

14. REDUCING UNCERTAINTY IN FATIGUE LIFE ESTIMATES

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SUMMARY

A method of estimating fatigue-life variation is presented. The approach consists of introducing finite element results and probabilistic material property simulations into a fatigue or crack-growth model and then analyzing the data to develop the cumulative distribution function for life expectancy. Justification of this method stems from the fact that many empirically-derived material constants, such as the fatigue-ductility exponent and the fatigue-ductility coefficient, are calculated by regression of a data set whose correlation coefficient is less than unity. The approach is general and can be applied to any fatigue or crack growth-model.

It has been recognized that in well-controlled constant-amplitude fatigue tests, the observed variation in fatigue life can be wholly attributed to variations in material properties. Without simulating material property uncertainties, realistic characterization of fatigue outcomes is impossible, as only point estimates of fatigue life result. The approach that has been taken consists of three steps. The first is to model material properties using the Monte Carlo method. The second is to solve the fatigue model of choice at the physical point of interest for cycles to failure. The third is to analyze the resulting data.

The Weibull distribution is often used to describe quantities such as life expectancy, time to failure, strength, etc. We have employed it in this work and offer it as only one of many possible stochastic models, e.g., log-normal. The simplest approach to Weibull data analysis is calculation of linear least square estimators. Although easily calculated, linear least squares estimators (LLSE) are not unbiased. Maximum likelihood estimators (MLEs), which are unbiased, are therefore generally preferred. Both sets of estimators are presented and a simple approach to calculating the MLEs for a large number of samples is discussed.

An approach to simulating correlated random variables is presented. Application of the fatigue-life prediction methodology will be discussed. A number of finite element models will be presented as examples demonstrating the process and the insight that can be gained from the resulting output.