Using a high-resolution full-field measurement technique to study heterogeneous strain fields obtained during an off-axis test on T700GC/M21 unidirectional composite.

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Full-field kinematic measurement techniques such as Digital Image Correlation (DIC) are widely used nowadays in experimental mechanics. Indeed, thanks to the wealth of data they provide, such measurement techniques perfectly are well-suited to feed characterization methods. Composite materials, which feature by essence heterogeneous material properties, are excellent candidates whose characterization is greatly facilitated by the use of full-field measurement techniques. Indeed, the latter provide the heterogeneities of the strain fields that appear on the specimen surface under loading. A keypoint with DIC, is that the method relies on a random pattern deposited on the specimen surface. Yet, although such patterns help solve the DIC problem it is not optimal because it does not lead to the best metrological performance. Indeed, the gray level gradient of such patterns is not maximal [1]. The aim of this study is to use a technique based on optimized checkerboard patterns to observe and to quantify the heterogeneity of the strain fields that occur in a unidirectional composite specimen subjected to off-axis loading. Gray levels gradients are maximum for this kind of pattern, and this guarantees the best possible metrological performance [1,2]. However, classic DIC cannot handle the corresponding images due to the periodicity of the pattern. The extraction of the displacement and strain fields are therefore performed here with an adapted spectral technique called Localized Spectrum Analysis (LSA) [3]. This technique almost directly minimizes the optical residual in the frequency domain, while DIC iteratively minimizes the same residual in the spatial domain.
It has been shown recently that micro-checkerboard can be deposited with a laser marking technique on flat specimens which must be white painted before [4]. The specimen tested here is a unidirectional T700GC/M21 carbon/epoxy composite equipped with two oblique glass/epoxy tabs bonded at the ends to limit undesirable effects due to shear coupling [5] see (Fig. 1).

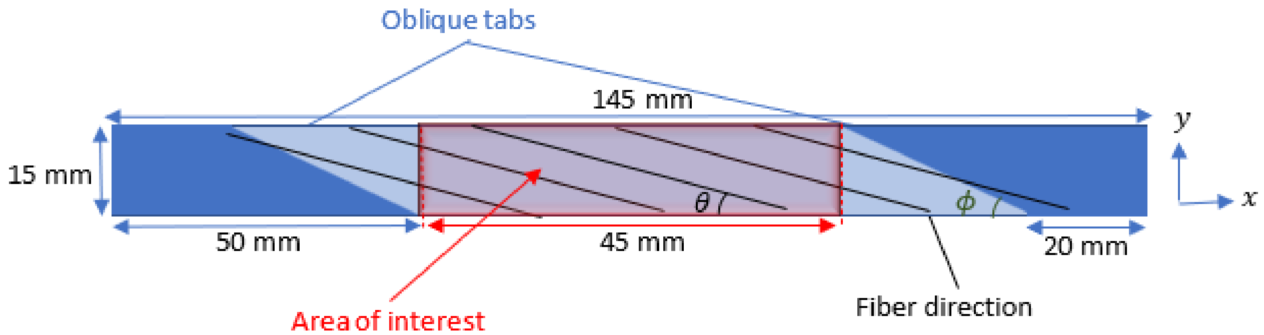

Fig. 1: Schematic of the T700GC/M21 specimens used in the off-axis tensile tests, ϕ=37° and θ=30°

Checkerboards of 32 µm squares were deposited on the specimen, see (Fig. 2). The strain fields are obtained at the pixel level, on a measurement basis corresponding to circles of about 200 microns in diameter. This leads to strain maps featuring highly localized information. The fibers are oriented at 30 degrees with respect to the specimen axis. A cyclic quasi-static tensile test was conducted with an increase in load at each cycle. The objective is to observe the viscoelastic behavior of the composite and its damage through a possible residual strain after each load increment. In this cyclic test, 10 loading steps interspersed with 10 unload steps were performed. A relaxation time of 1000 seconds was applied at each step (Fig. 2). A 29 million pixel Prosilica camera was used to take 100 images in each loading and unload step. The size of a pixel is approximately 9.5 µm in size after projection on the specimen.

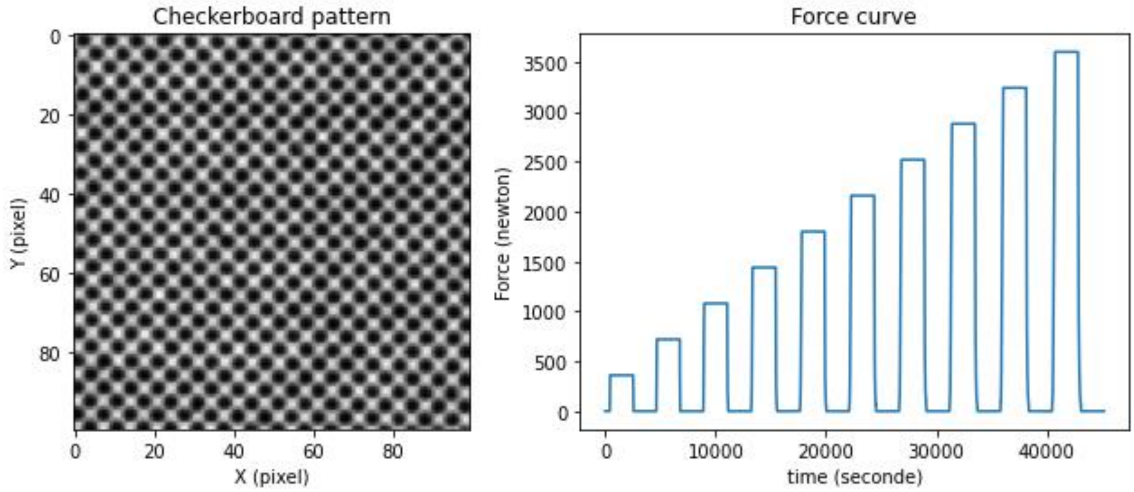

Fig. 2: Right: Image of the 64 µm pitch checkerboard used in the cyclic test. Left: Loading versus time curve applied in the cyclic test.

The high resolution of the pattern, and hence of the measurements, reveals marked heterogeneous strain maps, see (Fig. 3). These heterogeneities are obviously more related to the microstructure of the composite than to the effects of the shear coupling that may occur during such an off-axis test.

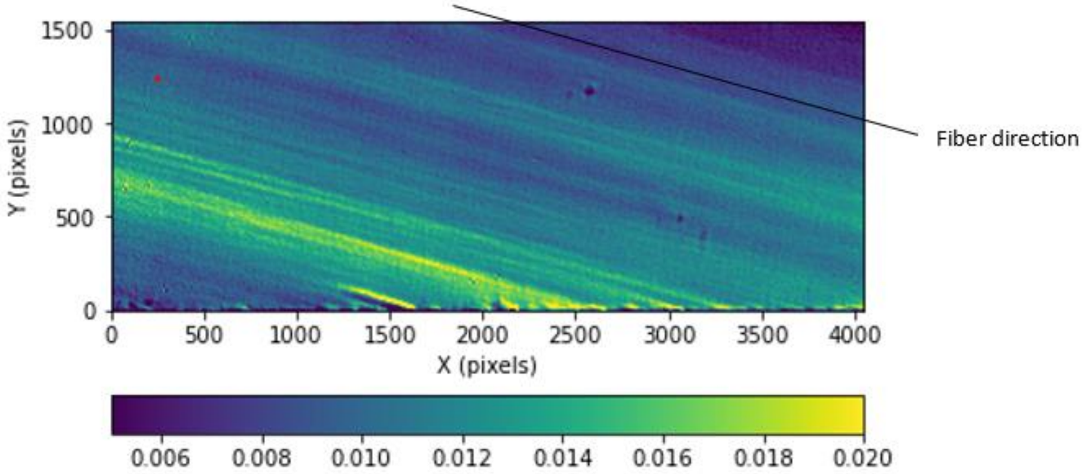

Fig. 3: Shear strain map at the end of the last loading step (F=3600N), the red circle shows the size of the area used to calculate the strain at each pixel

Various strain maps obtained during this cyclic test will be discussed during the presentation. The heterogeneities observed in these maps will also be analyzed and discussed, particularly with regard to the average deformations expected for this type of test.

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