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The work performed in the reporting period has been focused on determining the crack driving forces for transverse cracks of different sizes formed by coalescence of fiber/matrix debond cracks. Using the J-integral method, the driving forces are compared for different cases of fiber mobility.

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Quarterly Progress Report, July 1, 2019 – September 30, 2019

A Hybrid Approach to Composite Damage and Failure Analysis Combining Synergistic Damage Mechanics and Peridynamics

Award Number N00014-16-1-2173

DOD – NAVY – Office of Naval Research

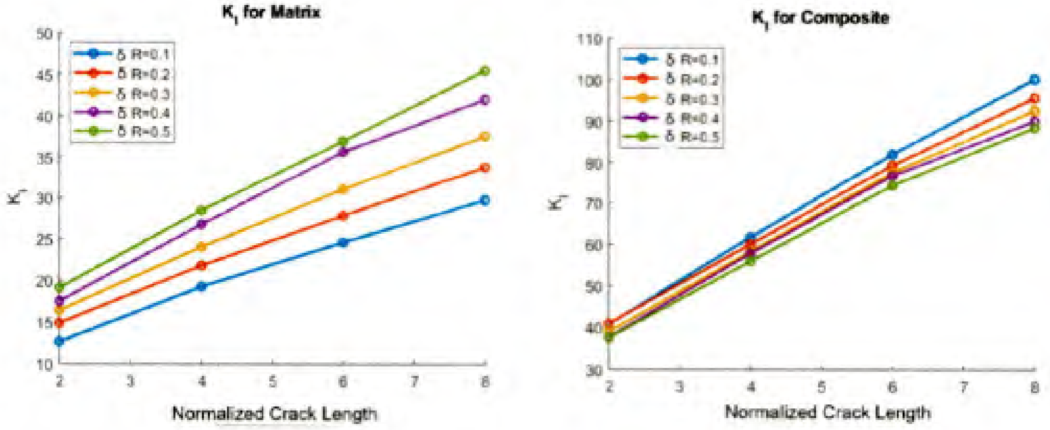
PI: Ramesh Talreja

Executive Summary

The work performed in the reporting period has been focused on determining the crack driving forces for transverse cracks of different sizes formed by coalescence of fiber/matrix debond cracks. Using the J-integral method, the driving forces are compared for different cases of fiber mobility.

In the previous Quarterly Report, we reported the effect of fiber mobility during the resin infusion process on the frequency of debonding and, via coalescence of the debonds, on the formation of cracks of different initial lengths given as multiples of fiber diameter Φ. Illustrative results were reported to show the effect on the extent of debonding in the RVE for different degrees of fiber mobility given by the radial mobility Δr. The ability of the initiated transverse cracks to grow under the applied tensile force when the cracks are surrounded by a heterogeneous field of discrete fibers in the composite cross section was then studied. The method to investigate the crack driving force utilized was the J-integral, which is suited for calculating the crack-tip energy release rate.

In the reported period, the focused was on clarifying how the presence of fiber clusters influences the crack driving force. As a baseline, the mode-I stress intensity factor is calculated for the unreinforced matrix and for the homogenized composite within the embedded cell as a function of the crack size for different fiber mobility parameter values. Figure 1 shows the two cases side-by-side. The curves for the matrix case get higher as the fiber mobility increases. This is because the size of the circular embedded cell of matrix increases with the fiber mobility, thereby requiring higher force to be applied for crack growth. The homogenized composite within the cell shows the opposite trend. In this case, the stress intensity factor approaches that of surrounding homogenized composite as the fiber mobility parameter decreases, while it tends towards the matrix stress intensity factor (which is lower) as the fiber mobility parameter increases.



(a) Matrix

(b) Homogenized Composite

Figure 1. Mode-I stress intensity factor variation with crack size normalized by the fiber diameter for different normalized fiber radial mobility parameter δr. (a) matrix, (b) homogenized composite.

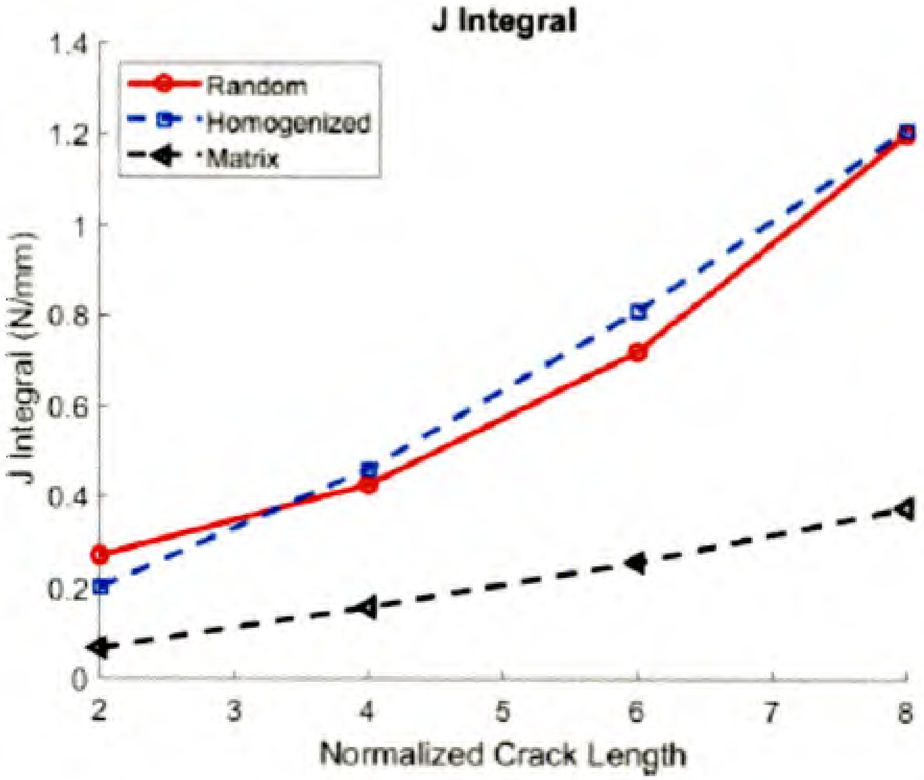


Figure 2. J-integral variation with the crack length normalized by the fiber diameter for the embedded cell with matrix, with homogenized composite and with randomly distributed discrete fibers, all for one normalized fiber mobility parameter, δr = 0.1.

Figure 2 shows the variation of the J-integral with the normalized crack length for the three cases for $\delta r = 0.1$. For this low fiber mobility case, the difference between the homogenized composite and the composite with randomly distributed fibers is small and tends to disappear at large crack size. Both cases of composites have higher crack driving forces compared to that of matrix, as expected.

The **Ongoing research** will continue to analyze the driving forces of the initiated cracks by the J-integral method for different values of the fiber mobility parameter. The effect of constraint by the adjacent plies in a laminate will also be investigated.