Simulation of crack patterns in CMC combining GFEM & Finite Fracture Mechanics

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Keywords: Generalized Finite Element Method, Finite Fracture Mechanics, Ceramic Matrix Composites (CMCs), handbook problems.

Recently a computational approach for handling complex Ceramic Matric Composite (CMC) microstructures was presented [1]. In this work, in order to handle the associated high level of complexity, a GFEM-like approach for modeling the CMC yarn was proposed along with a pattern-based description of the microscale. The classical difficulties associated with the implementation and computation cost of the GFEM [2, 3] are dealt through a multiscale approach based on the Saint Venant principle. This multiscale vision enables the microstructure and the microkinematics to be handled on the scale of the pattern regardless of the discretization on the macroscale.

A direct extension of the approach for the simulation of different crack events (strong discontunuities) is introduced inside the framework of finite fracture mechanics. This comes from the fact that many failure processes of CMC are characterized by fracture events instead of by continuous crack growth. Typical fracture events are fiber breaks, matrix cracks and fiber/matrix debonding. This step by step crack formation appear instantaneously on the experimental time scale and is not possible or of interest to follow the history of their development. The crack growth is often not observable; all that can be observed is the occurence of fracture events. Therefore, Hashin [4] has recently termed an extension of fracture mechanics as finite fracture mechanics because it extends fracture mechanics to handle failure by events that involve a finite amount of new fracture area.

There are two major tasks in the current computational approach: first, selection of appropriate mesh handbook problems for crack modeling i.e., a pattern of two fibers with an interconnecting crack, fiber/matrix debonding, etc. The presence of inclusions and cracks disturbs localy the uniform stress field. Thus the total stress field at any point of the handbook domain can be decomposed into the uniform and disturbed stress fields. An investigation of the length scale of the disturbed (localized) stress field induced by the different crack patterns is important in order to use the Saint Venant principle instead of the Partition of Unity as the main mechanism to reconstruct the global solution from the handbook problems. However, the non-interaction between patterns is hard to be respected because of the strong discontinuites (free surfaces) of size of several fiber diameters.

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Second, finite fracture mechanics computations are performed for different crack patterns in the global domain in order to specify patterns that maximize the energy release rate at the current loading stress state. In order to avoid performing such a large number of combinations between different patterns, certain criteria for the formation of a new crack are established. These criteria are based on the energy release rate G by the formation of a specific crack event. A stress analysis of a specific crack event is required to calculate the total energy released by the formation of the complete crack. The most important physical property which must be determined is the surface energy per unit area or critical energy release rate G_c. This section is concerned with the development of a criterion for the formation of new cracks as a result of stress load.

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