X-µCT AND DVC USE FOR COMPOSITE MATERIALS ANALYSIS

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ABSTRACT: The complex mechanical behaviour of composite materials, due to internal heterogeneity and multi-layered composition imposes deeper studies. This paper presents an experimental protocol to perform volume kinematic measurements in composite materials. This work is centered on the transverse shear effects in relation with the composite materials mechanical behaviour. A lot of theories exist in literature to consider the existing warping section during high transverse shear stresses, but very few studies have been realized in the experimental way. The association of X-ray micro-computed tomography acquisitions and Digital Volume Correlation (DVC) technique allows the measurement of displacements and deformations in the whole volume of composite specimen. To elaborate the latter, composite fibres and epoxy resin are associated with metallic particles to make contrast in X-µCT acquisitions. A specific *in-situ* loading device is presented for three-point bending tests, which enables the visualization of transverse shear effects in composite structures.

1. CONTEXT

Up to the present numerous studies have been performed about the mechanical response of composite structures, at different scales. Among the characteristics of composite materials, transverse shear stress effects constitute an important phenomenon which must be taken into account in the design of composite structures. Structural damages or fractures can occur because of wrong evaluation of the transverse shear effects. A large number of works show that the warping of sections due to the transverse shear can be identify with various analytical theories. Kirchhoff-Love and Reissner-Mindlin have respectively proposed the classical and natural theories to consider these effects, which are now available in commercial finite element softwares. More recently, refined theories have been developed on the formulation of warping functions $f(x_3)$ (Figure 1) [1,2]. However, very few studies exist on the identification and the validation of these theories by the experimental way. This paper which is a part of a research project, which deals with the visualization of transverse shear effects from volume measurements, with the major interest of observing the evolution of results in the thickness. It is proposed to develop an experimental method to make 3D displacement fields measurements in composite structure volumes.

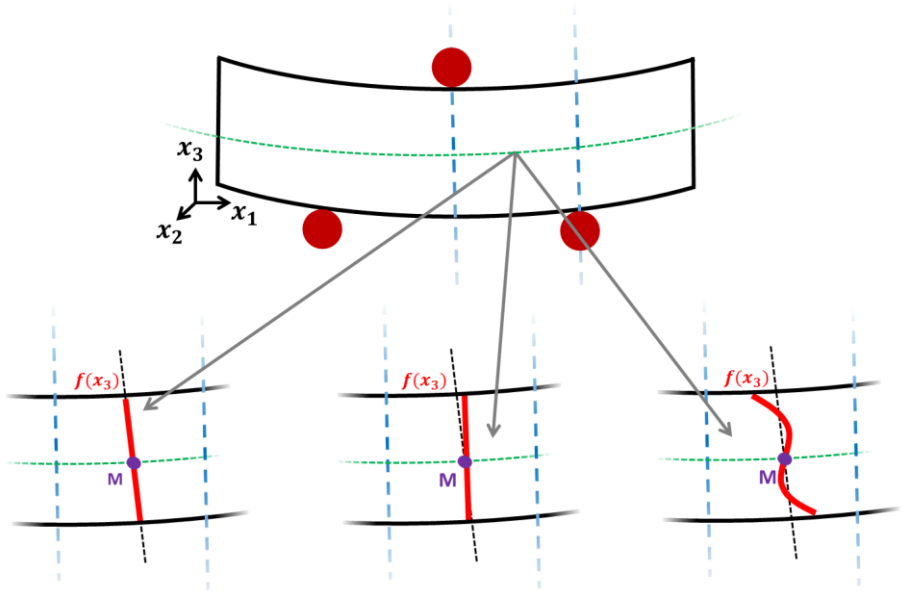

Figure 1- Analytical theories for transverse shear effects analysis

2. EXPERIMENTAL TECHNIQUES

This work aims to perform experimental observations within composite materials under loading. For that, a laboratory X-ray micro-tomography (X-µCT) device is employed. Furthermore, experimental measurements of displacement fields within the material must be performed from a volume measurement method. That's why it is proposed to use the Digital Volume Correlation (DVC) technique. Volume measurement techniques are very interesting

to perform kinematic calculations which provide a high level of results [3-6]. As it is made for 2D field measurement techniques where a specific speckle pattern is used to make the discretization of specimen surfaces, a 3D pattern must be made inside the composite structure, by marker inclusion, to make a 3D grey level distribution.

A specific in-situ loading device is proposed in order to perform measurements in the three-point bending testing configuration. Bending case is chosen to impose shear stresses, which allowing the warping visualization. The new device allows bending loadings to analyze other 3D mechanical effects linked with transverse mechanical response. Also, tests are carried out at the scale of composite structures, which is new in comparison with previous volume measurement studies. Figure 2 presents an example of displacement field obtained by DVC during bending tests.

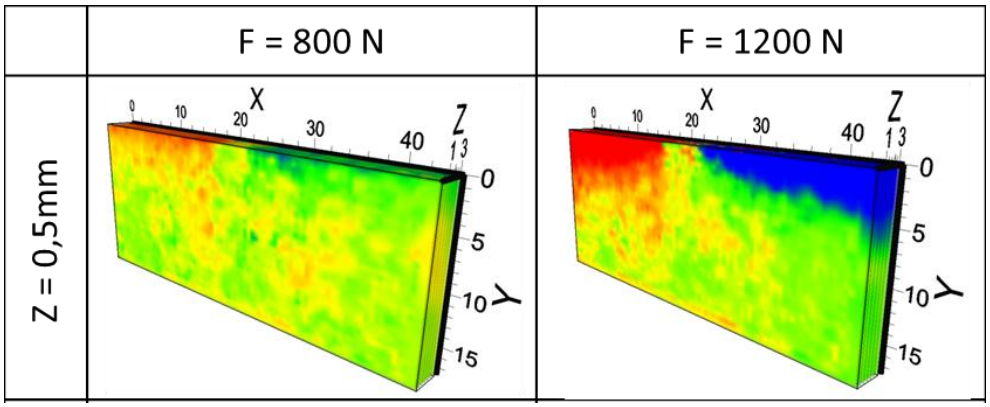

Figure 2 – Longitudinal displacement field measured by X-µCT and DVC

3. RESULTS

Different kinds of results are used in this study. Experiments from DVC are confronted to the analytical values, calculated with different warping functions. A numerical modelling is also used to constitute the reference results of the work. All results are analysed to study the transverse shear effects in the thickness direction. Also, numerical modelling and theoretical theories are discussed to determine their validity, regarding of the mechanical properties and the specimen geometry. For metrology aspects, the global error is determined to validate the DVC parameters and the use of metallic particles in the composite structures.

4. REFERENCES

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