EVALUATION OF A NEW EXPERIMENTAL DEVICE FOR SHEAR MODULUS MEASUREMENT

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ABSTRACT

The identification of the different stiffnesses of an orthotropic behavior of laminate composite or 3D printing material needs different samples geometries. To avoid this, this paper is dedicated to study an experimental device for the characterization of shear modulus, the « single cube apparatus » (SCA) figure 2.b, previously developed for wood using the same specimen geometry for all the stiffnesses coefficients. [1]. It is just required to rotate the sample following the different loading directions. A numerical study is also performed in order to provide a correction factor [2]. This factor is calculated in the shear zone, figure 1.b., with the maximum shear strain divided by the mean shear. Moreover, the shape specimen is a cube and the specimen size is reduced (10 x 10 x 10 mm when in [2] the sample size was 40 x 40 x 40 mm) while Arcan device [3], which also classically used to measure shear modulus, needs butterfly specimen. In our knowledge, this setup has never been used for composite laminate or 3D printing materials.
We propose to improve the setup previously design for wood in [1] to study the shear behavior of an orthotropic 3D printing ABS sample.
In order to improve the experimental setup, and particularly because no information is given concerning the shear zone (L) and the angle of the device (θ), we propose to simulate the shear test and the device using ABAQUS Implicit (Dassault Systèmes®, France). The design of the experimental setup is simplified following figure 1. The shear length range L needs to respect L ∈ [1,4] mm and [20,45]° because over these values, the setup is unstable. The geometries are imported in Abaqus finite element software. The grips are in steel (E = 210 000 MPa, ν = 0.3) and the sample is in ABS and assumed isotropic (E = 1 200 MPa, ν = 0.4). The contact is assumed without friction. The inferior grip is fixed in all directions. A vertical force (2 000 N) is imposed to the superior grip. This configuration induces shear in the sample.
A parametric analysis is then performed which goal is to maximize the shear between the grips. The correction factor is then calculated using this finite element simulation. The grips are meshed by 110 000 hexahedral elements and the sample is meshed with 64 000 hexahedral elements.

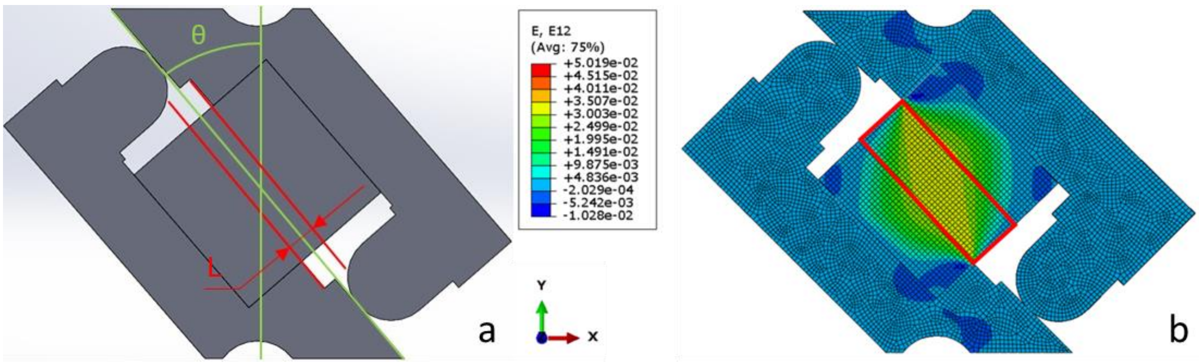

Figure 1: a. Numerical model, θ angle between load application axis and longitudinal direction of the sample. L is the length of the shear zone; b. Deformation due to shear stress and shear zone in red.

After simulations, the configuration that leads to maximizing the shear behavior in the central region of the sample is the one where L = 4 mm and θ = 45°. In this case, the factor correction is 1.8.

Experimental validation of the previous simulations is then performed. Different ABS cubes are processed by 3D printing on Zotrax M200 plus. Density is 100% and lines oriented at ± 45° are processed. 9 cubic samples with 10 mm length are fabricated from the blocs in order to avoid irregular surfaces of the cubes. 9 prismatic specimens of section 10 x 10 mm and length 80 mm are manufactured for the Iosipescu tests [4], particular attention is paid at this time to the orientation of the specimens so that the tests carried out allow us to characterize G12, G13 and G23 (figure 2.c). Samples manufactured by 3D printing, figure 2.a. are used. The tests are carried out on an Instron E10000 tensile compression machine. A displacement of 1 mm/min is imposed for both types of test.

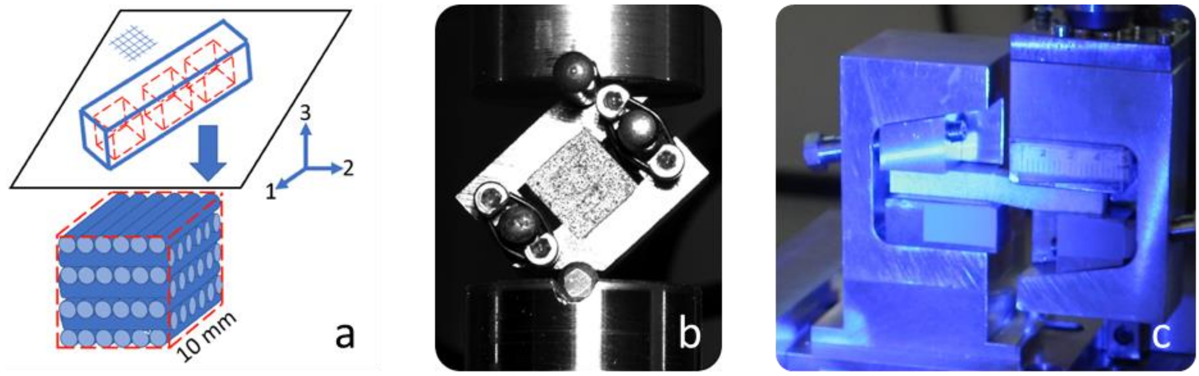

Figure 2: a. Samples production; b. Single cube apparatus (SCA); c. Iosipescu setup with the sample position.

The shear modulus obtained by the new experimental setup is then compared to shear modulus measured with a classical Iosipescu experimental device. For this, the results of the cube tests are processed according to the protocol described by Hassel, B et al [2] and the Iosipescu tests are processed according to ASTM D5379 [5]. The results with Iosipescu test are G12 = 560 ± 21 MPa, G13 = 448 ± 14 MPa and G23 = 458 ± 21 MPa. While SCA test give G12 = 548 ± 27 MPa, G13 = 550 ± 53 MPa and G23 = 517 ± 43 MPa. The average error between the two methods is 12.5%. Adding image correlation to the processing of the tests with cubes should reduce this error.

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