Surrogate Models for High-Order Integration of Fatigue Crack Growth Models

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Modeling fatigue crack growth is a challenging computational fracture mechanics problem because (1) it requires expensive simulations to calculate the crack growth rate, and (2) the accurate crack growth rate can only be evaluated at the current crack size. This paper addresses the computational issues related to modeling crack growth via numerical integration of the crack growth rate. The forward Euler method has been a natural method of choice in integrating fatigue crack growth, but accuracy is only guaranteed with a very small size of increment. This hinders failure investigation of systems with complex geometry, which would require expensive finite element simulations. Higher-order integration methods, such as the midpoint method, might allow larger increment size but require additional evaluation of crack growth rate at crack sizes larger than the current one. For arbitrary geometries, this is not an easy task because the direction of crack growth is unknown in advance, and additional simulations are often prohibitive. Here, a kriging model generated using the past crack sizes is used to provide the crack growth rate at future locations without the need for additional finite element simulations. Kriging is also used to estimate the accuracy of the predicted crack size, and further use this information to determine the appropriate step size. The approach was tested in various examples with different crack configurations. The preliminary results showed that a large increase in the allowable step size may be used with increased accuracy over the Euler method without the need for additional simulations.

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