi:

N2P-08-C032A-500. The tension voltage supply for the Wheatstone bridge was U_A=2V, in order to limit the heating of composite material, into the vicinity of transducers.

In order to obtain an accurate measurement, the shear strain on each rosette was read, separately, for an entire loading-unloading cycle, and with a previous bridge calibration at the beginning of each process. Secondly, the shear strain was determined as the average of signals delivered by the transducers placed both on the front and back of the specimen.

The shear modulus is determined as the slope of the straight line which approximates the shear stress-strain curve, in the loading stage of the experiment:

$$G_{12} = \frac{\Delta\tau_{12}}{\Delta\gamma_{12}} \tag{1}$$

where, $\Delta\tau_{12}$, $\Delta\gamma_{12}$ are the increments of shear stress and strain, respectively, for two precise levels of loading force (see Fig. 4).

For the calculus of the stress increment the following relation is used:

$$\Delta\tau = \frac{\Delta F}{A} = \frac{\Delta F}{w \cdot h} \tag{2}$$

where ΔF is the load increment, and A=wh is the gage area of the specimen.

The shear strain directly results from the extensional strains measured by the two transducers from the gage rosette:

$$\gamma_{12} = \varepsilon_1 - \varepsilon_2 \tag{3}$$

The shear stress level is determined from the loading forces and the sectional area of the specimen. On the other hand, the shear strain values are calculated on the basis of extensional strains indicated by some strain transducers which are transversally placed onto the gage section. It must be emphasized that the real shear strain value must be calculated on the basis of the corresponding instrument indication γ_{12}^{read}, multiplied by the following two factors:

- the ratio of the standard and the real voltage supply of the bridge: 4V/2V=2
- the transverse sensitivity correction factor of transducer, determined from the producer recommendations [Ref.10], as

$$C_{s-tr} = \frac{1-\nu_0 K_t}{1+K_t} = \frac{1-0,285 \cdot 0,019}{1+0,019} = 0,97604 \tag{4}$$

As a consequence, the effective shear strain is:

$$\gamma_{12} = \varepsilon_{+45^\circ} - \varepsilon_{-45^\circ} = 2 \cdot 0,97604 \cdot \gamma_{12}^{read} = 1,952\gamma_{12}^{read} \tag{5}$$

In order to be replaced into the above relation (1), the strain increment $\Delta\gamma_{12}$ is determined as the difference of the shear strains corresponding to two different level of loading force, the same values that were used at the calculus of $\Delta\tau_{12}$ (Fig. 4).

4. RESULTS AND CONCLUSIONS

On the basis of experimental data, one can plot the shear stress-strain dependence for the studied material. As a consequence, the shear modulus can be determined as the slope of the trend line of that curve, plotted by a mathematical computer programme (Fig. 5). On the other hand, one can observe that the shear modulus value is done by the coefficient of the shear strain term, γ, from the trend line equation. As an example, using the experimental results that were plotted in figure, the value of shear modulus is:

$$G_{12} = 6730{,}1\text{MPa}.$$

That value of shear modulus can be evaluated to be in good agreement with experimental data that are presented in literature for unidirectional carbon/epoxy composites, and also with the results previously obtained, by the same authors, using some other types of test methods.

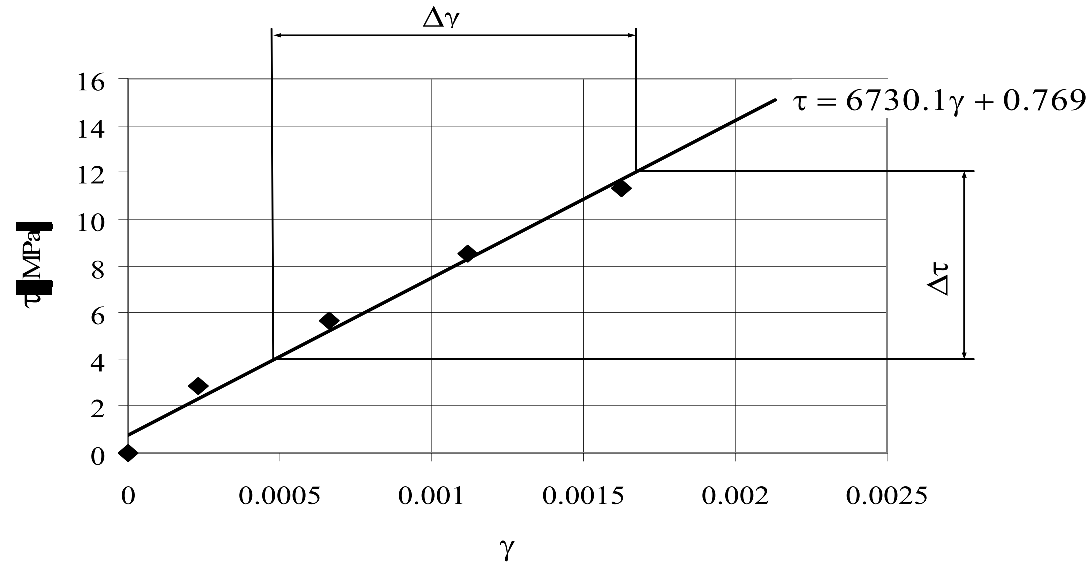

Fig. 5. The typical trend line for the shear stress-strain response of the studied composite.

One can conclude that the Iosipescu shear test leads to an accurate determination of shear modulus of composite materials, on condition that one can use a precise fixture design, with respect to the entire experimental procedure indicated by the standard test method.

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