ENVIRONMENTALLY ASSISTED FATIGUE CRACK GROWTH

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Modeling of environmentally assisted fatigue (or corrosion fatigue) crack growth in terms of environmental variables and of microstructure is presented. The models serve as a framework for understanding the mechanisms for corrosion fatigue and the crack growth response. Crack growth response is determined by the underlying rate controlling processes (namely, transport, surface reaction and hydrogen diffusion), and can be modified by metallurgical processes, such as strain induced hydride formation. The principal features of fatigue crack growth response and the current state of understanding are illustrated by data on structurally important alloys. The interactions between environment and microstructure are illustrated by recent results on a high-strength steel and an aluminum alloy. The need for utilizing such a framework and for environmental control in the study of fatigue mechanisms is emphasized. Implications for design are discussed.

1. INTRODUCTION

In this paper, chemical and microstructural modeling of corrosion fatigue crack growth is described. The models serve as a framework for understanding the role of environmental variables and of microstructure in determining corrosion fatigue crack growth response. The primary intention is to provide insight into the complex nature of corrosion fatigue, and an overview of the current state of understanding of the chemical and microstructural aspects of corrosion fatigue crack growth. It is hoped that the paper will stimulate further systematic studies of the influences of environment and microstructure on corrosion fatigue crack initiation and growth, and the incorporation of the resulting fundamental understanding into design practices. The principal features of corrosion fatigue crack growth response and the current state understanding are illustrated by data on structurally important alloys in gaseous and aqueous environments. The interactions between environment and microstructure are illustrated by recent results on a high-strength steel and an aluminum alloy.

Metal fatigue is well recognized as an important cause for failure or early retirement of engineering structures. The fatigue performance of structures can be further degraded by the interactions of fatigue loading with the external (service) environment, or with an environment (e.g., hydrogen) that is internal to the material; in other words, by corrosion fatigue or environmentally assisted fatigue cracking. One of the principal challenges for fatigue science and technology, therefore, is the quantitative and reliable prediction of structural fatigue life under projected service loading and environmental conditions. The quality of the prediction impacts upon structural reliability, the planning for maintenance, and the validity of estimates of life-cycle costs.

Current design approaches are based upon the presumption that short-time data can be extrapolated and used in predicting long-term structural performance. The extrapolations involve both size (small test specimen to structure) and time. Time extrapolations can amount to one to three orders in magnitude (i.e., from 1 year to 1,000 years) (see Fig. 1), and

![FIGURE 1. The design challenge. Schematic illustration of the time gap between design data and desired service life.](image-url)

often involve ad hoc assumptions or simple neglect of long-term variations of environmental conditions and changes in material properties. "Safety factors" are used to cover uncertainties associated with these extrapolations, and designs are "verified" through service simulation tests. Unfortunately, the appropriateness of safety factors and the relevance of design-verification tests (where the projected service conditions are significantly compressed in time) cannot be adequately quantified. The level of assurance for safety and reliability offered by these approaches (or the degree of risk), therefore, cannot be quantitatively assessed.

To improve upon the current fatigue design approaches, it is essential to develop quantitative methods for fatigue life