Experimental Study on Compression and Shear Strength of CFRP

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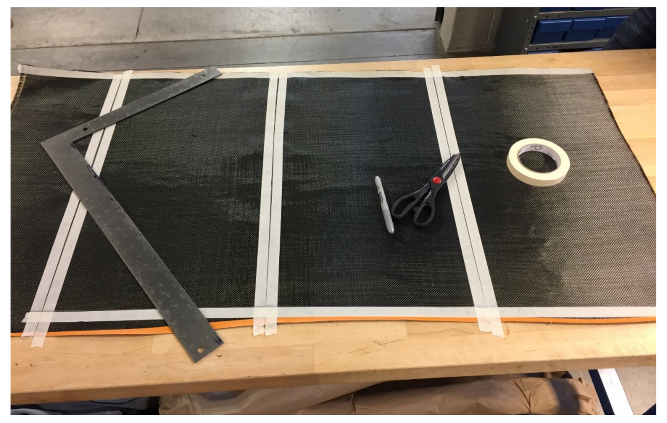
Abstract

The increasing use of carbon fiber-reinforced polymer (CFRP) in the aerospace industry requires a better understanding of its damage properties. Many modern aircraft under high loads are utilizing this material for their primary structures due to its high strength to weight ratio. However, CFRPs are sensitive to out-of-plane loading such as low-velocity impact and indentation. These damages can reduce the compressive strength significantly without leaving a visible mark on the surface, which is known as Barely Visible Impact Damage (BVID). The behavior and residual strength of CFRPs after impact damage under compressive loading are still not fully understood.

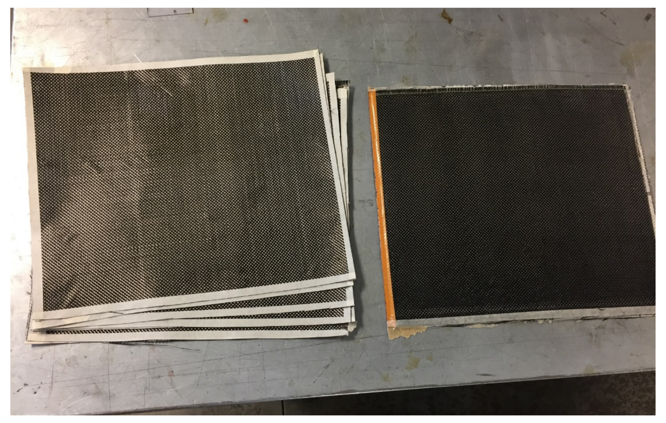
The purpose of this research is to use Digital Image Correlation (DIC) to study the failure mechanism and better understand the shear properties of CFRP after impact. To study the trend in CFRP damages, a series of shear tests with different impact levels will be performed. The strain values from the DIC method will be validated by conventional measurement using strain gauges that will be collected concurrently.

Layup

- Samples: Four samples were made, each measuring 5" x 6" (L x W) with a thickness of 8 plies.
- Material: $[0/45/0/45]_s$ AS4 Plain Weave 3K 5.7oz. The epoxy mixture was 3 parts resin to 1 part hardener. TenCate BT250 E-6 Resin.
- Curing Cycle: The samples were first left at room temperature for seven hours. Then they were put into the oven where the temperature increased to 180 degrees F for eight hours.



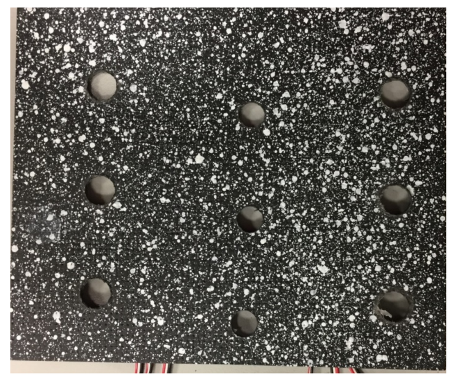
The plates were cut into 5"x6" samples.



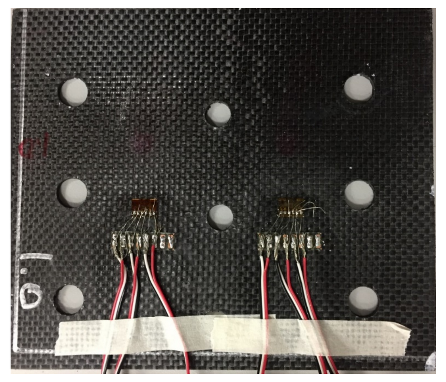
Each sample consisted of eight plies.

Digital Image Correlation (DIC)

The Digital Image Correlation (DIC) Technique uses a speckle pattern on the surface of the sample to show the stress and strain behaviors of a material without the need for strain gauges. The speckle pattern in this research was created by spray paint. A program called Ncorr is used process the images and to visualize the stress and strain field of each sample. Ncorr works by tracking the movement of each speckle from sequential photos taken during testing. The DIC data was validated using strain gauges.



The speckle pattern used for DIC

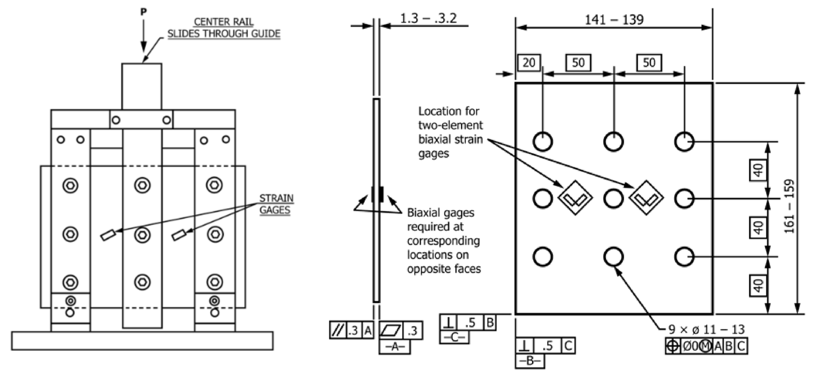


Strain Gauges were used to validate the DIC results.

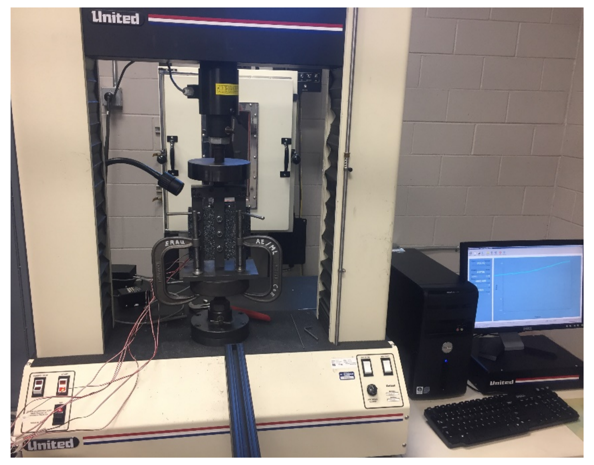
Testing

The damages applied to each sample were done by dropping a round metal rod from two different heights of 0.5 feet and 1 foot. These impacts had energies of 0.709ft-lb and 1.417ft-lb respectively.

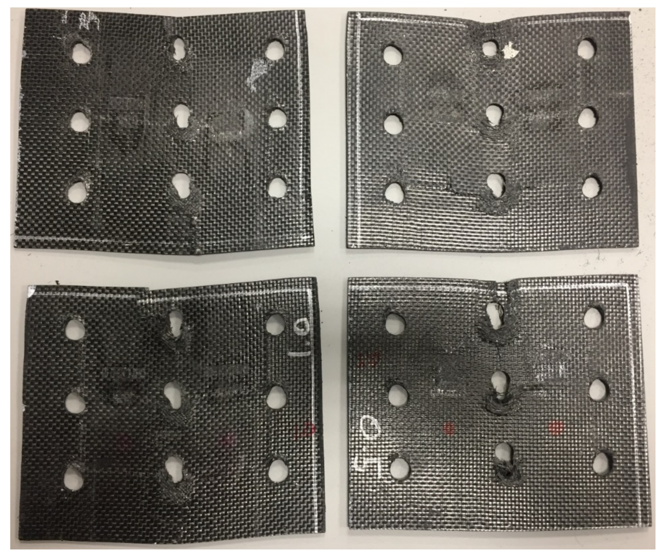
The testing setup included a hydraulic press, a three rail shear fixture, a camera, and the hydraulic press' computer system recording the displacement and force applied.



The 3 rail compression shear fixture



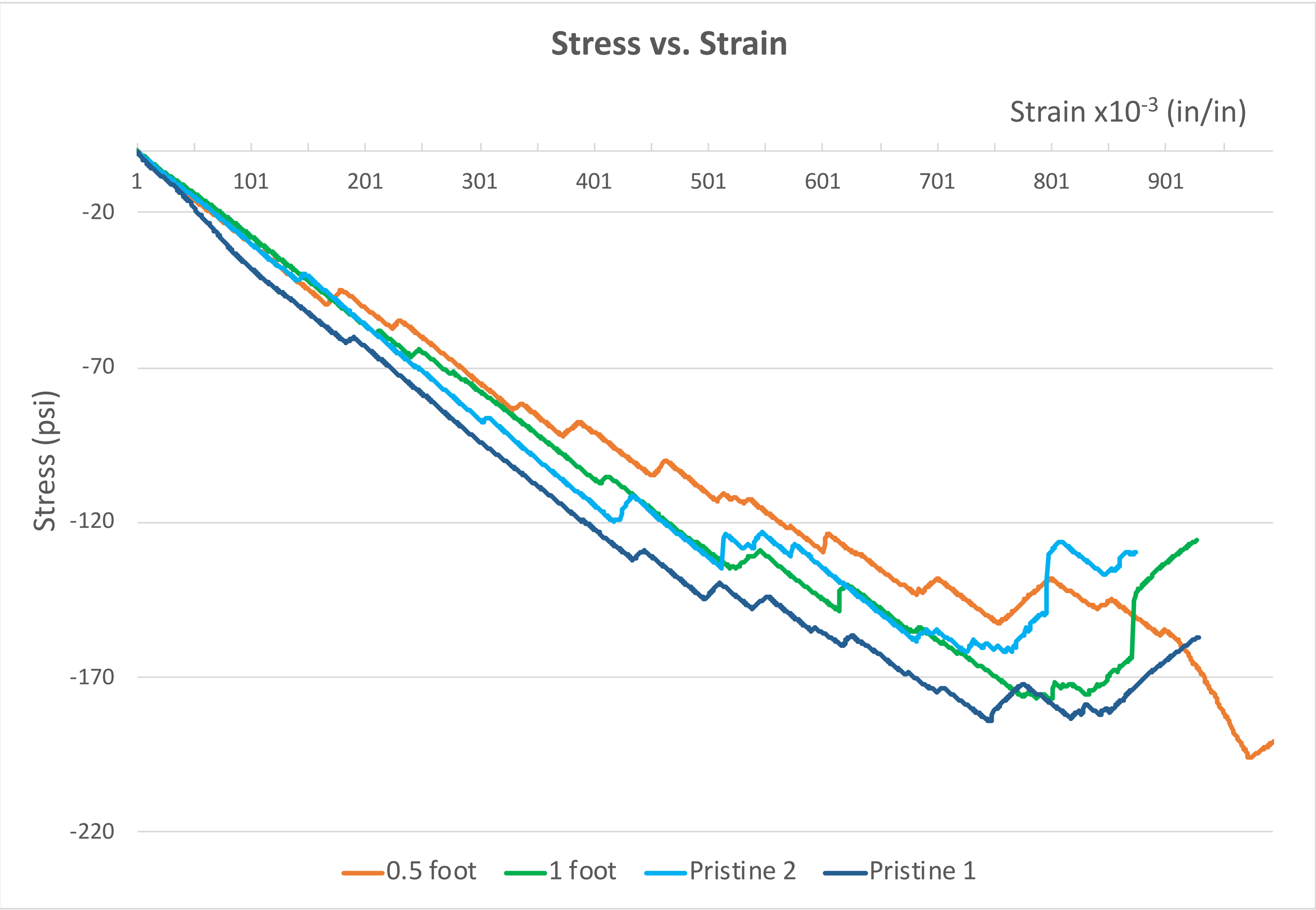
The testing setup



The samples after testing:
Top left- Pristine 1
Top right- Pristine 2
Bottom left- impact from 1 foot
Bottom right- impact from 0.5 feet

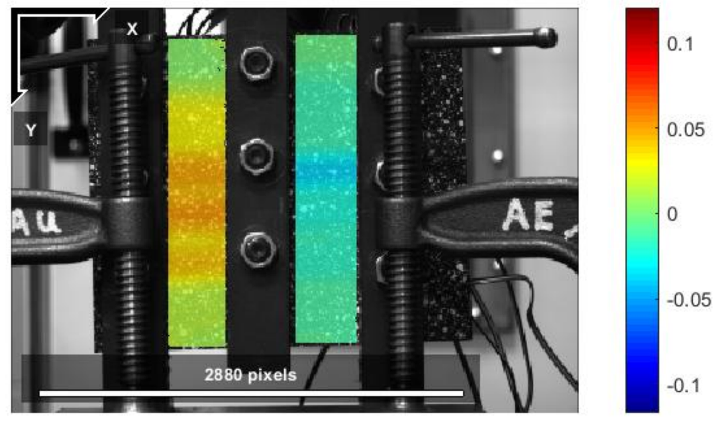
Stress and Strain Behavior

The following charts plot the strain and stress of each sample.

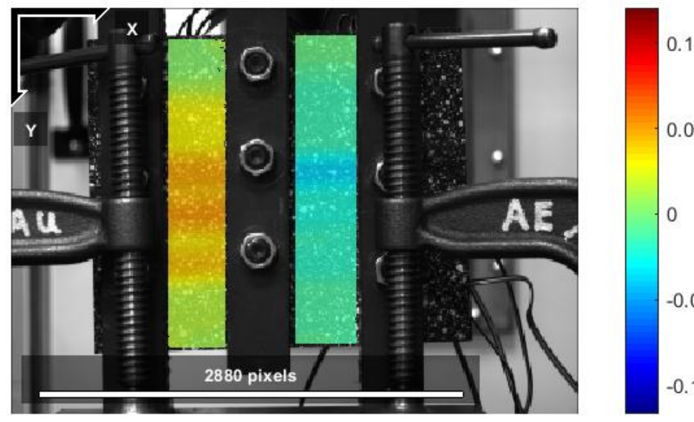


Shear Strain Results

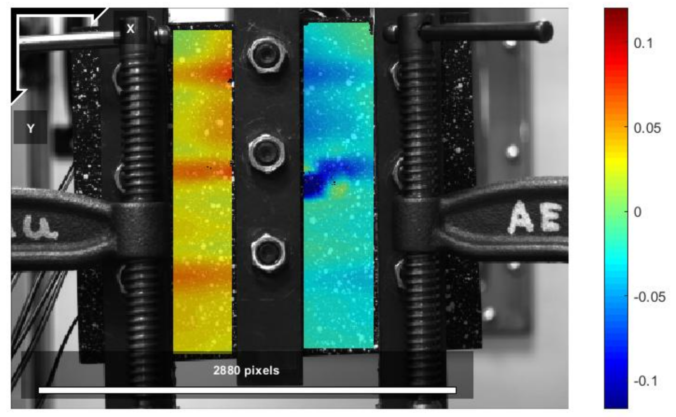
Pristine 1



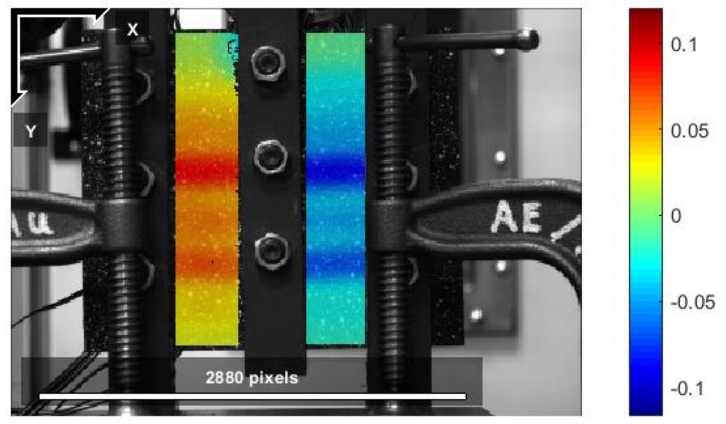
Pristine 2



0.5 foot drop



1 foot drop



These images show the shear strain of each sample to the point of failure. The areas with warmer colors show high strain while areas with cooler colors show areas with relatively lower strain. As the magnitude of the impact increased, the amount of strain that each sample could withstand decreased. This is shown in the contrast of colors; the pristine samples have less color contrast than the damaged samples.

While the high shear strain region for pristine samples was concentrated in the center of the samples, the impact damage causes multiple high intensity shear strain locations. Further investigation and more testing are required to study the relationship between the physical damage due to impact and the strain field produced by the DIC techniques.

Summary

It was found that the damage from the 1 foot drop caused the sample to fail sooner than the rest. This damage accelerated the failure, as shown in the stress vs. strain plot. The sample damaged from the 0.5 foot impact withstood a similar amount of shear stress before failure. The stress and strain behavior in this sample was more similar to the pristine samples.

Both pristine samples behaved similarly and withstood more shear stress than the damaged samples, as expected.
The correlation between magnitude impact damage and shear strain failure appears to be linear. More testing with different impact levels are required to verify this assumption.

Future work will also include study of impact damage on composite sandwich plates under compressive load by conducting compression after impact (CAI) tests, which was part of our original plan to further study the effect of impact damage on composite structures.

Acknowledgement

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