In Situ Testing of Carbon Fiber Reinforced Composites

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Abstract

Carbon Fiber Reinforced Polymers (CFRP) are used in aerospace, automobile racing, wind energy, sports equipment, and many other areas in which safety is critical. Fundamental to the engineering of safe CFRP products is the understanding CFRP failure in all modes and the development of mathematical models that correctly predict failure. The goals of this research project were to develop a machine and method to perform in situ testing of a CFRP under a Zeiss AX10 optical microscope. Achieving these goals will provide the rare opportunity to view the failure of a CFRP material at a micro structural level in a slow motion video. This will help validate the current failure models and provide new insight into the effects of the material's inherent variability and variations in the manufacturing process on the material properties.

Background

In contrast to the macroscopic level the micro structure of a composite material is comprised on many different features. These include resin rich areas, voids, and inconsistencies in the fiber packing as shown in Figure 1. These features lead the unpredictable nature of composite failure. Temperature changes also change failure characteristics. These microstructural features and environmental can significantly change the failure characteristics of the material. The observation of this failure is paramount to the accurate modeling composite material failure.

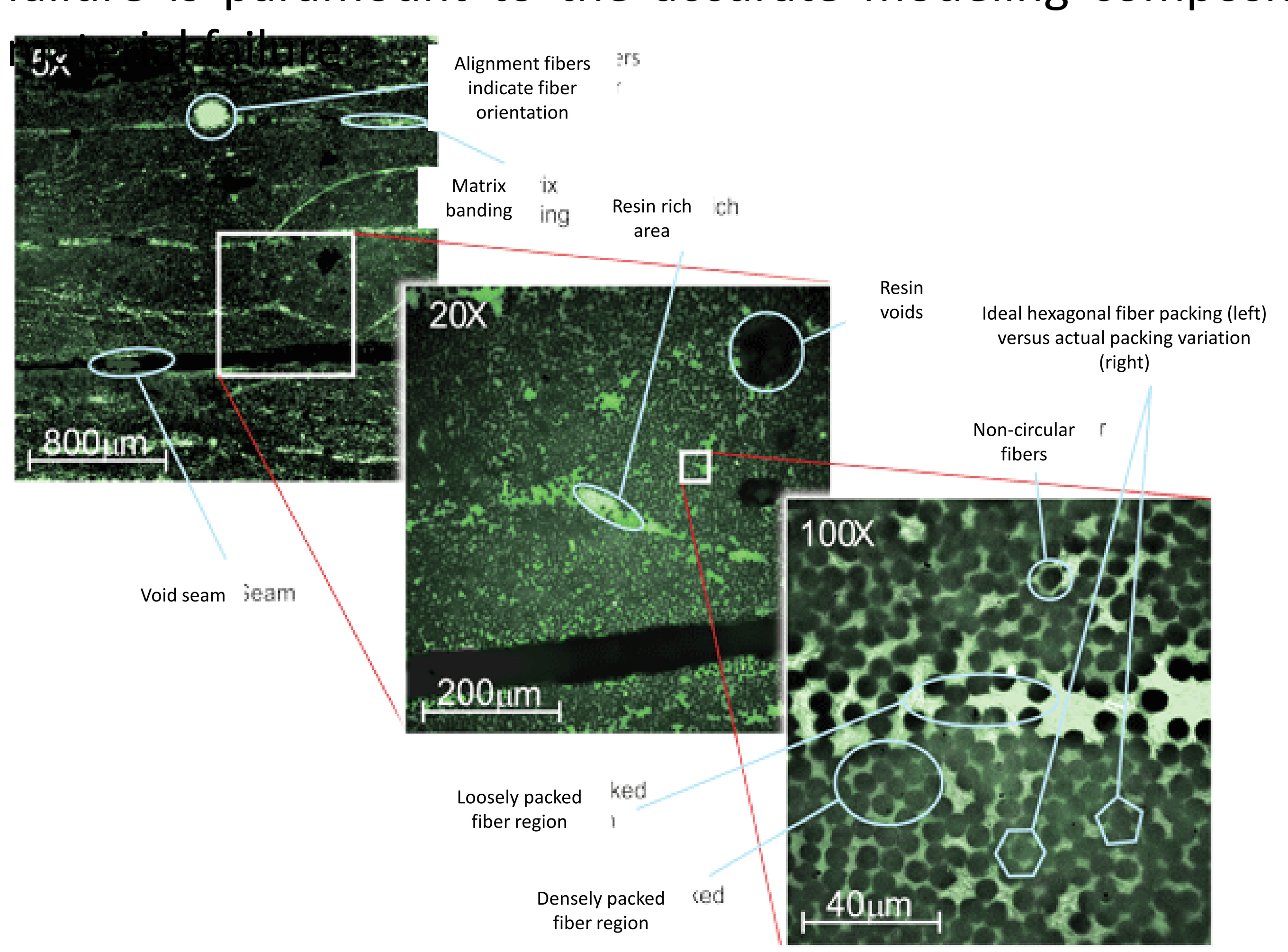

Figure 1. Microstructural features of composite specimen
Image courtesy of Abigail Huyler

Custom Load Frame

The custom load frame was designed to fit in the Zeiss AX10 microscope and allow the testing of micro composite specimens for a low initial investment. It was required that the entire machine weigh less than 11lb, physically fit on the pedestal provided with the microscope, and be able to apply a load of at least 250lb to a specimen loaded in tension. The machine was entirely designed and built in house to lower the cost. The completed load frame is shown mounted in the microscope in Figure 2.

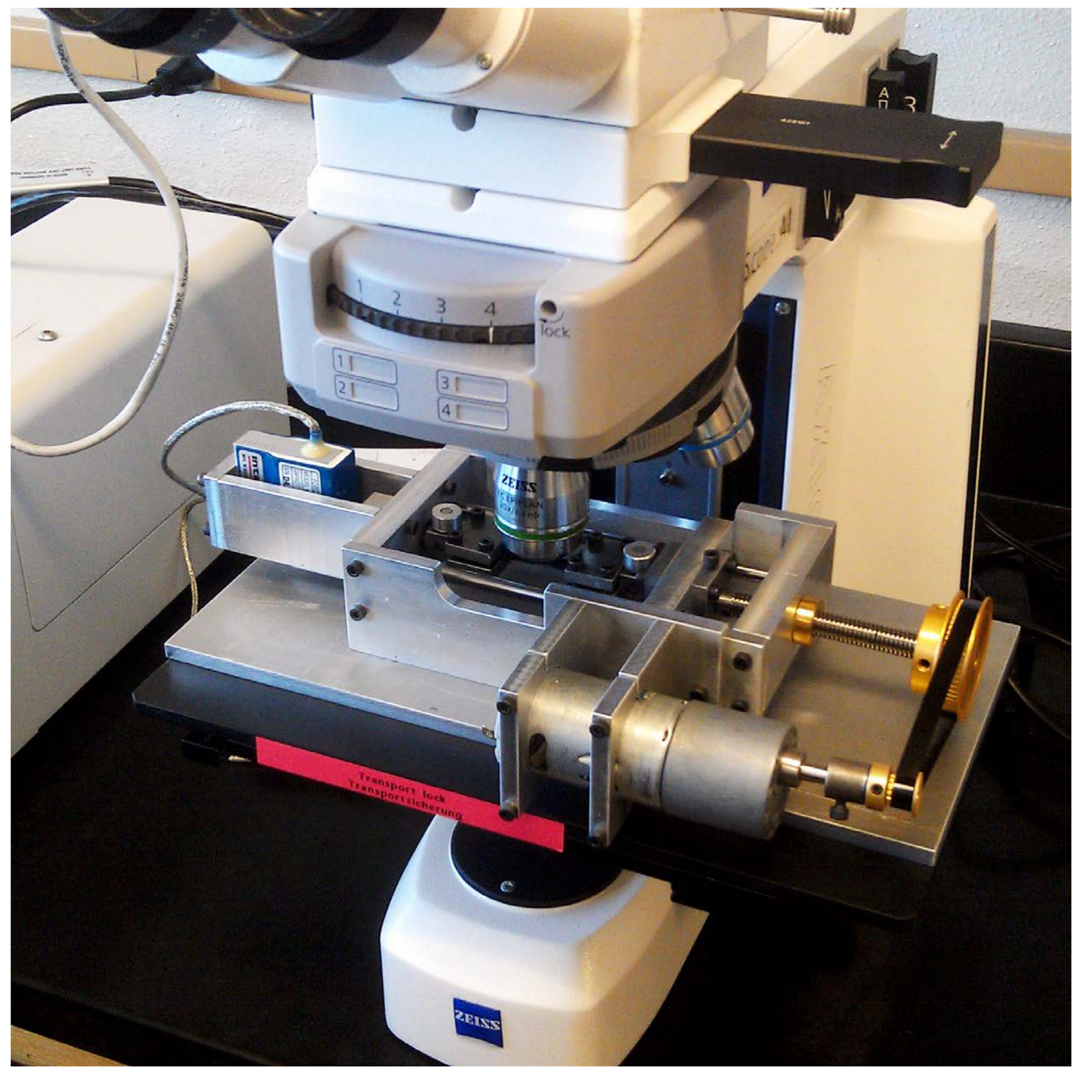

Figure 2. Load Frame in microscope

Results

Specimen failure was observed under two different types of microscopy, epifluorescent and dark field. Under epifluorescent microscopy the specimen was heated as a side effect. Under dark field microscopy the specimen remained at room temperature. Figure 3 (a) shows failure of a specimen under dark field microscopy and Figure 3 (b) shows the failure of a specimen under epifluorescent microscopy. The specimens show distinctly different failure characteristics.

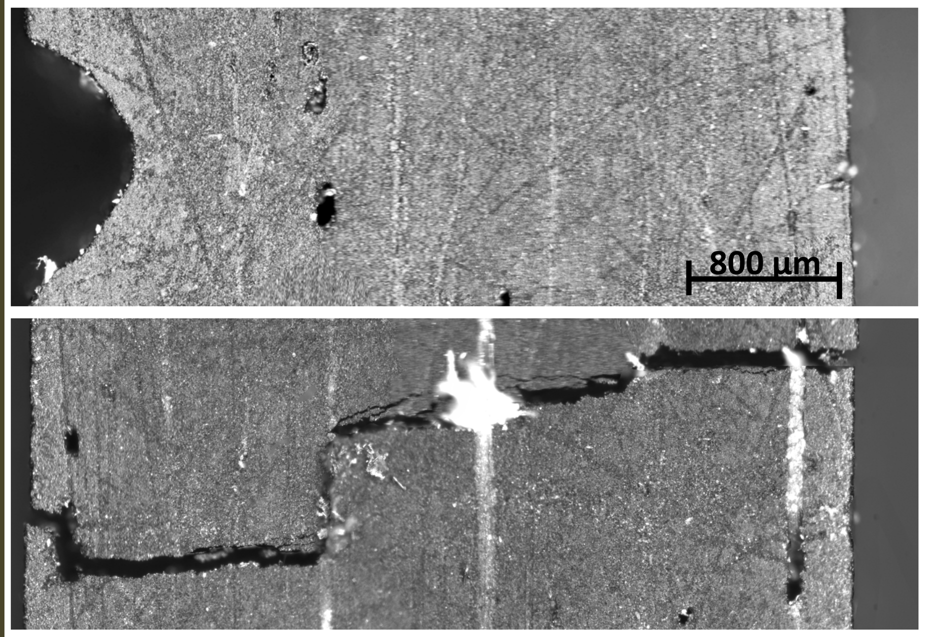

Figure 3 (a). Brittle failure

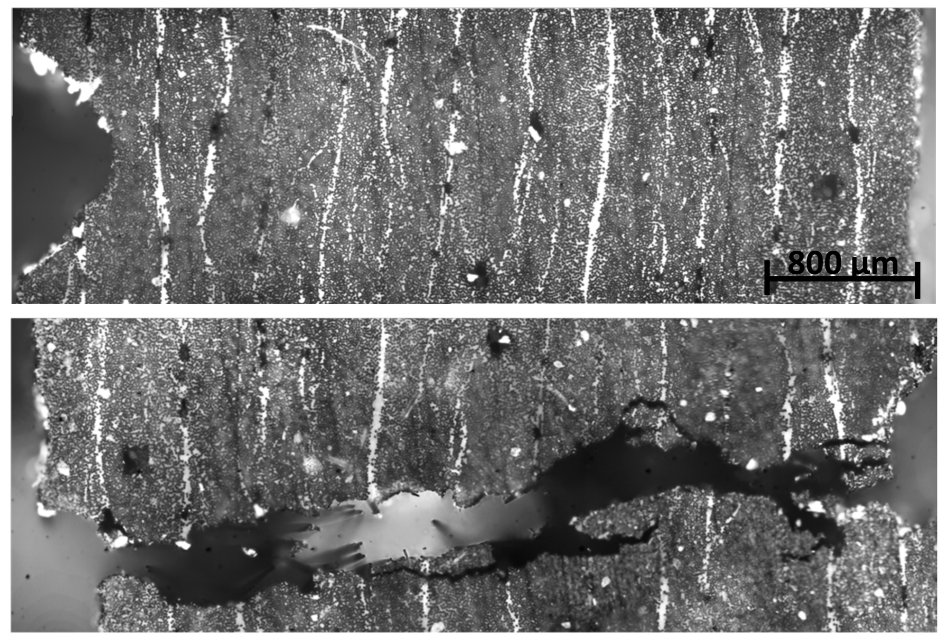

Figure 3 (b). Ductile failure

Conclusions

The results revealed some interesting features of fracture initiation and propagation. The images taken with epiuorescence showed ductile fracture of the material that propagated relatively slowly across the specimen. All the specimens broken under epiuorescence experienced heating of the area directly under the focal point of the light. The concentrated heating of the notch area resulted in a degradation of the epoxy and changed the fracture characteristics markedly. This was completely unexpected and interesting when compared to the results observed when the specimens were observed through dark field microscopy, which did not heat the specimen significantly. The specimens that were viewed under dark field fractured outside of the notch area every single time. This led to the conclusion that there exists within the natural micro structure of the material a stress concentration greater than that introduced by the notch. This could be a result of the inherent variability of the fiber packing the material of the inclusion of the alignment fibers by the manufacturer.

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