



UNIVERSITI PUTRA MALAYSIA

**IMPROVING THE FATIGUE LIFE OF FUSION-WELDED JOINTS USING
SHOT PEENING METHOD**

NUR AZIDA BT CHE LAH

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**IMPROVING THE FATIGUE LIFE OF FUSION-WELDED JOINTS USING
SHOT PEENING METHOD**

By

NUR AZIDA BT CHE LAH

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in
Fulfilment of the Requirements for the Degree of Master of Science**

July 2009



DEDICATION

To my dear husband, Shafie Zulkifli Datuk Sulaiman for his support and affectionate caring each moment in my life, especially throughout my study, specially dedicated to my late father in-law, Datuk Sulaiman Mohamad and my late father, Haji Che Lah Jusoh, to my mother in-law Datin Zubaidah Abdullah and my mother, Puan Khuzaimah Saat, that I owe them each moment of my life.



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman : Aidy Ali, PhD

Faculty : Engineering

Fusion welding (FW) has been the greatest importance in metal industry application, until today the weld itself still gives significant problems such as porosity and incomplete joint penetration due to the manually handled process. In the present work, FW of ASTM A516 grade 70 carbon steel was characterised in terms of macrostructure, microstructure, hardness, elemental composition, and common internal defects using radiography testing. Fatigue endurance of Manual Metal Arc (MMA), Metal Inert Gas (MIG) and Tungsten Inert Gas (TIG) welded joints were investigated and discussed. Moreover, the assessment of the effectiveness of shot peening in improving fatigue life of FW have been analysed. The results show that the shot peening process greatly improved fatigue strength by removing surface concentration, shifted and closing the discontinuity such as porosity into the internal area. It was seen that the effect of shot peening and skimming process improved the fatigue life of fusion weld (at 190 MPa stress level), it is approximately 78% increase in fatigue life cycles for MMA peened



skimmed joint, 94% increase for MIG peened skimmed joint and 90% increase for TIG peened skimmed joint. Based on the observations, the good correlation achieved between the experimental data and previous research suggests that TIG peened skimmed joints shows the greatest quality compared to MMA and MIG regarding to its controllable and cleanest method that can produce high quality weld with low defects. Finally, the findings from this research give the manufacturer better option in joining metals in order to increase their product performance and safety.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**PENINGKATAN JANGKA HAYAT KELESUAN STRUKTUR KIMPALAN
PELAKURAN DENGAN MENGGUNAKAN KAEDAH ‘SHOT PEENING’.**

Oleh

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Kimpalan pelakuran adalah kaedah penting dalam aplikasi industri logam dan sehingga ke hari ini, masalah berkaitan struktur kimpalan seperti liang-liang dan kurang pelakuran pada bahagian penyambungan masih wujud kesan daripada proses pengendalian manual. Dalam kajian ini, struktur kimpalan pada ASTM A516 grad 70 logam karbon diperincikan dalam makrostruktur, mikrostruktur, kekerasan, komposisi bahan, dan kecacatan dalaman melalui ujian radiografi. Mekanisme kelesuan untuk ‘Manual Metal Arc’ (MMA), ‘Metal Inert Gas’ (MIG) dan ‘Tungsten Inert Gas’ (TIG) dikaji dan dibincangkan. Selain itu, penilaian terhadap keberkesanan rawatan kejuruteraan permukaan, ‘shot peening’ dalam meningkatkan jangka hayat struktur kimpalan dikaji. Hasil kajian menunjukkan proses ‘shot peening’ meningkatkan kekuatan kelesuan dengan mengubah konsentrasi permukaan, menganjak dan menutup kecacatan seperti liang-liang ke dalam struktur dalaman. Berdasarkan kajian, kesan rawatan kejuruteraan ini menunjukkan peningkatan jangka hayat (pada tahap tegasan

190 MPa) sebanyak 78% peningkatan untuk MMA 'peened skimmed', 94% untuk MIG 'peened skimmed' dan 90% untuk TIG 'peened skimmed'. Berdasarkan pengamatan, korelasi yang baik dicapai di antara data eksperimen dan kajian terdahulu menyatakan bahawa struktur kimpalan TIG menunjukkan kualiti terbaik berbanding MMA dan MIG kerana kaedah kimpalannya lebih bersih dan terkawal dapat menghasilkan kualiti kimpalan yang kurang kecacatan. Akhirnya, hasil kajian ini dapat memberikan pilihan kepada pengilang dalam menentukan prestasi dan keselamatan produk mereka.

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I certify that an Examination Committee has met on 3rd July 2009 to conduct the final examination of **Nur Azida Bt. Che Lah** on his **Degree of Master** thesis entitled **“Improving the Fatigue Life of Fusion-Welded Joints Using Shot Peening Method”** in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as Follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citation which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

NUR AZIDA BT. CHE LAH

Date:



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Abbreviations

ASTM	American Society for Testing Material
Al	Aluminum
BM	base metal
Ca	Calcium
EDX	Energy Dispersive X-ray
Fe	Iron
FSW	Friction Stir Welding
FW	Fusion Weld
FZ	fusion zone
FEAM	finite element alternating model
FCAW	Flux Cored Arc Welding
GMAW	Gas Metal Arc Welding
HAZ	heat-affected zone
HCF	high-cycle fatigue
HRC	Rockwell Scale Hardness Test
IQI	image quality indicator
K	Potassium
LCF	low-cycle fatigue
LOP	lack of penetration
Mn	Manganese
MMA	Manual Metal Arc



MIG	Metal Inert Gas
NDT	non-destructive testing
O	Oxygen
PSB	persistent slip bands
PJL	plate joint line
SEM	Scanning Electron Microscope
SMAW	Shielded Metal Arc Welding
SP	Shot Peening
Si	Silicon
S-N	Stress - Life
TIG	Tungsten Inert Gas
WM	weld metal
Zn	Zinc



Symbols

σ_x	transverse direction stress with respect to the weld line
σ_y	longitudinal direction stress with respect to the weld line
K	stress intensity factor
$\Delta\gamma_p$	plastic shear strain range
b	constant dependent on material softening
M	material parameter
R_{eff}	effective stress ratio
K_{res}	stress intensity factor due to the residual stress distribution
K_{max}	applied maximum stress intensity factor
K_{min}	minimum stress intensity factor
σ_{max}	applied maximum stress
σ_{min}	applied minimum stress
σ_{op}	applied stress when crack open
P_{op}	opening load
σ_m	mean stress
$\Delta\varepsilon$	applied strain range

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I certify that a Thesis Examination Committee has met on 3rd July 2009 to conduct the final examination of Nur Azida bt. Che Lah on her thesis entitled "Improving the Fatigue Life of Fusion Welded Joints Using Shot Peening Method" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the (Master Science Degree (with Thesis)).

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CHAPTER 1

INTRODUCTION

In this topic, the introduction, the objective of the research, the scope and limitation and the problem statement have been extensively discussed. The introduction chapter covers an idea on how the research will be carried out.

1.1 WELDING JOINTS IN INDUSTRIAL COMPONENTS

Welding process is the most widely used joining methods for components or structures in industry [1]. The wide variety of welding application is a typical phenomenon in technological industry from small and thin objects such as transistor cases to large structures. There are many different procedures including manually handled welding, semi-automatic and fully automatic welding. Several of welding process which is widely used are Manual Metal Arc (MMA), Metal Inert Gas (MIG), Tungsten Inert Gas (TIG), Friction Stir Welding (FSW) and Laser Welding (LW) [1,2].

Development in welding technology was greatly investigated since 1800 [1]. During the late 1800s, gas welding and arc welding were developed and became a common

