11th International Conference on Composites Testing and Model Identification
J. Costa, J. Renart and N. Blanco (Editors)
Girona, 2023

2013-2023: TEN YEARS OF EXPERIMENTAL, NUMERICAL AND MEASUREMENT DEVELOPMENTS WITH THE VERTEX MULTIAXIAL TEST BENCH

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Keywords: Notched Composite Plate, Test pyramid, Non-Proportional Loading, Envelope Validation Method

ABSTRACT

The VERTEX test bench (Figure 1) was designed to fulfil the need of virtual testing in the framework of certification of aeronautical structures. Funding obtained in 2013 for a total amount of 3000 k€ made it possible to both fund the test rig design and manufacturing (500 k€) and initiate research. The choice of the design of the machine and the size of the specimen is based on a first experience of Castanié et al [1]. The specimens [1] are said to be technological in the sense that they do not represent a particular part of an aircraft but a technology and/or make it possible to study a scientific or industrial problem. In the first version, the area of interest (200 x 200mm^2) proved to be too small and difficulties in finding the force and moment fluxes locally applied were raised. As a result, the area of interest was quadrupled (400 x 400 mm^2) in VERTEX and a specific test/calculation dialogue had to be developed. VERTEX provides a low-cost solution for testing at an intermediate scale, representative of larger scale tests, to provide rapid feedback on new technologies and/or materials. The machine is mainly made up of a tubular box on which the specimen is bolted to complete the upper face of the central part. Jacks 1 and 2 can be pushed or pulled symmetrically to bend the box, locally creating tension or compression on the sample. Jacks 3 and 4 can be pushed to twist the centre of the box, locally creating shear on the sample. An air-pressurised rubber bladder can be added in the central box to load the sample with pressure. The four jacks and the bladder pressure can be controlled independently to apply combined structural loadings in tension/compression + shear + pressure on the sample.

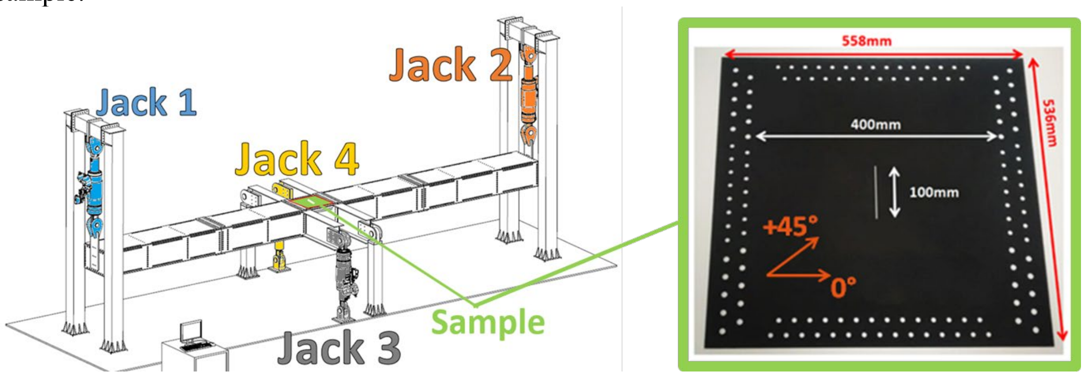

Figure 1: The VERTEX test bench and overview of a large notch specimen.

In the first work by Serra et al. [2], a specific full-field measurement technique was developed. It is based on a multi-camera instrumentation and an original Finite Element approach to Stereo Digital Image Correlation (FE-SDIC). Within such a framework, given that the very same mesh can be used for the simulation and the measurement, the corresponding displacements can be compared directly. In addition, a mechanical regularization of the FE-SDIC measurements allowed mechanically consistent fields to be evaluated, such as displacement and rotation fields that could be used as boundary conditions in the simulations. The experimental procedure, the measurement methodologies and the calculation/test dialogue were validated on isotropic metallic plates.

One of the important issues in the certification of composite aeronautical structures is large notches [3]. Tests were carried out on technological specimens under tensile, shear and combined loadings. Strong interactions between postbuckling and propagation of cuts were observed. The specifically developed FE-SDIC methodology allowed a first dialog between calculation and testing. The Discrete Ply Modeling method is able to compute the onset of failure in such complex tests. New test responses called "envelope curves" were proposed. They are obtained by following a load path that allows the behavior of the notched structure to be validated for certification purposes. This point was also developed recently and is presented in a companion paper.
In the same way, Trellu et al. [4] used the VERTEX test bench to study the combined loading after impact of Carbon Fiber Reinforced Plastics (CFRP) plates and highlight a specific behavior quite different from the usual CAI (Compression After Impact) response at the scale of coupons. In particular, compression, shear and combined shear/compression loadings were applied to large CFRP laminated plates and the interaction of the impact damage with the post-buckling behavior has been investigated. This structural detail method offers the possibility of a closer approach to the behavior of real structures.
Ginot et al. [5] used the VERTEX methodology to the study the local buckling of light aircraft sandwich structures which can be the primary cause of failure of such structures. Sandwich specimens were specifically designed and were tested under compressive and shear loading. A wrinkling scenario was identified thanks to Stereo Digital Image Correlation and a high-speed camera. Wrinkling localisation is driven by mechanical and geometrical aspects. Experiments on wrinkling in sandwich panels remain rare in the literature at this level of the test pyramid for certification of aeronautical structures. This upper scale presents some advantages as it allows multiaxial loading and boundary conditions consistent with a lightweight aeronautical structure.
In the framework of the VIRTUOSE Project [6] thermoplastic notched specimens were tested and a numerical model of the bench to understand and predict complex boundary conditions was developed. Preliminary tests on impacted composite stiffened structures were also carried out.

The VERTEX test bench has demonstrated its capacity and usefulness for testing aeronautical structures, both for light aviation and large aircrafts manufacturers. Phenomena and rupture scenarios different from overly simplistic and conservative coupon tests have been demonstrated, in particular for compression after impact and large notches. However, the procedures for implementing the test and the management of stress flows and boundary conditions require additional analyzes before making it a test certified by the aviation authorities. Future work will focus on analysis of thermoset and thermoplastic stiffened panels and on wood-based sandwich structures for light aviation.

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