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# In Application

# High Speed DIC applied to Blast Testing of Sandwich Composite Materials

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## Introduction

Recent advances in composite manufacturing have occurred predominantly in the aerospace, marine, automotive and related industries. Whilst, formerly, naval vessels were constructed from steel, composites provide a significant weight reduction and increase in stealth properties whilst maintaining high strength properties. However composite sandwich materials have yet to be widely adopted in the construction of naval vessels despite their excellent strength to weight ratio and low radar return. One barrier to their wider use is our limited understanding of their performance when subject to air blast.

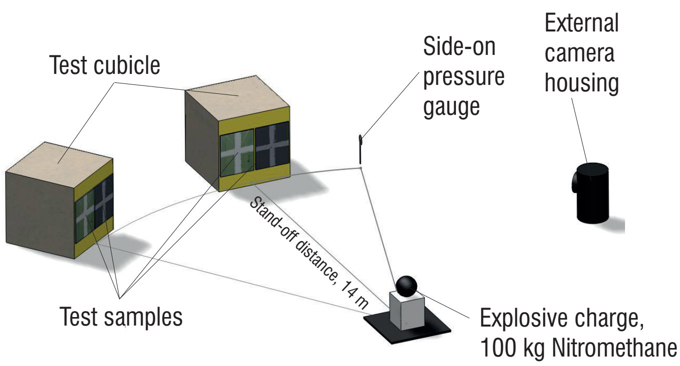


***Figure 1**: Schematic diagram of the experimental layout on the test pad*

## Principle

High-speed 3D digital image correlation (DIC) was employed to capture full-field displacement plots of the rear surface of the targets. Pairs of high speed video cameras were positioned inside each cubicle, whereby each cubicle supported both types of specimens (two pairs of specimens were tested) and a frame rate of 2000 fps was used to image the blast event. Figure 2 shows images captured by an external camera during the event.


***Figure 2**: Images taken at regular intervals with the shock wave impinging on test samples GL1 and CA1 after 16.5 ms.*

## Experimental Setup

Carbon fibre reinforced polymer (CFRP) and Glass fibre reinforced polymer (GFRP) were blast tested in this research. Each panel was constructed with a 25 mm thick closed-cell M130 Corecell™ styrene acrylonitrile (SAN) foam core.

The 1.6 m x 1.3 m sized panels were subject to 100 kg TNT equivalent at a stand-off distance of 14 m. This represents a surface blast threat, where the shock wave propagates in air towards the subject. The experiments were carried out at RAF Spadeadam, Cumbria, UK.

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## Results

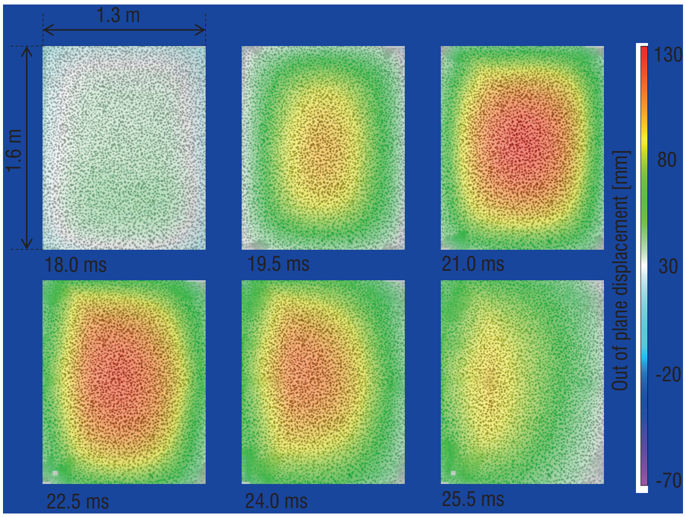
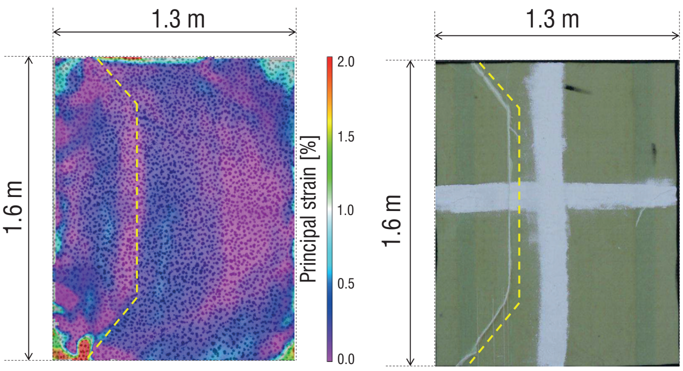



***Figure 3**: DIC analysis of blast on GL1 featuring contour plots of out-of-plane displacement*

Clear indications of damage induced are shown in the DIC results showing the maximum principle strains. There is a region of material in compression of around -1% when GL1 is at its peak rebound displacement (out towards the origin of the charge). This region builds in strain due to the lack of support provided by the core. A core shear failure propagated through the panel resulting in a front-skin failure as well which can be seen in the image taken by the external camera.




GL1 at 31.5 ms after detonation

GL1

**Figures 4a&b**: DIC analysis of GL1 showing the maximum principal strain (a) and the mirrored images of the damaged front faces of the panel (b)

Subsequent to the blast tests the panels were recovered and subjected to controlled static loading in compression to assess the ability of the panels to support applied load after blast damage has already occurred. It could be seen in this data that it is possible to anticipate where failure will occur based on the strain field evolution at lower loads.

## Conclusion

The tests showed that the CFRP-skinned sandwich panels provided a greater resistance to the blast wave impact, deflecting a smaller amount compared to the GFRP-skinned panels. The post-blast damage inspection showed that, unlike the GFRP panels which experienced visible skin cracking, the CFRP panels suffered minimal to no visible skin damage but comparable severity of core damage to the GFRP panels.

The trends observed here indicate that, if residual strength is a key design factor after severe blast, then a drop of two-thirds of the residual compressive strength in CFRP and half in GFRP needs to be taken into account in the design process.

For further details please refer to Arora, H., Kelly, M., A. Worley, A., Del Linz, P., Fergusson, A., Hooper, P.A. and Dear, J.P. "Compressive strength after blast of sandwich composite materials" Proceedings of the Philosophical Transactions of Royal Society, DOI: 10.1098/rsta.2013.0212

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