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Fatigue Crack Growth due to Random Loading

Paul S. Veers

Sandia National Laboratories
Albuquerque, New Mexico 87185-5800

ABSTRACT

Fatigue crack growth due to random loading is investigated, showing a variety of approaches that are tailored to the level of complexity required for the application at hand. The emphasis is on creating the simplest models, of both the crack growth process and the random loading, that maintain the desired level of accuracy.

A new crack growth model, which combines some of the features of existing models, is introduced and shown to predict several sets of published test results. The model provides a means of approximating load sequence effects by continuously updating the crack opening stress, accounting for both acceleration and retardation effects in a simplified manner. This model is used as the standard crack growth model that includes sequence effects.

Random load models, which describe the relevant events in the loading necessary to implement the above crack growth model, are outlined. These models range from simple random variable descriptions, which are useful in sequenceless applications, to random process simulations, which include the relative likelihood of various load sequences. Existing random variable descriptions of narrow-band loadings are shown to be useful approximations for any Gaussian loading. New results that account for the overall peaks and ranges in wide-band loadings are obtained through *racetrack filtering*. An efficient sequential simulation method uses the random variable results to simulate only the most significant events in a random process by breaking the loading into slow (mean variations) and fast (amplitude variations) parts.

Practical methods for calculating crack growth life are presented by applying the load models to the above crack growth model, and to an alternative model that neglects sequence effects. Inherent difficulties in the traditional, sample-block, load model can be eliminated with a continuously defined loading, which can be obtained by the sequential simulation method. This simulation method is used in studies that illustrate the relative importance of including load sequence effects in crack growth analysis. For stationary Gaussian loadings, sequence effects can often be neglected. Nonstationary random loadings are also simulated and shown to produce greater sequence effects. When distinct overloads are present, the regularity of the spacing is important; assuming uniform spacing can be nonconservative.

As an alternative to simulation, analytical estimates of crack growth life, including sequence effects, are examined using diffusion models. The emphasis is on simplifying the problem (i.e., scalar diffusion models) so that solutions can be obtained with limited computational resources. Solutions for mean and variance of the time to failure due to constant amplitude loading with distinct tensile overloads are presented. The mean time to failure due to stationary Gaussian loading is also estimated. More complete, but computationally expensive, solution methods using vector diffusion models are outlined.