Repair of Fiber Reinforced Thermoplastic Composite Panels

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Introduction

In the aircraft industry, composite structures have increased in use because of their high strength to weight ratios and improved resistance to corrosion and fatigue [1]. These composites structures consist of a fiber weave contained inside a thermoset (TS) or thermoplastic (TP) polymer matrix material. TS materials have a permanent shape once cured while TP have the ability to be heated and reformed repeatedly.

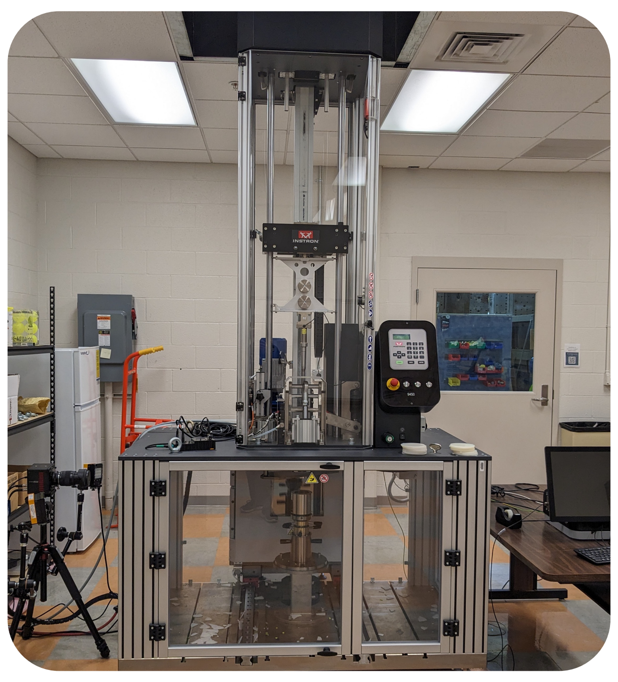
Composite structures, like all structures, on aircraft are subjected to various types of damage which requires repair before returning to service. Currently, thermoplastic composites (TPC) used in the aircraft industry are repaired using the TS repair methods such as bolted and bonded repair. These methods cause stress concentrations and added weight. However, TPC's can be reheated and reshaped allowing for other methods of repair that do not cause the same issues as TS repair [2]. One repair method that can be used in a mould press which applies both heat and pressure to repair the impacted area. The heat created will allow for the damaged area to be reformed for repair.

Objectives

- Replicate impact damage experienced on aircraft by TP's
- Characterize damage of TP panels
- Determine a repair method for TP panels using a mould press
- Characterize the quality of the repair

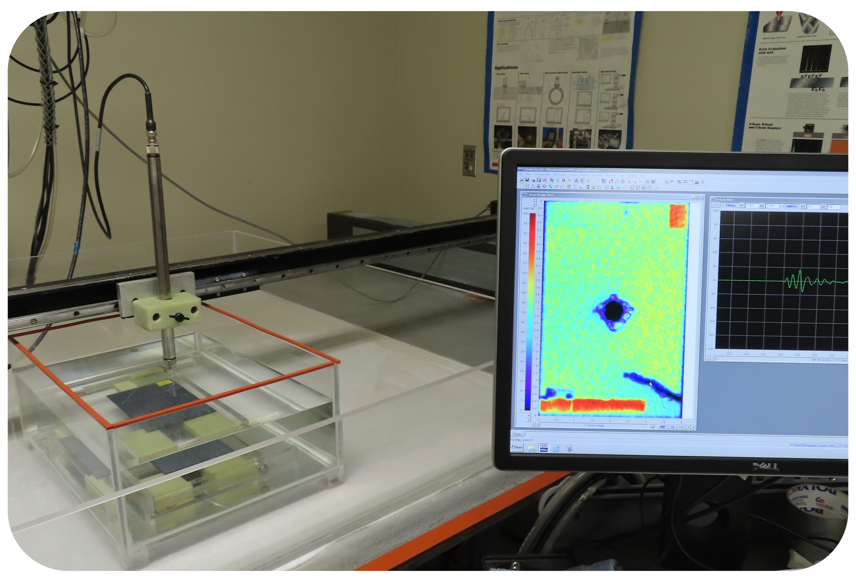
Methodology

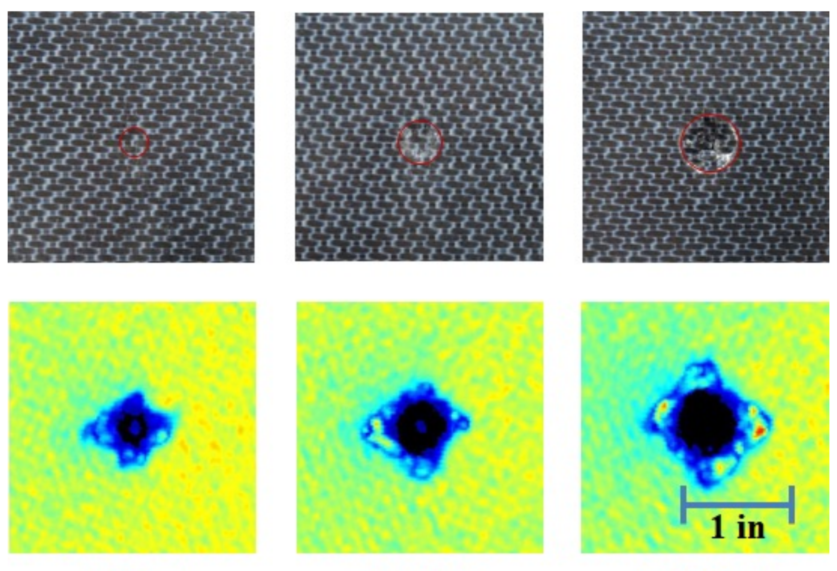
- Materials: 4" x 6" x 0.1" PEEK– Carbon Fiber Panels



Impact Damage: Instron 9450 Drop Weight Impact Tester at energy levels: 10.3 J, 17.0 J, and 23.7 J

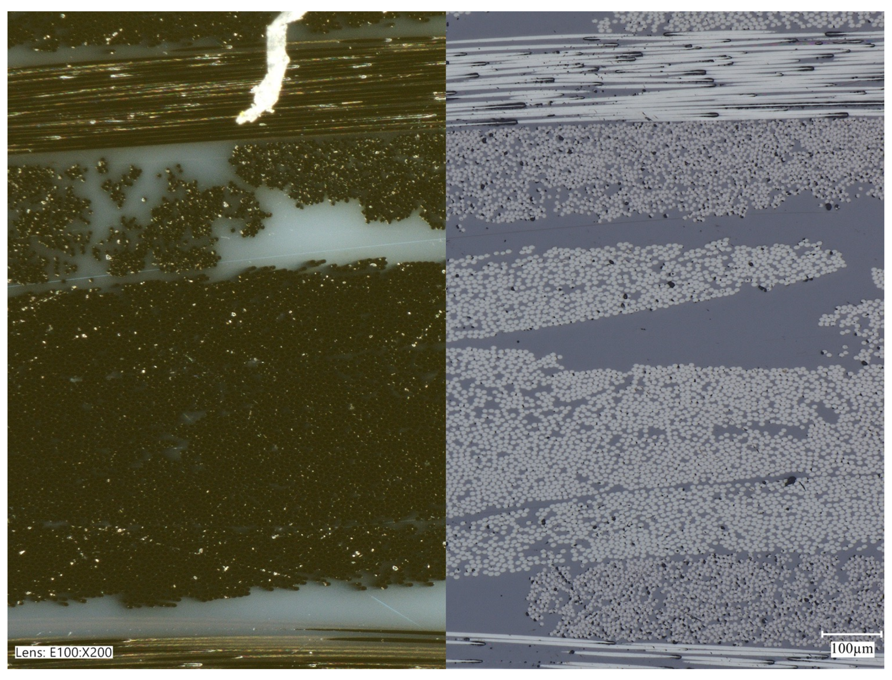
Mechanical Testing: Compression After Impact (CAI) using Instron 5584 Load Frame





10.3 J **17.0 J** **23.7 J**

Ultrasonic Scanning:
Panels were scanned after impact, after CAI, and after repair

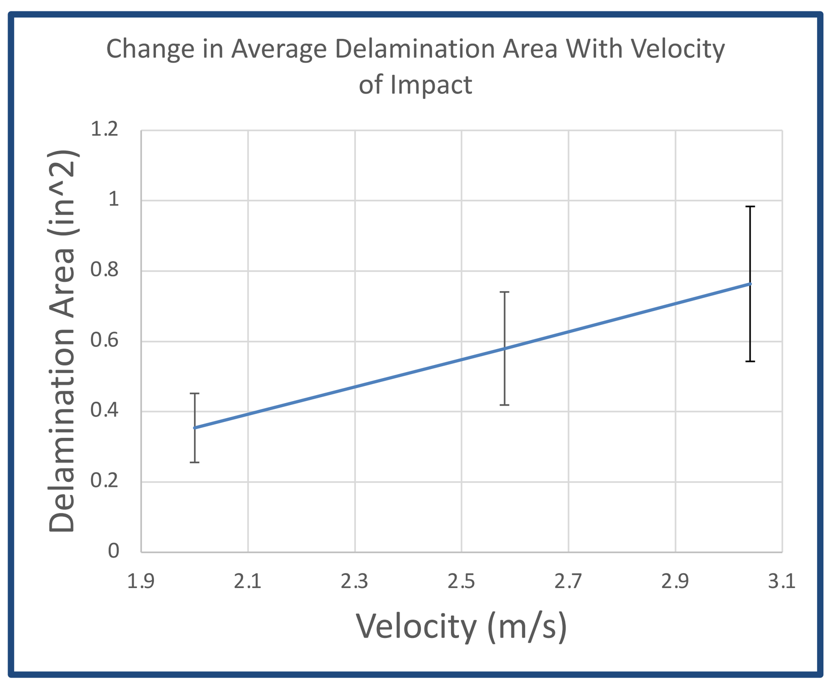


Microscopy: Using a Keyence VHX-7100 to view damage before and after repair

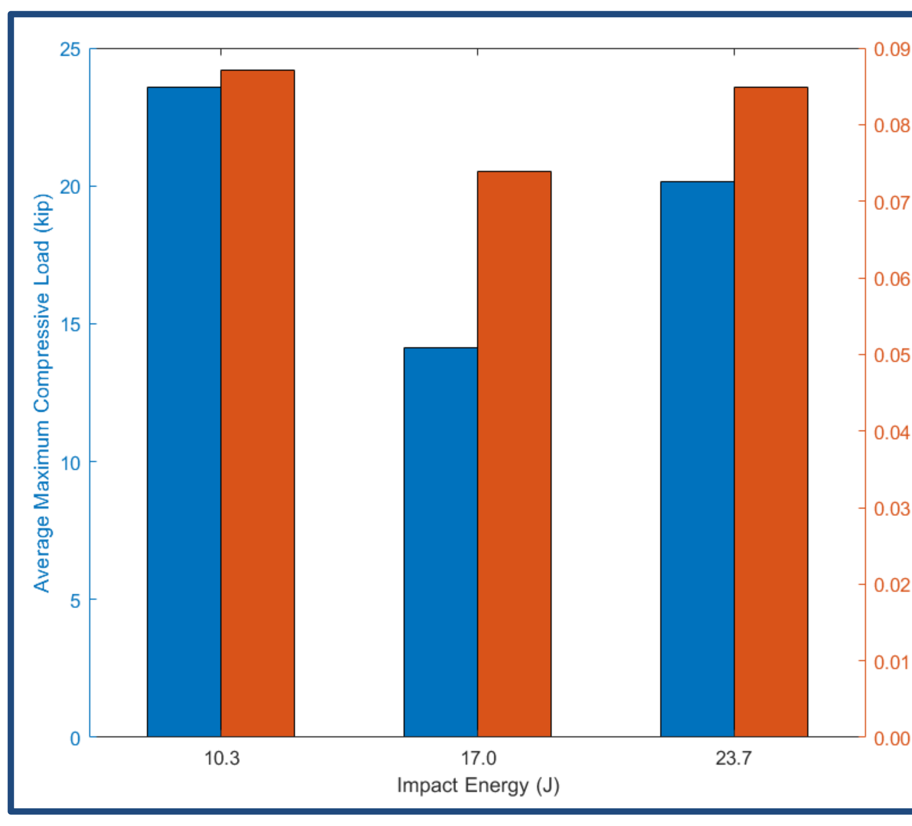
Mould Press: Using 4 MPa and 300 ° C to repair the impacted area

Results / Analysis

Visually, a difference in impact size could be seen as the impact velocity was increased. The impact was the only damage that could be seen visually. However, the ultrasonic scanning showed the delamination area was greater that what could be observed with the naked eye. The size of the delamination area increased linearly with an increase in the impact velocity.

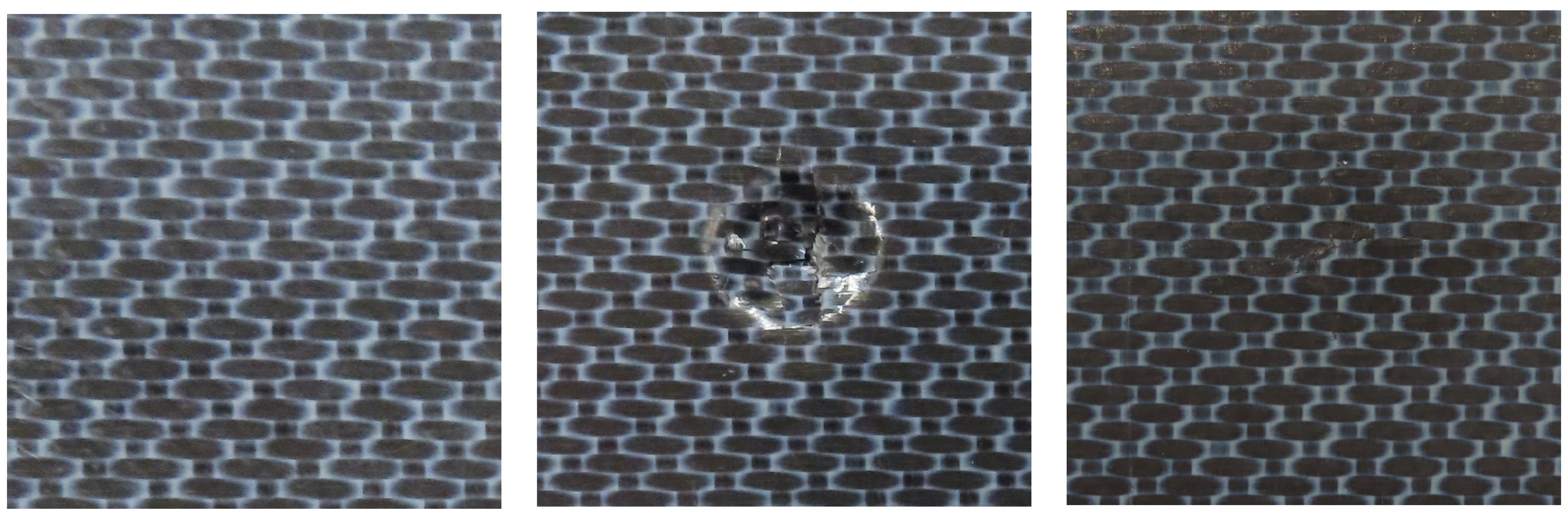


Change in Avg. Delamination Area

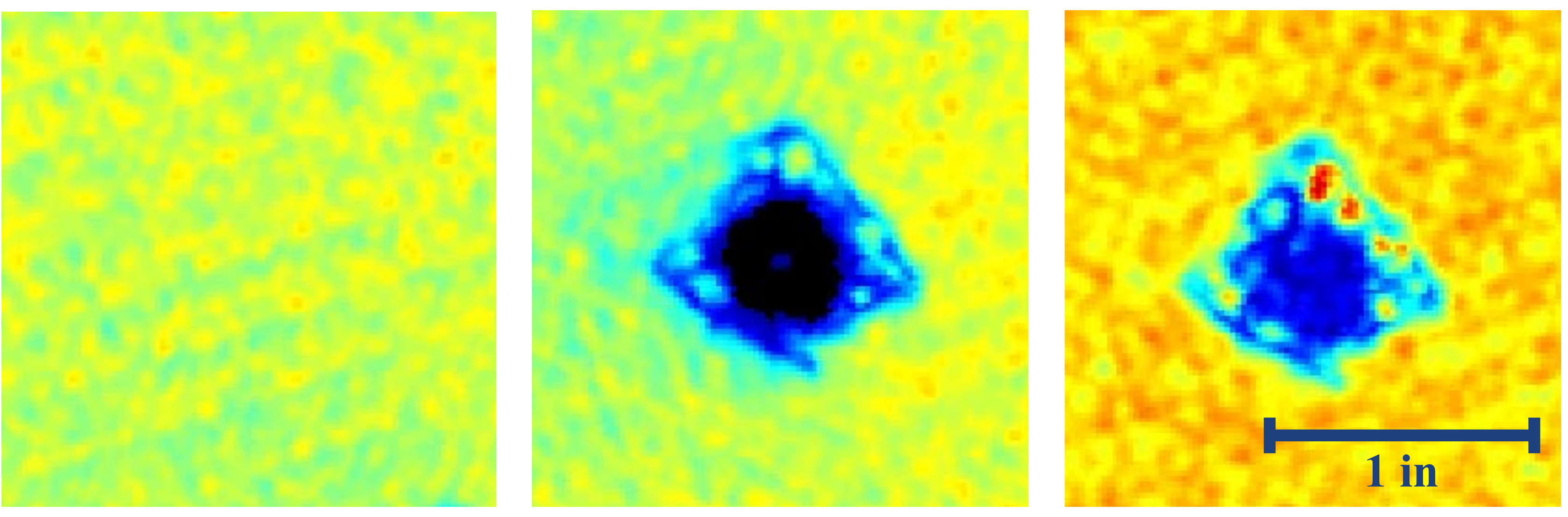


CAI: Compressive Load vs. Compressive Extension

The compression after impact (CAI) testing revealed that the 10.3 J energy level failed away from the impact location and demonstrated greater resistance to compressive loads. Comparatively, the 17.0 J and 23.7 J failed through the impact, with the 17.0 J panels failing at lower compressive loads. The 23.7 J panels however had a varied response to CAI due to failing with different modes at different compressive loads.



Before Impact **After Impact** **After Repair**



Ultrasonic Scanning of Damage and Repair Process

The mould press was able to melt the surface of the panel and reform the shape to a flat panel similar to the original undamaged panel. Fiber breakage was still visible after repair.

Future Objectives

Fabricate glass-fiber panels infused with different monomers using in-situ polymerization, and repeat the repair analysis using repair methods such as mould press, ultrasonic welding, and in-situ polymerization for repair. Mechanically test all repaired panels.

Acknowledgements

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References

[1] Stelter, et. al., "In-situ consolidation automated fiber placement of thermoplastic composites for high-rate aircraft manufacturing," Society of the Advancement of Material and Process Engineering, 2022.
[2] Robles, et al., "Repair of Thermoplastic Composites: An overview," Advanced Manufacturing: Polymer & Composites Science, vol. 8, Apr. 2022, pp. 68–96.