

UNIVERSITI TEKNOLOGI MARA

**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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TABLE OF CONTENTS

	Page
CONFIRMATION BY PANEL OF EXAMINERS	ii
AUTHOR'S DECLARATION	iii
ABSTRACT	iv
ACKNOWLEDGEMENT	v
TABLE OF CONTENTS	vi
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF SYMBOLS	xvi
LIST OF ABBREVIATIONS	xviii
LIST OF NOMENCLATURE	xx
CHAPTER ONE INTRODUCTION	21
1.1 Research Background	21
1.2 Motivation	23
1.3 Problem Statement	24
1.4 Objectives	25
1.5 Scope and Limitation	25
1.6 Significance of Study	26
CHAPTER TWO LITERATURE REVIEW	28
2.1 Development of High Strength Structural Steel	28
2.1.1 Production Routes of HSS	28
2.1.2 Classification of HSLA	30
2.1.3 Advantage of HSLA	31
2.2 Gas Metal Arc Welding (GMAW)	32
2.3 Implication of Welded High Strength low alloy (HSLA) Steel on its Structural Integrity	33
2.3.1 Weld Metallurgy of HSLA Steel	34
2.3.2 Thermo-mechanical Response of Welded HSLA steel	36

2.4	Welding Procedure Specification (WPS)	39
2.4.1	Preliminary Welding Procedures Specification (pWPS)	39
2.4.2	Weld Procedure Qualification Record (WPQR)	40
2.4.3	Standard Tests	40
2.4.4	Process Variable for WPS Development Based on AWS D.1.1.	45
2.5	Fatigue Strength Assessment of Welded Joint Using Fracture Mechanics	45
2.5.1	Linear Elastic Fracture Mechanics	48
2.5.2	Mode of Loading (Crack opening)	51
2.5.3	Fatigue Crack Growth Rate Analysis for Welded Structural Steel	51
2.6	Numerical Computation for Welding and Fatigue Crack Growth Analysis	58
2.6.1	Gas Metal Arc Welding with Finite Element Method	59
2.6.2	Thermomechanical Analysis	59
2.6.3	Strain Energy Release Modelling with LEFM Parameter for FEM	70
2.6.4	Numerical Analysis of Coupled Welding - Fatigue Crack Growth	73
2.7	Research Gap	74
CHAPTER THREE RESEARCH METHODOLOGY		77
3.1	Introduction	77
3.2	Material and Welding Process	78
3.2.1	Base Material	78
3.2.2	Welding Consumables: Filler Wire and Shielding Gas	79
3.2.3	Welding Equipment	81
3.3	Development Process of Welding Procedure Specification (WPS)	82
3.3.1	Evolution of Preliminary Welding Procedure Specification (pWPS)	83
3.3.2	Automated Welding Process of WPS Test Plate	85
3.3.3	Procedure Qualification Record (PQR)	89
3.3.4	Establishment of Welding Procedure Specification	97
3.4	Welding of the 10mm HSLA Steel Plate	97
3.4.1	Distortion Investigation	98
3.4.2	Residual Stress Investigation	99
3.5	Numerical Computational Analysis	99
3.5.1	FEM Thermo-mechanical Analysis	99
3.5.2	FEM Modelling and Procedure of Multi-Pass Welding	100
3.5.3	Heat Source Model	108