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An equivalent stress parameter for multi-axial fatigue evaluation of welded components including non-proportional loading effects

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Abstract

This paper presents a comprehensive investigation into non-proportional multi-axial fatigue of welded components by introducing an equivalent structural stress parameter that takes into account of load-path non-proportionality in addition to plate thickness and stress state effects. This is accomplished by formulating a "moment of load-path" or "MLP" based fatigue damage parameter that provides a consistent treatment of load-path non-proportionality under arbitrary multi-axial loading conditions for which cycle counting can be consistently performed by means of a previously developed path-dependent maximum range (PDMR) cycle counting procedure. To examine its broad applicability and effectiveness, non-proportional multi-axial test data obtained using different components, joint types, and loading conditions from various sources are analyzed using the newly developed equivalent stress parameter. The results show that the new equivalent stress parameter enables not only an effective consolidation of all multi-axial test data (up to about 300 tests) analyzed in this paper into a narrow band, but also the demonstrated transferability between the master S-N curve (dominated by test data under uniaxial cyclic loading conditions) adopted by the 2007 ASME Div 2 and API 579 RP/ASME FFS-1 Codes and the consolidated S-N curve dominated by severe non-proportional multi-axial cyclic loading conditions. As a result of the present development, a unified fatigue evaluation procedure based on the newly proposed effective stress parameter and a single master S-N curve can be implemented for arbitrary cyclic loading conditions regardless of stress multi-axiality or load path proportionality.

Keywords: *Multi-axial fatigue, welded joints, non-proportional loading, fatigue damage parameter, mesh-insensitive method, traction stress, structural stress, master S-N curve*

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