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FORMING EFFECTS ON HIGH-CYCLE FATIGUE IN AN ALUMINUM SHEET STRUCTURE USING THE OTTOSEN-STENSTRÖM-RISTINMAA MODEL

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Floating structures may suffer from high-cycle fatigue (HCF) failure as a result of complex stress histories caused by wave loads. Traditionally, fatigue life estimation is performed in three steps; simplifying the complex load history using a cycle-counting method [1], calculating the fatigue damage associated with each cycle using a fatigue limit function [2], and adding up the damage per cycle using a cumulative damage rule [3]. Opposed to this approach where fatigue damage is accumulated in discrete cycles, continuous models that describe damage as an integral of incremental quantities in the time domain [4] is gaining attention for the purpose of complete machinery simulations (CMS). In the Ottosen-Stenström-Ristinmaa (OSR) model [4], a back-stress modified endurance surface in six-dimensional stress space separates safe configurations, where fatigue damage cannot develop, from unsafe configurations, where fatigue damage can develop under certain conditions. The model, clearly inspired by plasticity theory, enables fatigue damage to be formulated in a unified manner, inherently accommodating multiaxial, non-proportional and complex stress histories.

In the past few decades, phenomenological plasticity models [5] describing the behaviour of rolled metal sheets during forming has been a topic of extensive research. Software based on the finite element method (FEM), allows conducting advanced simulations of deep-drawing processes, using state-of-the-art material models to predict spring-back [6] and residual stress distributions in the formed components [7]. Yet, as the major application is within the tooling industry, the main attention has been directed towards avoiding material failure in production, rather than assessing the functionality and capacity of final components [8]. Acting as a superimposed mean stress during variable loading, the presence of residual stresses may strongly influence the fatigue life of a component. Nevertheless, few efforts have been dedicated to the coupling of forming simulations and HCF analysis, investigating residual fatigue life of deep-drawn components.

In this work, the deep-drawing process and fatigue life of a floating aluminium structure made from 1.5 mm thick rolled AA5083-H111 sheets is investigated through analysis in LS-DYNA. Forming simulations of a subsection of the full geometry are performed in a realistic two-step drawing-springback cycle. A simplified global analysis of service load response is performed to obtain displacements at the submodel boundary, which are used to create boundary conditions in a local service load analysis. To evaluate how forming affects HCF, the local analysis is performed on three different models of the subsection: (I) excluding forming effects, (II) including effects of thinning, and (III) including effects of thinning and residual stresses.

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