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Toward the Automated Determination of Structural Detail Geometry for a Target Fatigue Life

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ABSTRACT

A method for evaluation of allowable stress concentration factors (SCFs) and hence the local geometry of structural details subject to complex loading is developed to meet a specified target fatigue life. The method is based on the local strain approach to fatigue, and takes into account the long term loading history. On the condition that cumulative fatigue damage equals unity, an upper bound of the allowable SCFs conditional on a selected mode of loading is found, and the corresponding changes to the initial detail geometry are determined. In the general case of multiple loading modes, the procedure normally needs to be repeated, until overall convergence in geometry occurs. The method is supported by necessary software and an SCF database.

KEYWORDS: fatigue, local strain approach, determination of geometry

INTRODUCTION

Fatigue life estimates are sensitive to small variations in the nominal stress and in the local conditions which control the crack initiation, in particular the stress concentration. One way of making the structural fatigue model less sensitive to these uncertainties is to directly base the fatigue evaluation on the theoretical stress concentration factors characterizing the local fatigue conditions in the structural detail. As a basis of such a model the local strain approach can be used. The approach is restricted mainly to the fatigue crack initiation period, wherein the local plastic strain range controls the conditions of the microscopic crack origination and the initial stages of macroscopic crack formation.

Examples of structural details of interest include openings in the deck and outer plating at hatches, side-ports, and transverse frame webs slots in FPSOs and other floating structures. A typical feature of these details is the presence of a combination of global or geometric stress concentrations and more localized stress concentrations produced by the presence of welds. The material of the "process-zone" at a crack initiation site therein deforms non-linearly due to the mechanisms of micro and macro-plasticity occurring under the total effect of these stress concentrations, leading to fatigue under cyclic loading.

In practice, the local stress history in such details results from the simultaneous application of several correlated cyclic loads, and this is considered in the proposed method. Also considered is the nonlinear material response at the fatigue crack initiation site(s). Ideally, the method would operate by first selecting an initial geometry, for which the corresponding stress concentration factors (SCFs) as a function of the loading modes and target fatigue life are obtained as the solution of an optimization problem considering several crack initiation points. Instead, what is done in the present formulation is to start with an initial geometry, select one of the modes of loading as the principal one, and vary the corresponding SCFs for that loading mode until the required target fatigue life is obtained. On the condition that the cumulative fatigue damage D equals unity, an upper bound of the allowable SCFs for the selected mode of loading is found, and the corresponding changes required in the initial detail geometry determined. The same procedure is repeated for considering the other loading modes, until convergence in geometry is obtained.