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COMPARING THE BLAST TOLERANCE OF HYBRID COMPOSITE SANDWICH PANELS

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1. INTRODUCTION

Due to the advantageous properties of composite sandwich panels, including high strength-to-weight ratio and low radar signature, these materials are of increasing interest in the naval sector along with many other industries. Naval vessels, however, must be able to withstand a variety of loads including very destructive loads, such as explosive blast loading. Representative materials must be tested under real blast conditions to ascertain whether the proposed composite sandwich materials are suitable for such applications. Arora et al [1] have performed full-scale blast experiments on composite sandwich panels with glass-fiber reinforced polymer (GFRP) face-sheets and on GFRP tubular laminates. The results demonstrated that sandwich structures are able to effectively resist blast loading and strain gauges are able to record the dynamic response of such structures. The same authors investigated the effect of different parameters, for example core thickness, on composite sandwich panels under air blast loading [1]. The research presented here focusses on full scale air blast testing on two types of composite sandwich panel with different combinations of glass- and carbon-fiber reinforced composite face-sheets.

2. EXPERIMENTAL METHOD

Two types of composite sandwich panel were subjected to air blast loading. The skin layups of these two panels are shown in Fig. 1. All panels had a total of 8 fiber plies in each skin, 4 glass-fiber and 4 carbon-fiber arranged quadriaxially. Both panels had a 30 mm polyvinyl chloride (PVC) foam core and the panels were 1.75 m × 1.55 m. During blast testing the panels were bolted side-by-side into a steel cubicle at a 15 m stand-off distance away from a 100 kg nitromethane charge. 5 mm thick steel frames were adhered to the front and back of the panels and the panels were bolted to the front of the steel cubicle. A pair of high speed cameras was placed behind each panel to record the full field out-of-plane displacement of the panels. To enable processing of the high speed images as 3D DIC data, the panels were speckled. Additionally, the edges of the steel cubicle were speckled to track movement of the boundaries. A pressure gauge block was placed at the same stand-off distance as the charge to record the blast wave pressure profiles. In addition, 14 foil strain gauges were adhered to the front skin of each panel. This would enable a comparison between the front and rear skin strain at certain locations.

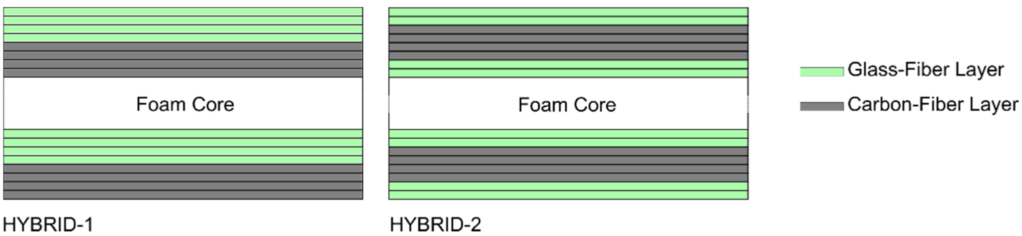

Fig. 1: Schematic of the two types of hybrid skin adopted in the full scale air blast panels.

3. RESULTS

The DIC contour plots for Hybrid-1 are shown in Fig. 2. Fig. 3 shows the displacement of the central horizontal cross-section of the panel, both the initial deflection and first rebound. Each displacement curve is 0.25 ms apart, the arrow on the right hand side of each diagram show the direction of movement of the panel. During the initial deflection, the panel deforms in the expected bath-tub shape before adopting a parabolic shape. The center point reaches a maximum displacement of 75 mm. Sharp changes in gradient observed during the rebound stroke indicate damage within the panel. The movement of the steel cubicle has been removed from the displacement of the panel. The performance of Hybrid-2 is very similar with a maximum out-of-plane deflection of 73 mm and comparable values of major strain. The out-of-plane displacement of the central point of the two panels is shown in Fig. 4. The panels both reach a maximum velocity of approximately 37 ms^{-1} during deflection.

The strain gauge data revealed that overall, the front skins undergo greater strain compared to the rear skin. As expected, the front skins experience compression and the rear skins tension during blast loading. The support offered by the steel cubicle is not equally stiff around the perimeter of the panel due to its design. This is highlighted by the strain gauge data where the edge bolted to the central support of the cubicle experience less strain.

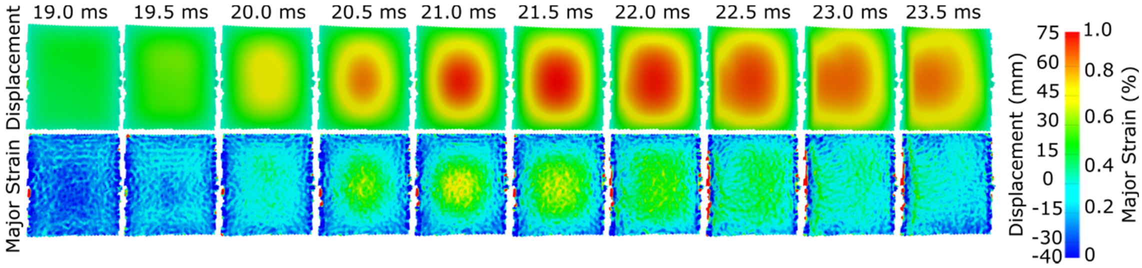

Fig. 2: DIC contour plots for out-of-plane displacement and major strain for Hybrid-1.

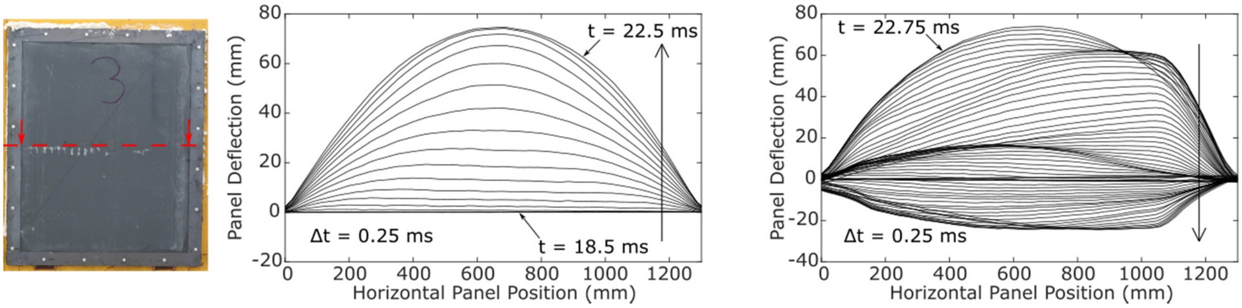

Fig. 3: Displacement of the central horizontal cross-section at 0.25 ms time intervals for Hybrid-1.

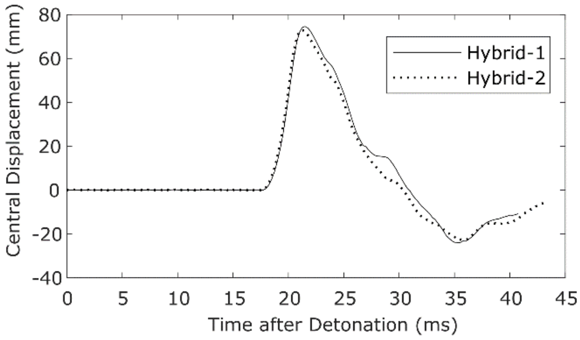

Fig. 4: Central out-of-plane displacement of Hybrid-1 versus Hybrid-2 panels.

4. DISCUSSION

The behavior of the two composite sandwich panels with different hybrid skins was very similar overall. The panels demonstrated comparable deflection, pull-out, velocity and discontinuous deflection gradients at the quarter points across the panel width. These panels can be compared to previous blast testing on sandwich panels with purely glass- and carbon-fiber reinforced polymer skins. The hybrid demonstrated a significantly lower deflection, even when variations in blast pressure are taken into account, and significantly less skin damage. The results suggest that on such a large scale, the incorporation of the two fiber types is the key factor in improving blast resilience rather than the layup order.

5. CONCLUSION

In conclusion, the use of hybrid glass-/carbon-fiber skins acted to attenuate blast energy and reduce the central deflection of the panel. The use of foil strain gauges on the sandwich panel front skins reveals the difference in strain experienced by the front and rear skins and across the front of the panel due to non-rigid boundary conditions. By speckling the steel cubicle and recording the blast event with high speed cameras, it is possible to accurately measure the displacement of the panel and subsequently remove the rigid body motion of the cubicle structure.

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REFERENCES

[1] H. Arora et al., “The effects of air and underwater blast on composite sandwich panels and tubular laminate structures”, *Exp. Mech.*, 2012;52:59-81.