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A FRAMEWORK OF COUPLED FEM SIMULATION FOR FATIGUE CRACK ASSESSMENT OF WELDED HIGH STRENGTH LOW ALLOY S460G2+M STEEL BASED ON LINEAR ELASTIC FRACTURE MECHANICS

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ABSTRACT

This thesis aims to develop sequential thermo-mechanical models and transfer the non-linear welding simulation results as pre-state condition data into fatigue crack propagation prediction model of offshore steel high strength low alloy (HSLA) S460 G2+M using finite element method (FEM), which is contrary to prior studies that applies the consequence of previous state indirectly on the model by superposition or even neglects it. The first section presents the verification study using the robotic gas metal arc welding (GMAW) procedure based on AWS D1.1 to develop welding procedure specification (WPS) with 10mm thickness of three layers V-groove butt-weld prior to the process of fatigue crack growth experiment. The microstructures of each weld zones of specimen were observed and compared. The second section represents the three-dimensional thermomechanical simulation analysis for GMAW process in which the multiphysics software and the thermodynamic as well as physical property for material modelling is computed to determine the material data of HSLA S460G2+M steel and ER 80S-Ni1 filler wire based on the chemical composition. The von Mises yield criterion and associated flow rule with isotropic hardening model were used to characterize the mechanical behaviour. In order to estimate transient thermal cycle and weld deformation, proper meshing strategy is analysed by comparing the widely acceptable hexahedral meshing against the tetrahedral with stiffness challenge in meshing for non-linear simulation. Third section describes the linear elastic fracture mechanics with eccentrically loaded single-edge tension specimen for crack growth analyses employed at the base, heat affected and fusion zone failure mechanism. The fourth section analyses the stress intensity with energy release rate using FEM- based virtual crack closure technique (VCCT). Singular enrichment with mesh geometry at nodes conforming to the crack front have been proposed with adaptive remeshing tools. Lastly, fatigue crack parameters of base material were used to predict the fatigue crack growth at the weld and heat affected zone (HAZ) by adding the effects of induced weld stress model. The structural analysis prediction with each fatigue crack parameter for each specimen and the coupled process using FEM were analysed and compared with the experiment. The outcomes of the research conclude that excellent correlation of destructive and non-destructive results showed accuracy and repeatability of the WPS process qualitatively. The tetrahedral meshing strategy shows good agreement towards weld deformation results compared to the experiment. For both numerical methods of VCCT only and coupled process, the mean relative percentage errors of load cycles were within 6.57% and 11.96% for HAZ. Meanwhile, the mean relative percentage error at weld zone was between 6.38% and 11.10% respectively. It results also show that the application of coupled process provides a potential to predict the fatigue crack growth of weld steel with acceptable percentage error.

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