Materials Science & Engineering Doctoral Defense

Investigation on Fatigue Behavior of Alloys by Various Approaches

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abstract

Fatigue is a degradation process of materials that would lead to failure when materials are subjected to cyclic loadings. During past centuries, various of approaches have been proposed and utilized to help researchers understand the underlying theories of fatigue behavior of materials, as well as design engineering structures so that catastrophic disasters that arise from fatigue failure could be avoided. The stress-life approach is the most classical way that academia applies to analyze fatigue data, which correlates the fatigue lifetime with stress amplitudes during cyclic loadings. Fracture mechanics approach is another well-established way, by which people regard the cyclic stress intensity factor as the driving force during fatigue crack nucleation and propagation, and numerous models (such as the well-known Paris' law) are developed by researchers. The significant drawback of currently widely-used fatigue analysis approaches, nevertheless, is that they are all cycle-based, limiting researchers from digging into sub-cycle regime and acquiring real-time fatigue behavior data. The missing of such data further impedes academia from validating hypotheses that are related to real-time observations of fatigue crack nucleation and growth, thus the existence of various phenomena, such as crack closure, remains controversial. In this thesis, both classical stress-life approach and fracture-mechanics-based approach are utilized to study the fatigue behavior of alloys. Distinctive material characterization instruments are harnessed to help collect and interpret key data during fatigue crack growth. Specifically, an investigation on the sub-cycle fatigue crack growth behavior is enabled by in-situ SEM mechanical testing, and a non-uniform growth mechanism within one loading cycle is confirmed by direct observation as well as image interpretation. Predictions based on proposed experimental procedure and observations show good match with cycle-based data from references, which indicates the credibility of proposed methodology and model, as well as their capability of being applied to a wide range of materials.

July 6, 2018; 3 PM; ERC 490