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CRACKING BEHAVIOR OF CORED STRUCTURES

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ABSTRACT

The effects of compositional gradients, are considered based on a thermodynamic analysis, referred to as the Cahn-Hillard analysis, which describes the degree to which a local surface energy is modified by the presence of a composition gradient. The analysis predicts that both ductile and brittle fracture mechanisms are enhanced by the presence of a composition gradient. Data on stress corrosion cracking and fatigue crack growth in selected FCC alloys are used to illustrate the significance of microsegregation on mechanical properties.

INTRODUCTION

The presence of microsegregation and other compositionally non uniform conditions have been found to directly affect the mechanical properties of a wide variety of systems. For example, Johnson and Grimsley (1) improved the stress corrosion cracking resistance of 17-7 PH stainless steel by homogenization, a heat treatment which eliminates compositional gradients. In weldments, both Savage et al (2) and Berry et al (3) reported that stress corrosion cracks in as-solidified microstructures follow the location in the microstructure where the concentration gradient is the steepest. To illustrate this point, Figure 1 shows the chromium microprofile in solidified stainless steel, along with the observed location (at the steepest point in the gradient) of a stress corrosion crack (3).

Other forms of cracking are also dependent on the magnitudes of microcompositional gradients. For example, Choi et al (4) showed that post-weld heat treatments decreased the susceptibility of Monel Alloy 400 weld metal to high temperature creep cracking. The decrease in cracking susceptibility correlated directly to changes in the microcompositional gradients due to the post-weld homogenization heat treatments.

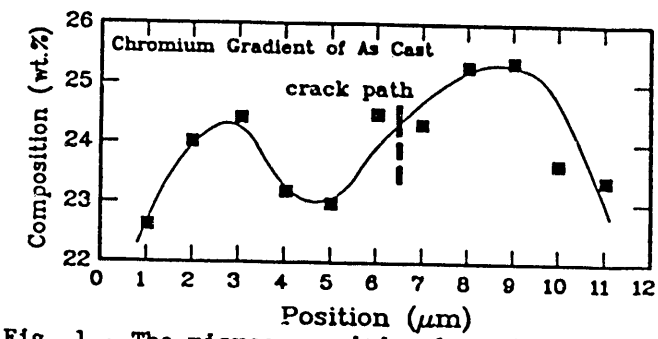

Fig. 1 - The microcompositional profile for chromium content across a stress corrosion crack of as-cast CK-20. Data were obtained on an unetched surface. Dashed line represents stress corrosion crack location (3).

These observations lead to fundamental questions about the role of microsegregation or compositional gradients on the local mechanical behavior and on the initiation and propagation of cracks. In this paper fundamental aspects of cracking in compositionally modulated structures are introduced. First-principle analyses are presented to illustrate the approach to the evaluation of both brittle and ductile cracking behavior in selected systems with controlled composition gradients.

BRITTLE FRACTURE

The magnitude of the brittle fracture stress of a material is strongly dependent on the specific surface free energy as suggested by the Griffith Crack theory (5) and described quantitatively by:

$$K_c = \alpha\sigma_F (\pi C)^{1/2} = \alpha (2\gamma E)^{1/2} \quad (1)$$

MASTER

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