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Effect of weld metal toughness on fracture behavior under ultra-low cycle fatigue loading (earthquake)

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Abstract

Results from 12 ultra-low cycle fatigue tests performed on the weld metals of both toughness and non-toughness rated grades are presented. Fracture resistance under these loadings seemed to be dependent on materials' toughness, displacement amplitude, and stress state triaxiality, while the toughness effect was more highlighted at high stress levels and concentrations. To study the effect of microstructures on these failures, supporting ancillary tests including all-weld tension coupons, Charpy V-notched impact tests, and optical and scanning electron microscope analyses were performed. The favored microstructures appeared to be those which absorbed energy by plastic deformation and, hence, hindered void formation and/or could avoid crack propagation by deflection. Considering the response of the tested materials to cyclic loadings and the requirements of the materials specified in AISC341 Provisions could question the adequacy of these requirements for weld metals. However, the role of microstructural features like inclusions would be the same in both the Charpy impact tests and ultra-low cycle loadings.

Keywords: Weld metal, Ultra-low cycle fatigue, Toughness, Microstructure

Notations

f Void volume fraction
 h Void depth
 J_{IC} Critical J-Integral fracture toughness for Mode I cracking
 L Characteristic length of microstructures
 M Dimple morphology parameter
 R Notch radius
 σ_y Yield stress
 w Void width

1- Introduction

Welded connections are critical components in earthquake-resistant steel structures. Severe damage to these connections during the 1994 Northridge and 1995 Kobe earthquakes has highlighted the effect of weld metal toughness on the response of the welded connections to seismic loadings [1, 2]. Investigations have clarified two

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