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Modeling of path-dependent multi-axial fatigue damage in wrought aluminum alloys

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Abstract

This paper presents a comprehensive investigation into non-proportional loading induced multi-axial fatigue damage in wrought aluminum alloys using a recently developed multi-axial fatigue damage parameter. The moment of load path (MLP) based fatigue damage parameter is formulated in a form of an equivalent stress or strain range that measures both the extent of load-path deviation from proportionality within a fatigue cycle and material sensitivity to load-path non-proportionality. The use of such a fatigue damage parameter for correlating a large amount of test data is given in a recent publication by Mei and Dong (2016) for structural steels that are deemed very sensitive to non-proportional loading. This study examines another class of materials such as various types of wrought aluminum alloys (including 2000, 5000, 6000 and 7000 series) that are typically viewed as being less sensitive to non-proportional loading. A generalized procedure for extracting material sensitivity parameter from stress-life or strain-life test data under simple multi-axial loading conditions is first presented. After obtaining material sensitivity parameter for each of the wrought aluminum alloys examined in this study, It is found that material sensitivity parameter can be related to material ductility (in terms of percentage of elongation from tensile tests) in an approximately linear manner in both low-cycle and high cycle regimes. An excellent agreement (mostly within a factor of 3) is achieved between model-estimated fatigue lives and test lives for all materials under various non-proportional multi-axial loading conditions considered in this study.

Keywords: Multi-axial fatigue, wrought aluminum alloys, non-proportional loading, fatigue damage modeling, damage parameter, material sensitivity. cycle counting

1. Introduction

Over the past few decades, there has been a great deal of experimental evidence [1-10] documenting that additional fatigue damage can be introduced under non-proportional multi-

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