UNIVERSITI TEKNOLOGI MARA

INVESTIGATION ON FATIGUE LIFE ENHANCEMENT OF S460G2+M USING SEMI-AUTOMATED GMAW AND HFMI/PIT

DAHIA BIN ANDUD

Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy

Faculty of Mechanical Engineering

December 2019

ABSTRACT

Welding is a well-known method for joining various steel structures such as bridges, cranes, pipes and oil and gas platforms. Although numerous weld discontinuities might occur that can damage steel structures, many manufacturers still favour this method because of versatility and cost-effectiveness. Welding responsible for almost 90% of mechanical engineering fatigue failures since welding is always associated with various defects which sources of stress concentration where the location of the fatigue crack initiation. This research focused on the fatigue life investigation of the Butt weld, Transverse and Longitudinal T-joint welds of offshore steel S460G2+M with special attention on enhancing the fatigue life of welded structure using a new device of high-frequency mechanical impact using a pneumatic system (HFMI/PIT). In the first phase of the investigation, identification of the best welding parameters combination of the semi-automated GMAW process conducted by developing the Welding Procedure Specification (WPS) for the offshore steel S460G2+M following AWS D1.1 Section 4. WPS is a formal written document describing welding procedures and providing directions to the welder for making sound and excellent quality of welds. The second phase focused on the welding preparation of the fatigue test specimens followed by fatigue testing under a constant amplitude loading and all the fatigue data evaluated based on the International Institute of Welding (IIW) commission XIII. Some of the fatigue specimens were treated with HFMI/PIT for fatigue life enhancement. The third phase dealt with fatigue assessment of the as-welded Longitudinal T-joint welds based on the effective notch stress approach (ENS) using finite element software MSC Marc/Mentat. Based on this research, the development of the actual WPS for the offshore steel S460g2+M depends on the results of the destructive and non-destructive tests reported in PQR. After all testing results complied with the fabrication standard requirements, the actual WPS is to be established. A non-certified welder who has experienced in welding works is assigned to produce high-quality weld based on the welding parameters in actual WPS. It can be concluded that the most exceptional fatigue life of the untreated and HFMI/PIT specimen of the offshore steel S460G2+M is Transverse T-joint welds, followed by Longitudinal T-joint weld and Butt weld. The HFMI/PIT treatment shifted the fatigue crack initiation from the weld toe to the base metal region as the results of the elimination of stress concentration and conversion of the tensile residual stress to compressive residual stress which increased the fatigue life of the welded joint. The FAT class of the converted experiment fatigue data to ENS approach shows good agreement with the FAT class of the ENS fatigue assessment for Longitudinal T-joint weld because both FAT classes inferior to the FAT class recommendation of the IIW commission XIII for the ENS fatigue assessment. The single design S-N curve of FAT 225 of the IIW commission XIII for the ENS approach is relevant for the fatigue assessment of Longitudinal T-joint weld using the ENS approach.

ACKNOWLEDGEMENT

Firstly, I wish to the almighty God for allowing me to embark on my Ph.D. program and for completing this long and challenging journey successfully. My gratitude and thanks go to my supervisor Prof. Ir. Ts. Dr. -Ing. Yupiter HP Manurung CEng, IWE/EWE, VDI on his continuing support and motivation throughout the completion of this thesis.

My appreciation goes to the staff of the AMTEx of FKM UiTM Shah Alam on their overwhelming cooperation, kindness, and technical contribution. My appreciation also goes to Mr. Shahrizal for his patience and advice on the execution of my experimental work. Special thanks to my colleagues and friends for helping me with this project.

My appreciation also goes to lecturers and technicians of the Fabrication and Joining (F&J) of University Kuala Lumpur Malaysia France Institute (UNIKL-MFI) for their support, advice and technical contribution. Not forgetting the CEO of UNIKL Prof. Dato. Dr. Mazliham Mohd Su'ud on his support of UNIKL academic staff embarking on Ph.D. projects.

Finally, this thesis is dedicated to my beloved wife Rossie Taiman, my daughters Diva Deccy, Daniya Danica and my son Danish as well as my other family members for their continuous support and motivation. It is impossible for me to complete this thesis without their overwhelming support. Not forgetting my dear late father and mother for the vision and determination to educate me. This piece of victory is dedicated to both of you.

Special thanks also to Mr. Chong Kum Fatt for helping me with the grammatical correction of this thesis. Finally, to whom I have not mentioned their names, your contributions are most appreciated and may God bless you in your future endeavors. I, hereby, gratefully dedicate this thesis to all of the above

TABLE OF CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Welding is one of the well-known techniques for connecting the steel structure. One of almost 100 types of welding processes used in manufacturing, semi-automated Gas metal arc welding (GMAW) process cannot be neglected. Many steel structures such as bridges, cranes and oil and gas platforms were joined using this fusion welding. Even though there is a lack of consistency as compared to the fully automated GMAW, it is still widely used in the structural fabrication sector because of cost-effective, versatile and portable. Semi-automated GMAW uses continuous filler metal which the current and voltage control by the wire feed system and the weld pool protected by shielding gas from the atmosphere and nowadays, it supplied with steel material data in their system for an instant the semi-automated GMAW-Phoenix 355 Expert 2.0 [1]-[2].

Welded joint always suspected with various welding defects such as undercut, lack of penetration, and notches at the weld toe which becomes the sources of stress concentration, while residual stress because of welding heat increases the local mean stress [1]. These phenomena reduce the fatigue life of the weld since decreasing the fatigue crack initiation time because of the fluctuating loading. To reduce weld defects, a proper welding parameter combination should be established through the development of a Welding Procedure Specification (WPS) for the intended steel material. It is due to the WPS is a formal written document describing welding procedures and providing directions to the welder for making sound and excellent quality of welds as per the standard welding fabrication code requirements [3]. Hence, to produce sound welding, the foremost aim of structural steel fabricators is to develop the WPS for a welding project, which is one of the primary objectives of this research.

The used of proper WPS does not provide enough benefit to the enhancement of the fatigue life of the welded joint since the discontinuities in the welds are unpredictable. Therefore, to respond to this issue, many fabricators and manufacturers