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A "Parallel Universe" Scheme for Crack Nucleation in the Phase Field Approach to Fracture

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ABSTRACT

Crack nucleation is crucial in many industrial applications. The phase field method for fracture transforms the crack nucleation problem into a minimization problem of the sum of the elastic potential energy and the crack surface energy. Due to the polyconvexity of the formulation, starting from a crackless solid, a standard Newton iteration may lead to a solution with no crack, even though a cracked solution has a lower total energy. As such, the critical load for cracking is highly overestimated. Here, we propose an algorithm termed "parallel universe" algorithm to capture the global minimum. This algorithm has two key ingredients: (a) a necessary condition for cracking solely based on the current crackless solution, and (b) beginning from when this condition is met, Newton iteration with two initial guesses, a crackless one and a cracked one, will both be performed and the converged candidate solution with lower energy is accepted as the solution at that load step. Once the cracked candidate solution is accepted, the crackless one is discarded, i.e., only one universe is retained. This cracked initial guess is obtained only once for all load steps by solving a series of similar minimization problems with a progressively reduced critical crack energy release rate. Numerical examples with isotropic and anisotropic critical crack energy release rates indicate that the proposed algorithm is more reliable (as there is no need to retrace) and more efficient than the standard Newton iteration and a well-known backtracking algorithm.

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