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

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PI: Ramesh Talreja

Executive Summary

The work performed in the final reporting period has been focused on analyzing 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 on the cracking py has also been investigated.

In the previous Quarterly Report, we reported on clarifying how the presence of fiber clusters influences the driving force of an initiated crack in a unidirectional ply under transverse tension. As a baseline, the mode-I stress intensity factors were 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. As described in the previous report, the curves for the matrix case became higher as the fiber mobility increased. The homogenized composite within the cell showed the opposite trend. In this case, the stress intensity factor approached that of the surrounding homogenized composite as the fiber mobility parameter decreased, while it tended towards the matrix stress intensity factor as the fiber mobility parameter increased. The variation of the J-integral with the normalized crack length for the three cases were also reported for the fiber mobility parameter $\delta r = 0.1$. For this low fiber mobility case, the difference between the homogenized composite and the composite with randomly distributed fibers was found to be small and it essentially disappeared at large crack sizes. Both cases of composites had higher crack driving forces compared to that of matrix, as expected.

In Fig.1 we report the 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, $\delta r = 0.2$. Figure 2 shows the same results for the case of $\delta r = 0.3$. As can be seen, the deviation of the J-integral for discrete fiber case from the homogenized case increases for normalized crack size of 6, but this deviation then reduces with the crack size as the fiber mobility parameter increases, i.e., as the fiber clustering descreases. These trends remain consistent at larger fiber mobility parameters.

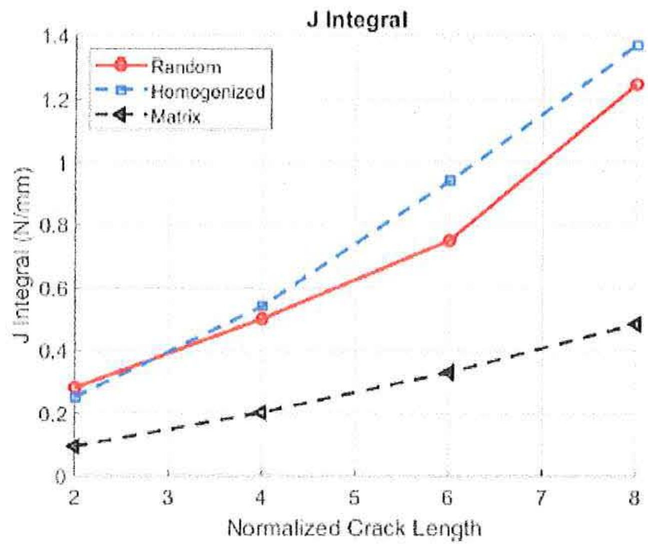

Figure 1. J-integral variation with the crack length normalized by the fiber diameter for the embedded cell with matrix, with homogenized composite and with randomly distributed discrete fibers, all for one normalized fiber mobility parameter, $\delta r = 0.2$.

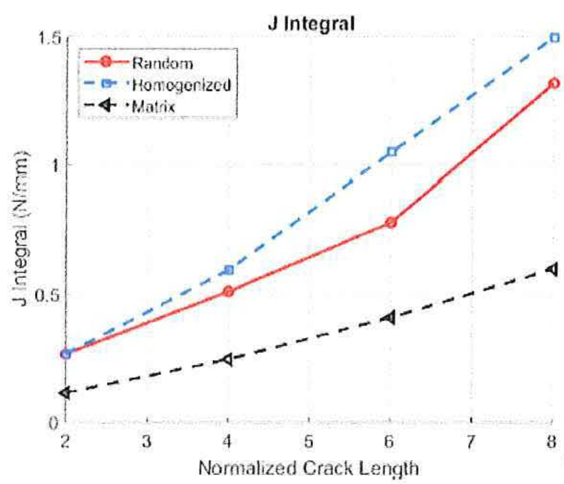

Figure 2. J-integral variation with the crack length normalized by the fiber diameter for the embedded cell with matrix, with homogenized composite and with randomly distributed discrete fibers, all for one normalized fiber mobility parameter, $\delta r = 0.3$.

In a laminate, transverse cracking in a ply occurs under the constraint of the neighboring plies. To study this constraining effect, a model was created in which the constraining ply is bonded to the cracking ply, as illustrated in Fig. 3. The constraining ply of axial modulus E_0 is regarded as a stiffener, while the transverse cracking ply of softer modulus E_{90} contains an embedded cell (RVE) of discrete fibers. Transverse cracks of different sizes as multiples of fiber diameter ϕ are placed at the center of the RVE. The J-integral calculated for these cracks is plotted against the ratio of the stiffening ply modulus E_0 to the laminate modulus E_c for one mobility parameter $\delta r = 0.5$. The increase of J-integral represents the decrease of the constraining effect.

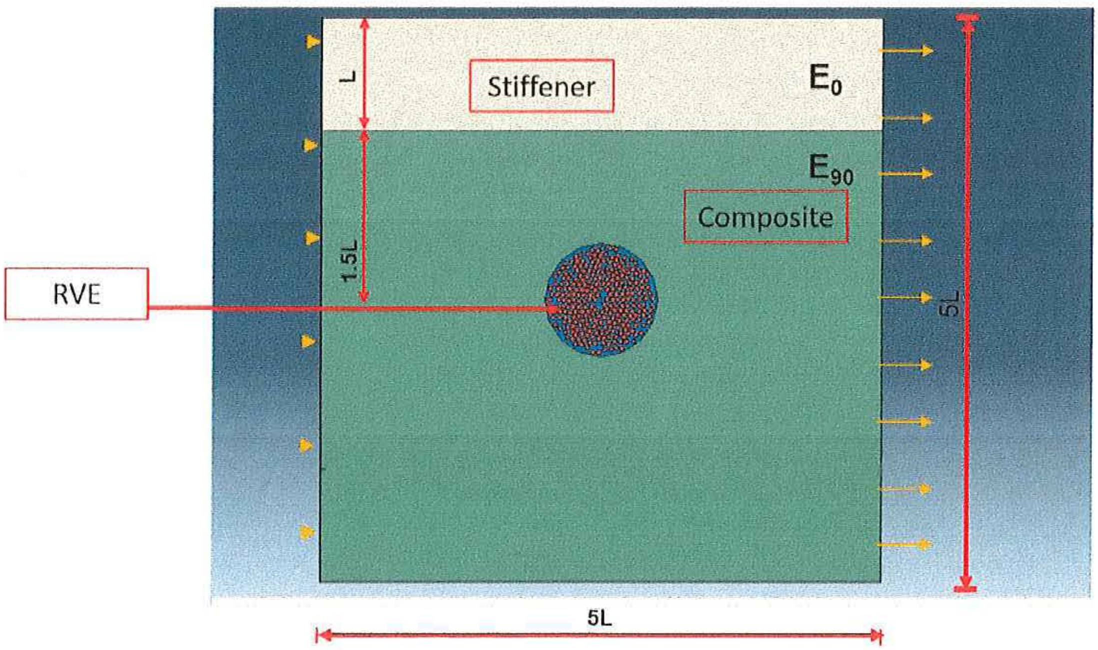

Figure 3. The model geometry for analysis of the ply constraining effect on the crack driving force on cracks initiated in the fiber clusters (RVE).

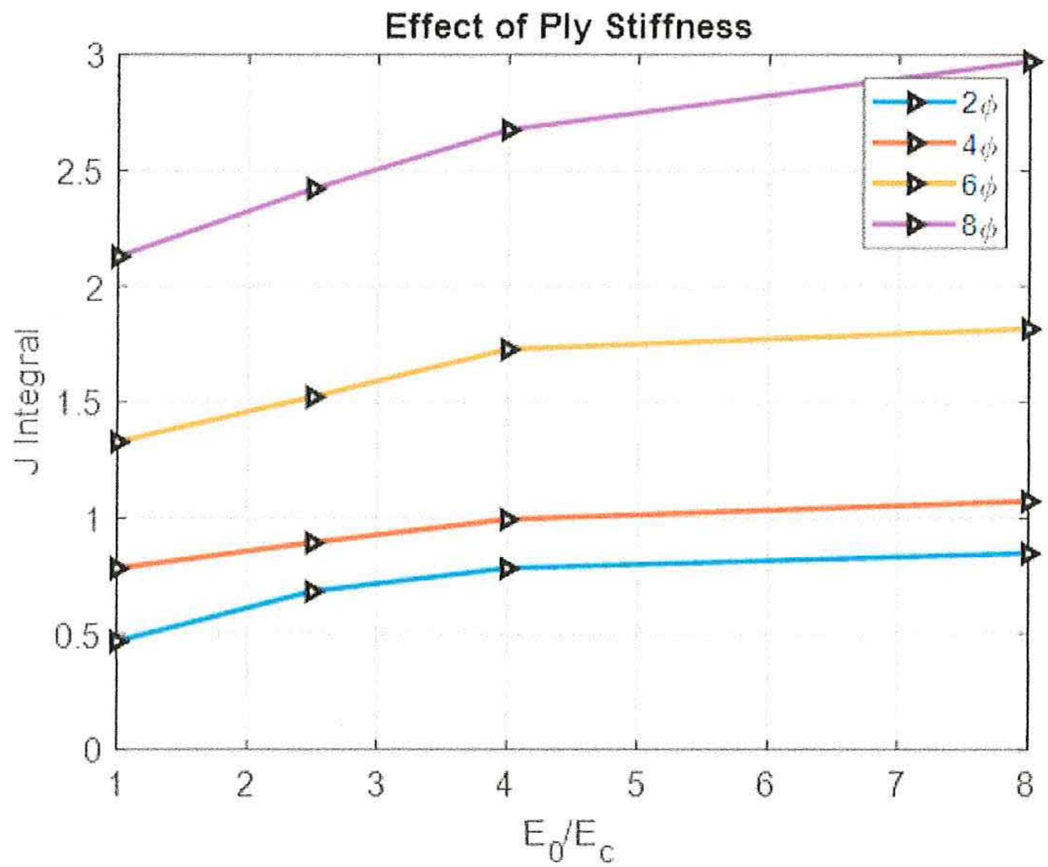

Figure 4. Effect of ply stiffness on the J-integral for cracks of different sizes within the RVE corresponding to the fiber mobility parameter $\delta r = 0.5$.

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Texas A&M Engineering Experiment Station (TEES)
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15. SUBJECT TERMS
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