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Materials Joining

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Materials Joining

Study of Composite Interface Fracture and Crack Growth Monitoring Using Carbon Nanotubes

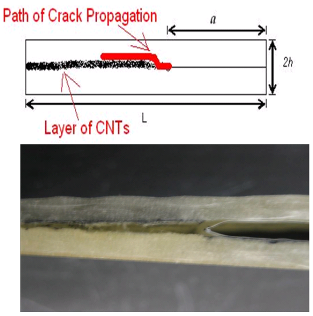
Young W. Kwon - Molly A. Bily - Randall (Ty) D. Pollak

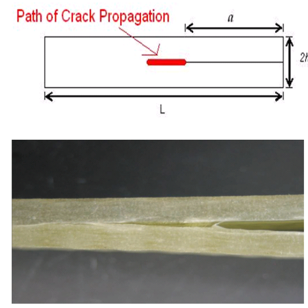
Overview:

The objective of the study is to examine the effect of carbon nanotubes at the joint interface of composite materials on the enhancement the fracture toughness of the interface, especially for Mode II fracture; and on the detection of crack growth for structural health monitoring.

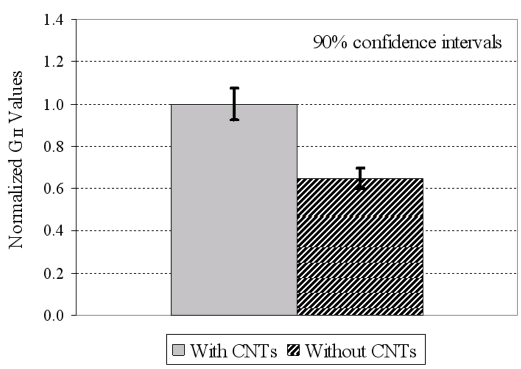
Project Description:

Interface fracture of woven fabric composite layers was studied using Mode II fracture testing. Both carbon fiber and E-glass fiber composites were used with a vinyl ester resin. First, the single-step cured (i.e., co-cured) composite interface strength was compared to that of the two-step cured interface as used in the scarf joint technique. The results showed that the two-step cured interface was as strong as the co-cured interface. Carbon nanotubes were then applied to the composite interface using two-step curing, and then followed by Mode II fracture testing. The results indicated a significant improvement of the interface fracture toughness due to the dispersed carbon nanotube layer for both carbon fiber and E-glass fiber composites. The carbon nanotube layer was then evaluated as a means to monitor crack growth along the interface. Because carbon nanotubes have very high electrical conductivity, the electrical resistance was measured through the interface as a crack grew, thus disrupting the carbon nanotube network and increasing the resistance. The results showed a linear relationship between crack length and interface resistance for the carbon fiber composites, and allowed initial detection of failure in the E-glass fiber composites. This study demonstrated that the application of carbon nanotubes along a critical composite interface not only improves fracture properties but can also be used to detect and monitor interfacial damage.





(a) With CNT (b) without CNT
Comparison of interface crack for E-glass composites with and without CNT



Comparison of critical energy release rates with and without CNT

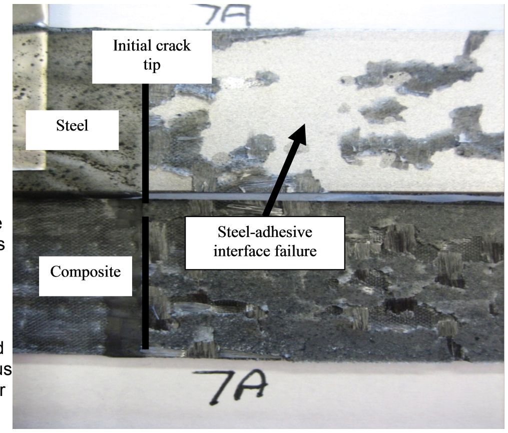
For more information, contact Young Kwon at ywkwon@nps.edu

Effect of Carbon Nanotube Reinforcement on Fracture Strength of Composite Adhesive Joints

Young W. Kwon, Garrett L. Burkholder, Randall (Ty) D. Pollak

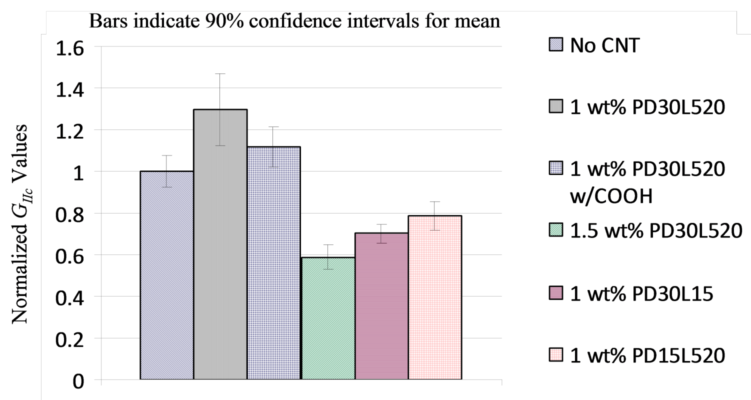
Overview:

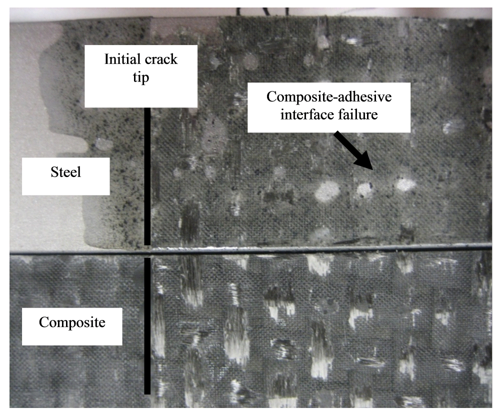
The objective of this research is to determine whether regular carbon nanotubes as well as functionalized carbon nanotubes can improve the joint strength of adhesives for composites and metals.



Project Description:

This study investigated the use of carbon nanotubes (CNTs) as an epoxy adhesive additive for adhesive joints between steel-composite interfaces and composite-composite interfaces. The study also examined the effect of CNT functionalization to improve CNT dispersion and thus improve joint strength. Specimens were constructed by adhesively bonding two parallel coupons, with a starting crack at one end. The specimens were loaded to final failure in three-point bending for Mode II fracture. Critical strain energy release rate was used to compare fracture properties of each set of specimens. It was shown that additions of multi-walled CNTs on the order of 1 wt% with diameters on the order of 30 nm and lengths 5-20 m enhanced fracture toughness for both steel-composite and composite-composite adhesive joints tested. However, other combinations of CNTs could significantly decrease fracture properties, likely due to agglomeration issues. Functionalization of nanotubes showed some limited promise. Scanning electron microscopy validated the improved dispersion of CNTs using functionalization, but also highlighted the shortening effects due to the harsh chemical treatment. In summary, the study illustrates the importance of various CNT parameters on fracture properties, and encourages further investigation and optimization of these parameters for applications of interest.





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Diffusion Multiple Approaches to Alloy Development

Luke Brewer

Project Description

Developing new alloy compositions can be a long and expensive task. The ability to screen new compositions for improved mechanical properties can greatly decrease the time and cost to identify new alloys worthy of further study. In this research, we explore the use of refractory metals (W, Nb, Ta, and Mo) for the solid solution strengthening of 316 stainless steels. In the initial studies, diffusion couples between 316 stainless steel and each of the refractory metals were made using hot isostatic pressing followed by a long anneal at 1100C. The backscattered electron image below shows the formation of at least two intermetallic phases between the steel and the niobium. (Figure 1) In order to connect the changes in mechanical behavior with the changes in phase and composition, nanoindentations were made perpendicular to the diffusion bond. (Figure 2) As expected, the elastic modulus and strength vary strongly with composition and intermetallic type. Future research will examine the effects of irradiation on these base-line diffusion couples.

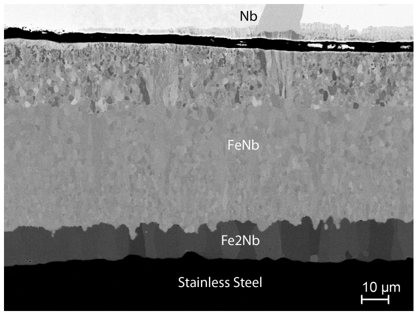

Figure 1 - Back scattered electron image of Nb-stainless steel diffusion couple.

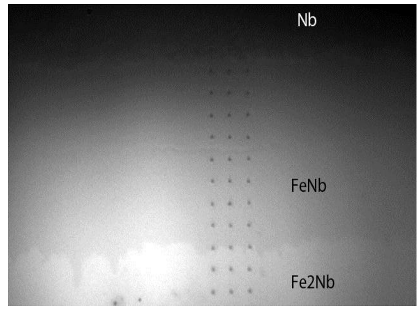

Figure 2 - Optical image of nanoindentations across interfaces in Nb-stainless steel diffusion couple.

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