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# MATERIAL TESTING 2.0 FOR COMPOSITES

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## ABSTRACT

Most of the current material testing procedures and standards have been designed at a time when camera-based full-field measurements were not available and only point-wise sensors could be used, like extensometers or strain gauges. As a consequence, such test configurations rely on simple strain fields (uniform, linear) that can easily be approached with such point sensors, and statically determinate stress solutions to obtain local stress information from global load-cell readings. While such tests are easy to analyse, they rely on strong assumptions on boundary conditions and specimen homogeneity, and are poor in contents, leading to the need for numerous test configurations to be used to calibrate complex constitutive models. This approach is denoted Material Testing 1.0 (MT1.0) and is illustrated in Figure 1.

Image-based deformation measurements like Digital Image Correlation (DIC) are now widespread in both academia and industry. They typically provide in excess of tens of thousands of independent data points at the surface of the test object, leading to what is often referred to as 'full-field' measurements, though rigorously, they are only 'spatially dense' as the data are still of a discrete nature. Interestingly, while the technological step between a few and tens of thousands of strain readings is spectacular, DIC and similar techniques are still mostly used in conjunction with MT1.0 test configurations and the design of new test procedures taking full advantage of this wealth of data is somewhat lagging. Such new test configurations rely on more complex test geometries and loadings leading to heterogeneous states of stress and strain. Such tests represent a much richer experimental window on the material behaviour, as each measurement point is like an independent MT1.0 test. The price to pay for this is the availability of such full-field measurements and the use of inverse techniques to relate the deformation field to the sought parameters. Fortunately, both families of techniques are now sufficiently mature to allow for the design space to be explored for these new tests [1, 2]. Recently [3], this new paradigm of mechanical testing has been christened Material Testing 2.0 (MT2.0) and is illustrated in Figure 1.

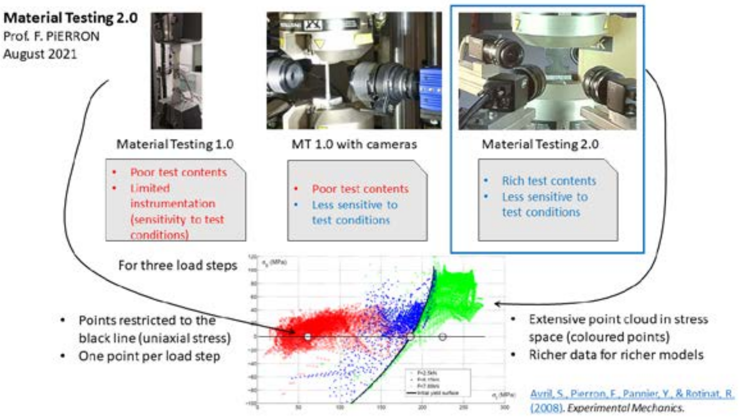

Figure 1: MT2.0 concept

To date, the bulk of the work on MT2.0 for composites has been devoted to orthotropic elasticity. Standard test procedures rely on three different tests to identify the four orthotropic stiffness components of thin unidirectional composite plates: a tensile test in the fibre direction, a tensile test across the fibre direction and a shear test, like an off-axis tensile test or a double V-notch shear test. Early MT2.0 efforts have been conducted to obtain these four components on a single test [4], with the first attempt dating back to 1990 [5], but an optimal and fully validated test is still missing. The presentation will review the current state of the art in MT2.0 test configurations for composites elasticity.

While most of the test designs reported above have been the result of the researchers' intuition, often recycling test ideas from MT1.0 (see for instance [6] where the test is inspired from the double V-notch shear test but with the notches removed), there is a need for a systematic approach to test design. This is sketched in [3] and relies on a realistic simulator that uses synthetic image deformation to take into account both camera noise and the low-pass filtering effect of DIC. This approach, akin to a Digital Virtual Twin, was applied in [7] on foams but there is a need for a more in-depth exploration and validation for fibre composites, along the line of the data in [8]. A VAMAS Technical Working Area (TWA) is currently being set up and a working group on the design of a single test for all orthotropic in-plane stiffness components determination is being constituted to move towards a new standard.

In addition, MT2.0 can be extended to nonlinear behaviour, damage and fracture. Ref. [6] already considered a damage model for the shear behaviour but other applications will need to be developed. For instance, creep testing is very time consuming, with the need to use many separate specimens to build a creep curve. An MT2.0 test has the potential to provide a whole segment of the creep curve in a single specimen, leading to significant reduction in testing times. The same idea could be applied to fatigue. As for fracture, it may prove relevant to identify damage and failure criteria directly on MT2.0 configurations where stress and strain states are more representative than in uniaxial tests. The presentation will offer some insight into the research needed to expend MT2.0 to these areas.

In conclusion, MT2.0 has the potential to bridge the gap between advanced simulation and material testing to reduce the test pyramid, speed up test campaigns and increase the fidelity of models.

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