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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. The effect of fiber disorder induced by manufacturing when resin is infused into dry fiber bundles is considered.

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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. The effect of fiber disorder induced by manufacturing when resin is infused into dry fiber bundles is considered.

In the previous Quarterly Report, we described the embedded cell method for conducting stress and failure analysis of a unidirectional composite subjected to a tensile force normal to fibers. The embedded cell (RVE) was analyzed to determine the initiation of fiber/matrix debonding based on the brittle cavitation criterion. Assuming coalescence of the debond cracks to form transverse cracks, the applied strains to formation of cracks of different initial sizes were reported in the previous Quarterly Report. Here we report 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. Figure 1 illustrates this effect on the extent of debonding in the RVE for different degree of fiber mobility given by the radial mobility Δr. As can be seen in the figure, at low fiber mobility (high degree of fiber clustering), the debonds occur earlier. The initial crack size formed by the debond coalescence is also indicated in the figure (two sizes, 2Φ and 8Φ).

Next step in the failure analysis is to study 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. The method to investigate the crack driving force utilized was the J-integral, which is suited to calculate the crack-tip energy release rate. In the literature it is common to homogenize the composite microstructure and place a transverse crack in the homogenized cross section to calculate its energy release rate. This doesn't allow to assess the effect of manufacturing induced defects on the composite failure process.

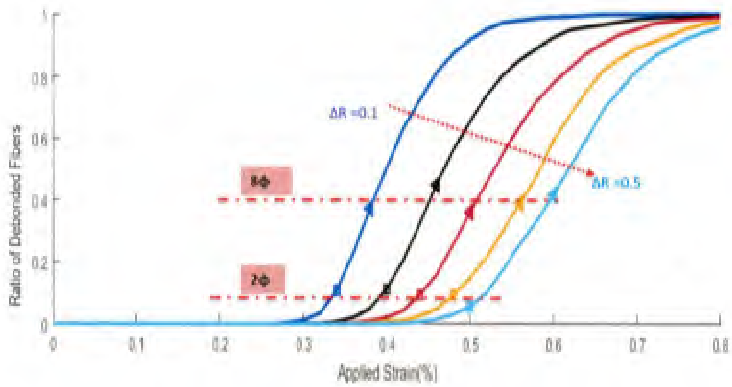

Figure 1. The number of fiber/matrix debonds as a fraction of total debond sites plotted against the applied transverse strain for different fiber radial mobility parameter Δr.

Figure 2 shows a transverse crack tip in the presence of discrete fibers, and the J-integral calculation on different paths around the crack tip is illustrated in Fig. 3.

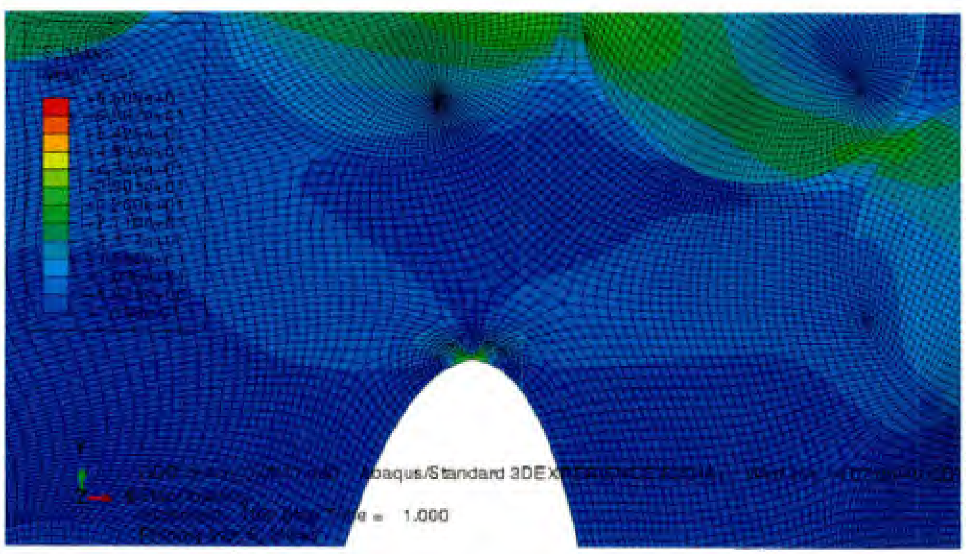

Figure 2. A transverse crack tip in the cross section of a composite where the nonuniformly distributed discrete fibers are present.

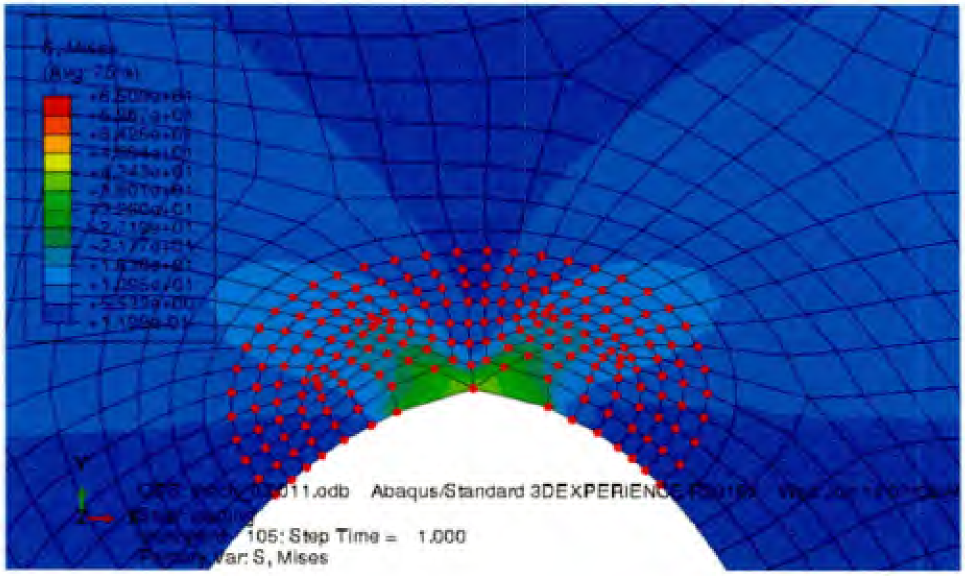

Figure 3. The paths for calculating the J-integral are incated. The path independency of the J-integral has been checked.

The **Ongoing research** will analyze the driving forces of the initiated cracks by the J-integral method to reveal the effect of discrete fibers distributed nonuniformly depending on the fiber mobility during the resin infusion process.