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Peridynamic model for fatigue cracks

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ABSTRACT

The peridynamic theory of solid mechanics is an extension of the classical theory whose field equations can be applied on evolving discontinuities, such as cracks and dislocations. As such, it potentially offers increased generality in the modeling of the nucleation, growth, and mutual interaction of cracks and other defects. Although most applications of the peridynamic theory to date have concerned dynamic fracture, a recent advance extends the theory to fatigue cracking under cyclic loading. The method consists of a peridynamic bond failure criterion that depends on the history of cyclic bond strain. Each bond has associated with it a scalar variable called the remaining life that decays over many loading cycles. The bond breaks irreversibly when this variable becomes zero. By calibrating the model to S–N data and Paris law curves, the essential features of fatigue crack nucleation and growth are reproduced while retaining the main advantages of the peridynamic formulation. A mapping from simulation time to the number of loading cycles avoids the need to explicitly simulate large numbers of cycles. This discussion will cover the basic equations of the peridynamic theory and the new fatigue model. The calibration method for real materials will be discussed, demonstrating good agreement with laboratory test data in computational modeling of fatigue crack growth in an aluminum alloy. Extension of the fatigue model to variable cycling loading amplitude will also be discussed.