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► **To cite this version:**

Karim Mharsi, Pascal Casari, Amira Sellami, Jamal Fajoui, Mohamed Kchaou. Mechanical Characterization of a Composite Sandwich Core Under Shear Stress Based on a Torsion Test. International Conference on Advances in Mechanical Engineering and Mechanics (ICAMEM 2019), Dec 2019, Hammamet, Tunisia. pp.299-305, 10.1007/978-3-030-52071-7_41 . hal-04755106

HAL Id: hal-04755106

<https://hal.science/hal-04755106v1>

Submitted on 26 Oct 2024

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Mechanical Characterization of a Composite Sandwich Core Under Shear Stress Based on a Torsion Test

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Abstract. The development of modern technologies requires the use of materials with high mechanical properties and lightest weight structure. With their low density, high strength, high rigidity and excellent durability, the sandwich structures are one of the best materials to meet these requirements. Despite of these advantages, sandwich structure is rather sensitive to failure by shear load. Previous work has shown that standard shear characterization tests of a sandwich structure (ASTM C273, Standard Test Method for Shear Properties of Sandwich Core Materials) exhibits shear stress concentrations at the edges, which negatively affect the results of this test. To solve this issue, this research work proposes a new test methodology to determine shear properties using a torsion test. A custom test rig has been developed in order to exert a torsional moment on a cylindrical specimen made of PVC foam. Based on the experimental results, this new test method provides a more precise characterization of the sandwich core materials since it eliminates the phenomenon of concentration of shear stresses on the edges found in the standard test.

Keywords: Sandwich structure · Shear test · Foam PVC · Torsion

1 Introduction

Sandwich structures are distinguished from other materials such as metals, ceramics and polymers by the fact that they consist of:

- Two skins, or face sheets; made of relatively high strength materials.
- A core material; much thicker with low density.

The core and the two face sheets are mechanically separable (Fig. 1). The mechanical properties of the sandwich structure can, therefore, be modified by varying the proportions or the properties of its constituents. These adjustments make it possible

to obtain the desired properties for applications which require a very high stiffness/mass ratio. Under solicitations, the core undergoes shear loading and the skins takes traction and compression loadings [1].

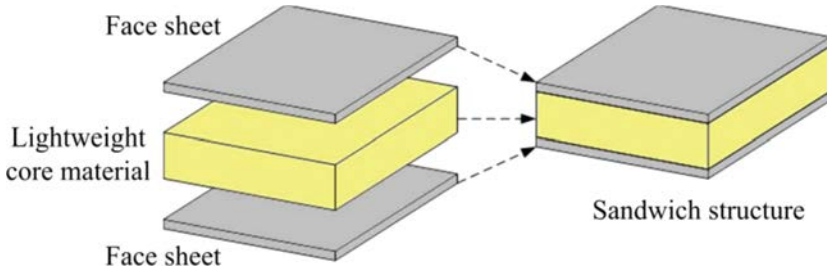


Fig. 1. Sandwich structure [1]

The determination of the mechanical properties of these structures is essential to predict their behavior in specific environments and solicitations [2].

Several researchers [3, 4] performed bending tests under static and cyclic loading conditions in order to identify the mechanical flexural properties of the sandwich material. This bending test was carried out according to ASTM C393 and D790 [5, 6].

Yet, this research work aims to identify the shear properties of the core of the sandwich structure, because during the service of a sandwich structure, the shear stresses are significant at the level of the core. ASTM C273 is one of the most widely used standardized tests to meet this need. The Fig. 2 shows the geometry of the specimen and the used technique.

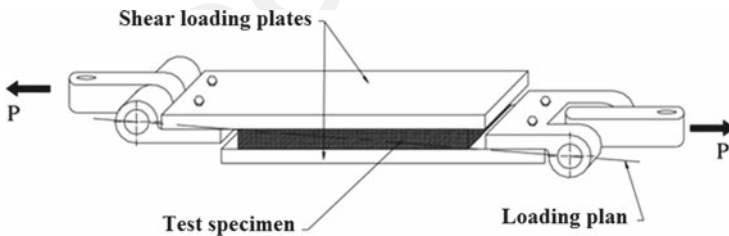


Fig. 2. Shear tests of Sandwich Core Materials: Standard C273 [7]

Experimental and numerical tests were performed for the ASTM C273 test. As the results show below (Fig. 3), the experimental test and the numerical simulation of the ASTM C273 test reveal that the shear stresses are concentrated at the edge of the specimen. For a static load, the concentration of shear stresses may not have much influence on the results, but with a cyclic load, it will be more influential.

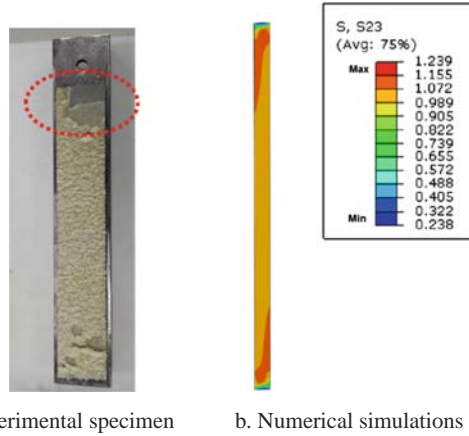


Fig. 3. S23 shear stresses concentrated at the edge of the sample of the ASTM C273 standard specimen [8]

Therefore, it is necessary to propose a new shear test methodology which eliminate stress concentration at the edges, gives the same results as the standard during a static load and improves the results of fatigue characterization.

2 Torsional Rig Shear Test

A new test rig has been designed in order to determine the mechanical shear properties of the core of the sandwich structure. The assembly applies a torque to a cylindrical PVC foam test specimen (Fig. 4).

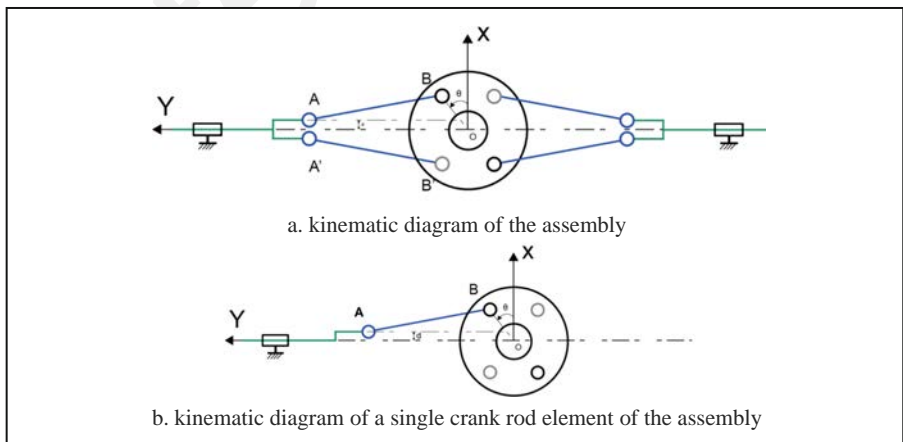


Fig. 4. Kinematic diagram of the assembly

It can be considered as a combination of two crank-rod mechanisms mounted in opposition in order to have two opposite torsion moments. These two moments produce shear at the section of the cylindrical specimen. The kinematic diagram of the assembly is presented in the Fig. 5-a. To simplify, we isolated a single crank rod element (Fig. 5-b).

As a hypothesis, we consider that the system's efficiency is equal to 1, the crank turns at a constant speed and the inertia is negligible. A simplified relationship is established giving the torque C as a function of the force F from the equality of the powers consumed and supplied.

$$C\omega = FV \quad (1)$$

The torque applied to the test piece can be expressed according to the geometric parameters as follows:

$$M_t = 4 \times C = 4F \times \left(R \left(\cos \theta + \frac{\sin \theta (\cos \theta + \varepsilon)}{\sqrt{\left(\frac{L}{R}\right)^2 - (\cos \theta + \varepsilon)^2}} \right) \right) \quad (2)$$

with; $d = \varepsilon \times R$.

For small displacements, we can get a simplified expression of the maximum torsional stress.

$$\tau_{max} = \frac{R}{\pi(R^4 - r^4)} \times M_t \quad (3)$$

$$\tau_{max} = 2F \frac{R^2}{\pi(R^4 - r^4)} \times \cos \theta \quad (4)$$

The following figure shows the torsion test rig assembled and mounted on the traction machine with its CAD design on Solidworks (Fig. 5).

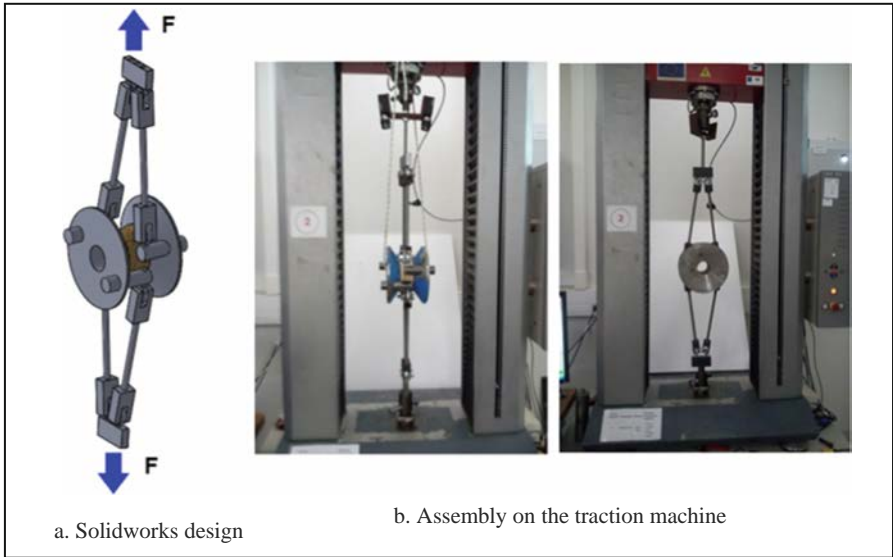


Fig. 5. Torsion assembly

3 Results and Discussion

The test has been done on the traction machine using this new assembly. The values of the applied force F has been recorded in order to trace the evolution of the maximum torsional stress during the test (Fig. 6).

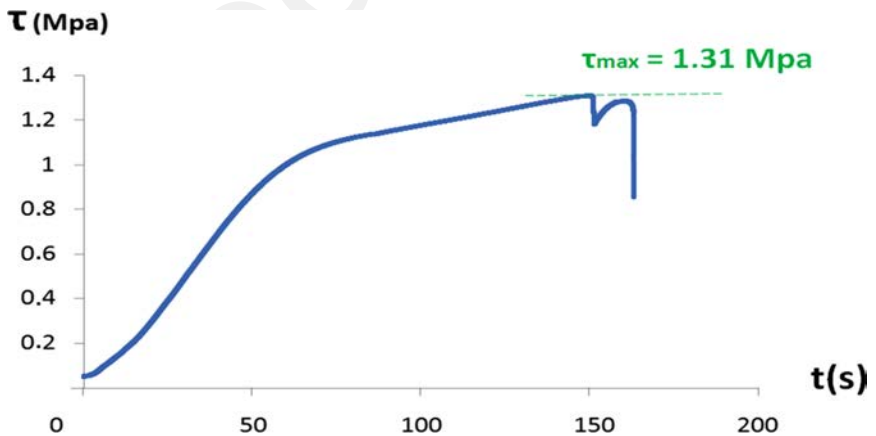


Fig. 6. Evolution of the maximum torsional stress during the test

The deformation values were recorded using digital image correlation (DIC), Fig. 7. This method enables us to draw the stress as a function of the deformation.

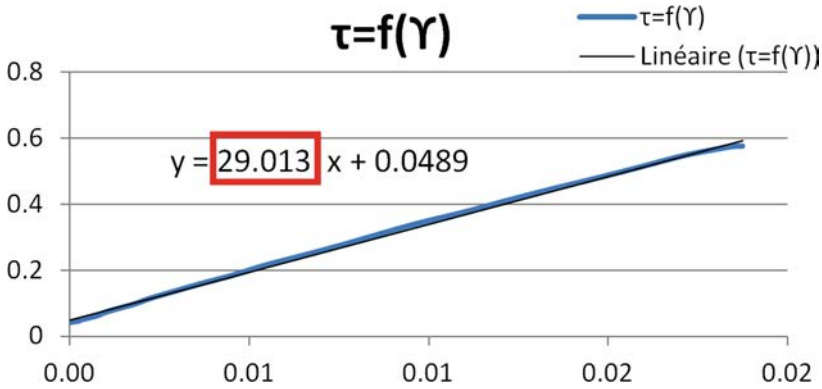


Fig. 7. Deformations according to shear stresses

The shear modulus G of the PVC specimen can be deduced graphically. It presents the slope of the curve $\tau = f(\gamma)$ in the elastic response region. The value found matches well to that mentioned in the Divinycell H100 foam data sheet used in this test.

4 Conclusion

The phenomenon of shear stress concentration at the edges of the shear characterization test (ASTM C273) may not be very influential for static characterization. But for a fatigue characterization, this phenomenon will influence the results considerably. The proposed new method relies on a torsion test using a cylindrical specimen which, according to the preliminary results found, avoided this unwanted phenomenon.

As a perspective, this method will be used equally for fatigue characterization test using H100 PVC foam as core material.

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