Progress in Full-Field Data Fusion for a Complex CFRP Aero Structure

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Introduction

Complex geometry Carbon Fibre Reinforced Polymers (CFRP) components exist in a range of engineering and structural applications. Yet, design verification and performance validation are ongoing challenges. Validation of predictive models becomes increasingly challenging with increasing part complexity, since stress and strain states are complex and more difficult to obtain through measurements using traditional techniques. In contrast, full field methods are non-contact and capture stress and strain over regions of interest rather than a single point. Combining Digital Image Correlation (DIC) and Thermoelastic Stress Analysis (TSA) enable metrics to be derived from images that are related directly to the strain and stress fields, respectively. The aim of the work is to employ Full-Field Data Fusion (FFDF) [1] to obtain data that is identically spatially resolved to a common coordinate system, so that comparisons can be made to numerical models for verification and validation. The work describes the required experimental setup and synchronous data acquisition procedure. Results from each test case are presented alongside a methodology to combine the image data.

Experimental Methodology

A C-shaped spar made from carbon fibre reinforced composite material (CFRP) is a common feature in modern aircraft wing structures. Such a C-spar, which is used to accommodate either compressive or bending loads, was selected as a demonstrator structural component. The C-spar was manufactured as described in [2] using 24 plies of AS4 8552 pre-preg plies in quasi-isotropic lay up $[(45/0/-45/90)_3]_s$. The tool included tapers, so that a 'joggle' could be created at the mid-section of both the web and flanges of the spar to create a waisted gauge section. The reduced cross-sectional area created a region of increased stresses and out-of-plane bending to provoke buckling failure modes, rather than edge delamination and/or compressive failure of the composite. Introduction of the joggle generated subsurface wrinkles due to the forming of the pre-preg material to produce the change in cross sectional dimensions. After curing, the C-spar was machined to final shape by trimming all edges to the final dimensions of overall length of 450 mm and a flange width of 55 mm, web of 150 mm. To further prevent compressive failure by brooming, each end of the C-spar was constrained in steel end caps manufactured from 25 mm thick plate which included a 15 mm deep groove to match the geometry of the c-spar cross section with a 3 mm clearance. The final assembly was mounted in a servo-hydraulic test machine. Image series captured using a Telops M3K photon detector infra-red camera were used to obtain the thermoelastic response of the C-spar subjected to cyclic compressive loading at 25 kN +/- 20 kN at 10.1 Hz loading frequency. Two FLIR Blackfly white light cameras were used for DIC with 50 mm lenses in a stereo DIC configuration. A trigger box supplied by MatchID® was used to trigger both the DIC white light cameras and the infra-red camera to achieve synchronous image capture. Before loading the specimen, images of a calibration plate, designed to be visible in both the infra-red and white light spectra, were acquired. To improve contrast in the infra-red spectrum, the plate was fitted with a resistive heater pad on its rear face. Figure 1 shows the resulting image from both camera types.

a) Thermal Image

b) White Light

Figure 1: Calibration plate

Results

Figure 2 shows an example of the data that will be presented showing the calibrated thermal response of the C-spar subjected to loading. Several manufacturing features are visible in the data including wrinkles and stress concentrations associated with the geometry of the part.

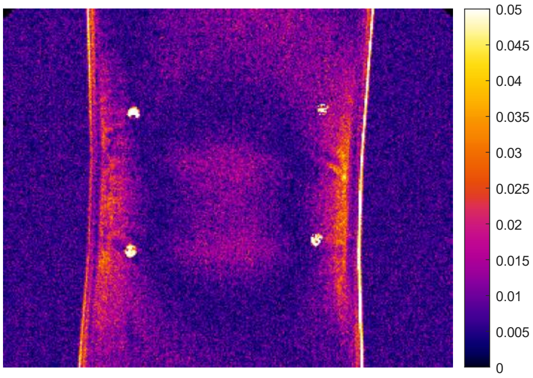

Figure 2: Thermoelastic response (*ΔT*) of c-spar subjected to 25 +/- 20 kN compressive loading at 10 Hz

Conclusions

A test configuration is presented where DIC and TSA data can be acquired synchronously. Using a calibration plate visible to both thermal and white light cameras, it is possible to calibrate DIC and TSA onto a common coordinate system. Once a 3D data point cloud is achieved from the experimental tests, demonstrating that integration and fusion with each other and numerical models is possible. This experimental methodology enables validation and verification of complex geometry components under multiaxial load paths applicable to CFRP aero structures.

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