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14. ABSTRACT

The work performed in the reporting period has been focused on completion of the stress and failure analysis of the manufacturing induced fiber distribution nonuniformity. The case considered is when resin is infused into dry fiber bundles.

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Quarterly Progress Report, October 1 – December 31, 2018

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 by the co-PI on the subaward issued to The University of Nebraska was completed on December 31, 2018. The last quarterly report included that work. The project was given a no-cost extension for the year 2019 to complete the work by the PI that was delayed during the originally funded period of performance. This report and the subsequent quarterly reports will report that remaining work.

The work performed in the reporting period has been focused on completion of the stress and failure analysis of the manufacturing induced fiber distribution nonuniformity. The case considered is when resin is infused into dry fiber bundles.

In previous reports, we described the process by which fiber mobility during the resin infusion into a dry fiber bundle is simulated. Using different ranges of radial and angular mobilities in a statistical algorithm developed for simulations, several (typically five) realizations of a representative volume element (RVE) are generated. Each realization is then embedded in a homogenized composite that represents the surrounding composite. The square-shaped embedded-cell model is subjected to uniform outwawd displacement on two parallel boundaries. Hill's concept is then used to determine the size of the surrounding homogenized composite. Figure 1 shows the final outcome of this exercise (details were given in the Third Quarterly Report, 2017).

The entire embedded cell is analyzed using the finite element method and the stress field in the matrix around the fibers is determined. This field is searched to find the most favorable point (or points) where the dilatational energy density crierion for initiation of brittle cavitation is satisfied. As the applied strain is increased, more sites in the embedded cell satisfy the cavitation criterion (see Fig. 2). In some of the sites, a clustering of the cavitation failure is found. The cluster sizes are quantified as the number of fibers, and assuming that these represent initiation of transverse cracks, the applied strains at which these cracks are formed are recorded. Figure 3 shows the applied strain at which cavitation initiates and when cracks of different sizes are formed.

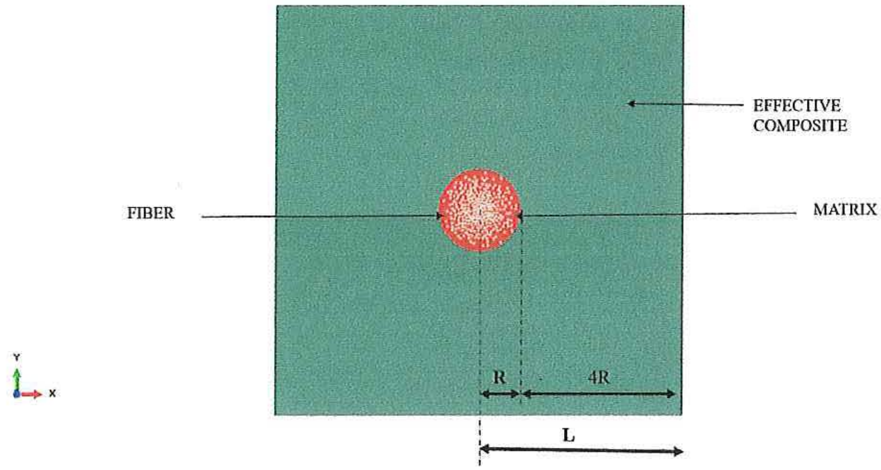

Figure 1. Embedded cell representation of a discrete-fiber region with manufacturing-induced nonuniform fiber distribution. The embedded cell model is subjected to uniform displacement on the vertical boundaries.

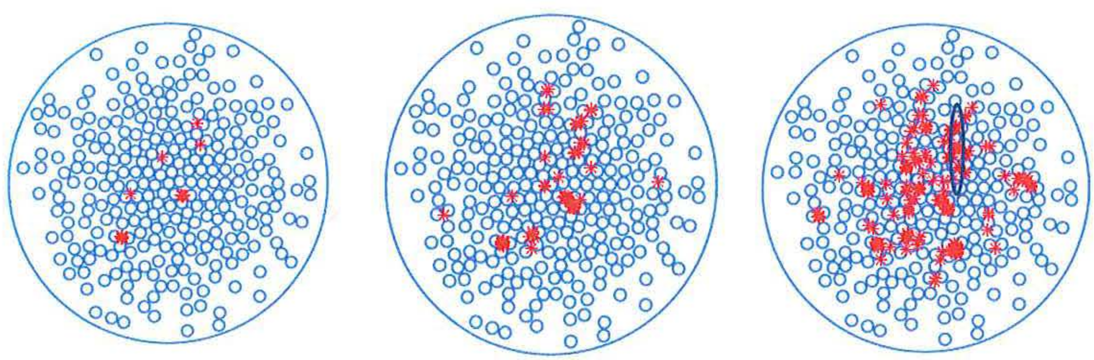

Figure 2. The embedded cell of Figure 2 subjected to uniform displacement normal to the vertical boundaries shows cavitation at different sites, increasing in number (from left to right) as the applied strain is increased. The last figure to the right illustrates crack formation by a cluster of cavitation points.

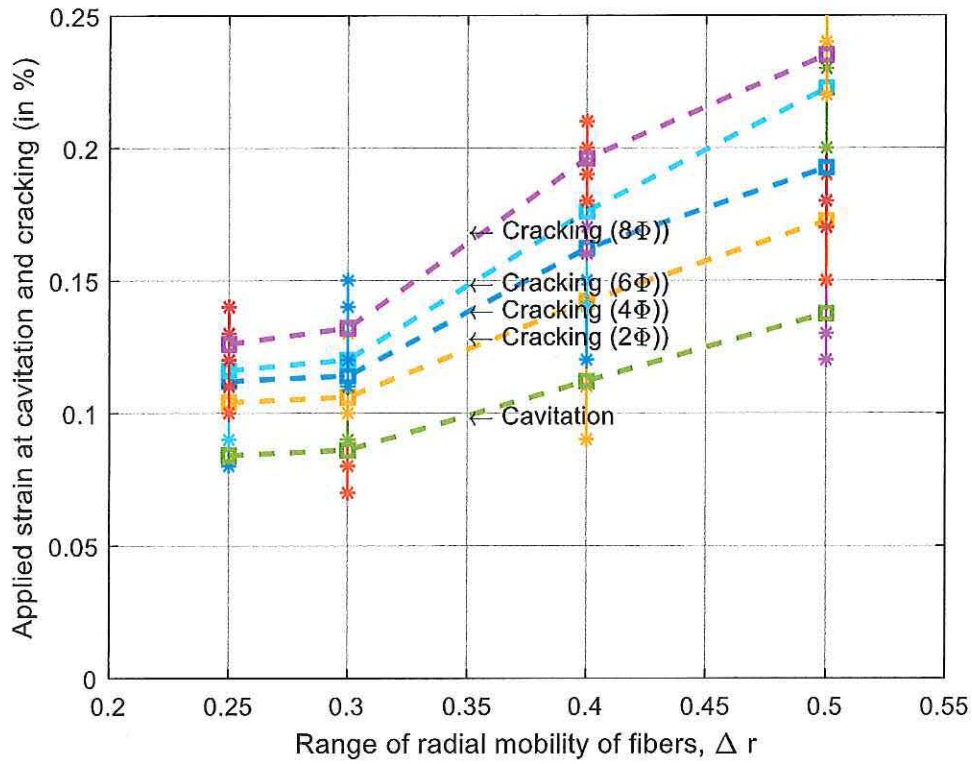

Figure 3. The level of applied transverse strain to initiate cavitation at different ranges of fiber mobility during resin infusion (bottom green curve) and to form cracks of different sizes (given as number of fibers).

The **Ongoing research** will analyze the driving forces of the initiated cracks by the J-integral method.