Identification of the elastic properties in CFRP composites

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The mechanical characterization of composite materials encounters nowadays a major interest due to their increasing use in the aeronautic industry. The design of most of these materials is based on their stiffness, which is mainly obtained by means of static measurement.

Regarding non-destructive evaluations, the measurement of ultrasonic wave velocities constitutes a qualified technique for the acquisition of the elastic constants of composite materials [1]. By sending several ultrasonic bulk waves within the material, phase velocity is calculated and thus the elastic constants can be obtained through the inversion of the Christoffel equation [2]:

$$\left| C_{ijkl} n_i n_l - \delta_{jm} \rho V_p^2 \right| = 0 \qquad (1)$$

In this paper, the elastic constants of a unidirectional carbon fiber reinforced laminates were determined with the back-reflection ultrasonic technique in immersion. For such anisotropic plates with small thickness, the time of flight was measured at different incidents angles θ_i (figure 1) using numerical methods [3].

In order to validate the ultrasonic characterization, classical mechanical characterizations using tensile tests were also performed for the same material and for 3 different directions of the fiber axis (0°, 90° and 45°). Deformation gauges were used to measure the axial and lateral strains and stiffness constants were then estimated from the elastic parts of the stress-strain curves. At the same time, a digital image correlation system was also implemented to corroborate the gauge data. Such technique aims at matching two digital images of a surface observed at two different states of strain [4]. The processed image allows then to obtain the deformation at these points for each loading condition.

These three results of stiffness tensor measurement (ultrasonic characterization, strain gauges and digital image correlation during tensile tests) were compared to literature and to the material manufacturer [Hexcel Corporation®] to evaluate the accuracy of the characterization methods. The calculated Young's modulus in the fiber axis using strain gauges was more accurate than ultrasonic characterization and digital image correlation in regards with the material manufacturer. Nevertheless, the other elastic constants were calculated with good accuracy for the three methods.

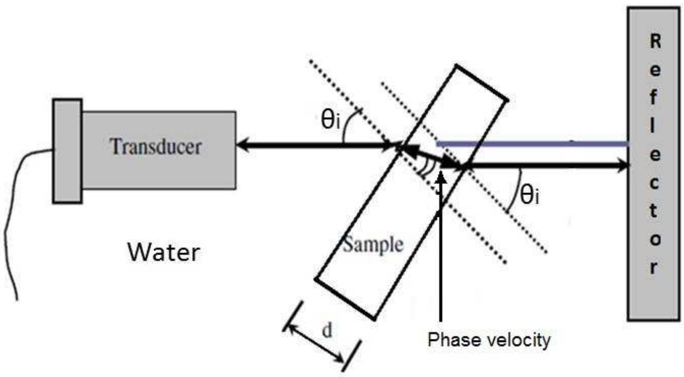

Figure 1 – Experimental setup for ultrasonic characterization

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