UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

GMAW PARAMETERS EFFECTS ON MICROSTRUCTURAL AND MECHANICAL PROPERTIES OF TOW SS304 AND BS1387

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A thesis submitted
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DECLARATION

I declare that this thesis entitle "GMAW Parameters Effects on Microstructural and Mechanical Properties of TOW SS304 and BS1387" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Masters of Science in Manufacturing Engineering.

Signature : …………………………..

Supervisor Name : …………………………..

Date : …………………………..

DEDICATION

To my beloved mother and father

ABSTRACT

Tailored orbital welding is a joining process of tubular product with dissimilar material and size depending on the application environment. One of the most common industries that apply this process is in power plant boiler water piping system. Dissimilar material is used to transmit water at various temperature, either in extremely high temperature water or room temperature water. In order to reduce cost and dependence on high-skill welder, tailored orbital welding of dissimilar material of Stainless Steel (SS) 304 and British Steel (BS) 1387 were performed by Gas Metal Arc Welding (GMAW) with automated fixed nozzle-rotational jig. The fixed nozzle-rotational jig was used to provide “steady hand” and constant travel speed for welding process. Thus, it will increase productivity and repeatability of the process, reducing the weld defects and produce good quality weldment. The study was focused on GMAW parameters variation effects on microstructure formation and mechanical properties of SS304 and BS1387 dissimilar material tailored orbital welding. The weldment quality was tested by performing non-destructive test and weld bead properties was studied to verify the influence of welding parameters variations. The study on microstructure formation, micro hardness and tensile strength were conducted to relate the solidification formation and mechanical properties. In addition, thermal effect was studied to understand the microstructure and micro hardness variations of tailored orbital welding. In this study, Design of Experiment (DOE) was employed to generate process parameter using Response Surface Methodology (RSM) method. Welding parameters include arc current, arc voltage and travel speed as input response, whilst, mechanical properties include micro hardness and tensile strength as output response. The effects of welding parameters on mechanical properties were also studied. Results from non-destructive test show no major defect was occurred. The weld bead dimension studies showed variation in welding parameters affect the weld bead formation. The heat generated during welding process also affect the microstructural and mechanical properties. The micro hardness value and tensile strength at weldment is higher than base material. The mathematical model for predicting hardness and tensile value was generated and validated. The validation fell within 90% prediction interval. The optimize parameters were generated in maximizing hardness and tensile value.

ABSTRAK

Kimpalan sambungan orbit merupakan satu proses penyambungan produk berbentuk tiub yang berlainan jenis bahan dan saiz yang bergantung kepada persekitaran penggunaan. Antara industri yang biasa menggunakan proses ini adalah sistem saliran dandang di pusat janakuasa. Berlainan bahan digunakan untuk mengalirkan air yang pelbagai suhu, samada air yang bersuhu tinggi atau air yang bersuhu bilik. Dalam mengurangkan kos dan kebergantungan terhadap pengkimpal berkemahiran tinggi, kimpalan sambungan orbit berlainan jenis bahan keluli tahan karat (SS) 304 dan keluli British (BS) 1387 dijalankan menggunakan Kimpalan Arka Logam Gas (GMAW) dengan berautomasi nozel tetap-jig berputar. Nozel tetap-jig berputar digunakan untuk menyediakan tangan yang tegap dan kelajuan yang malar untuk kerja kimpalan. Maka, ia akan meningkatkan pengeluaran dan pengulangan proses, mengurangkan kimpalan cacat dan menghasilkan kimpalan yang berkualiti. Penyelidikan bertumpu pada kesan parameter GMAW yang pelbagai pada pembentukan mikrostruktur dan sifat mekanikal kimpalan sambungan orbit berlainan jenis bahan SS304 dan BS1387. Kualiti kimpalan diuji dengan melaksanakan ujian tanpa-musnah dan sifat kimpalan di kaji untuk mengesahkan kesan parameter kimpalan yang pelbagai. Penyelidiukan pada pembentukan mikrostruktur, kekerasan mikro dan kekuatan tegangan bertujuan untuk mengaitkan pembentukan pemejalan dan sifat mekanikal. Kesan haba dikaji untuk memahami mikrostruktur dan kekerasan mikro yang pelbagai pada kimpalan sambungan orbit. Dalam penyelidikan ini, Rekabentuk Ujikaji (DOE) telah digunakan untuk membentuk parameter proses menggunakan Kaedah Tindak Balas Permukaan (RSM). Parameter kimpalan; arus arka, voltan arka dan kelajuan pergerakan sebagai tindak balas masuk, manakala, sifat mekanikal; kekerasan-mikro dan kekuatan tegangan sebagai tindak balas keluar. Kesan parameter kimpalan keatas sifat mekanikal dikaji. Keputusan dari ujian tanpa musnah menunjukkan tiada kecacatan besar berlaku. Kajian terhadap dimensi bentuk kimpal menunjukkan variasi dalam parameter kimpalan memberi kesan kepada pembentukan bentuk kimpal. Haba yang dihasilkan semasa proses kimpalan juga memberi kesan kepada ciri-ciri mikrostruktur dan mekanikal. Nilai kekerasan mikro dan kekuatan tegangan pada kimpalan adalah lebih tinggi daripada bahan asas. Model matematik untuk meramal nilai kekerasan dan tegangan telah dihasilkan dan disahkan. Pengesahan jatuh dalam 90% selang ramalan. Parameter optimum telah dijana dalam memaksimumkan nilai kekerasan dan tegangan.

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°C	-	Degree Celsius
3D	-	3 Dimension
A	-	Welding current
AISI	-	American Iron and Steel Institute
Amps	-	Ampere
ANN	-	Artificial Neural Network
ANOVA	-	Analysis of Variance
Ar	-	Argon
ASME	-	American Society of Mechanical Engineering
AWS	-	American Welding Standard
BM	-	Base Material
BS	-	British Standard
C	-	Carbon
CO_2	-	Carbon dioxide
Cr	-	Chromium
CRS	-	Controlled Random Search
Cu	-	Cuprum
DMJ	-	Dissimilar Metal Joint
DOE	-	Design of Experiment
DOP	-	Depth of Penetration

E	-	Arc Voltage
E	-	Modulus Young
EDX	-	Energy Disperse X-ray
Er	-	Erbium
FA	-	Ferrite-Austenite
Fe-C	-	Iron-Carbon
FZ	-	Fusion Zone
G	-	Groove Weld
GA	-	Generic Algorithm
GFW	-	Welding wire electrode
GMAW	-	Gas Metal Arc Welding
GMAW-P	-	Gas Metal Arc Welding-Pulsed
GPa	-	Giga Pascal
GTAW	-	Gas Tungsten Arc Welding
H	-	Heat input
HAZ	-	Heat Affected Zone
HV	-	Hardness Vickers
I	-	Current
ID	-	Inside diameter
in	-	Inch
ISO	-	International Standard Organization
Kg	-	Kilo gram
kJ	-	KiloJoule
min	-	Minutes
mm	-	milimeter

MMA	-	Manual Metal Arc
Mn	-	Manganese
Mo	-	Molybdenum
Mpa	-	Mega Pascal
MRA	-	Multiple Regression Analysis
Nb	-	Niobium
NDT	-	Non-destructive Testing
Ni	-	Nickel
O_2	-	Oxygen
OD	-	Outside diameter
OM	-	Optical Microscope
P	-	Phosphorus
Pb	-	Lead
PI	-	Prediction Interval
RPM	-	Rotation Per Minutes
RSM	-	Response Surface Methodology
S	-	Sulfur
S	-	Travel speed
S/N	-	Signal to noise
Sec	-	Second
SEM	-	Scanning Electron Microscopy
Si	-	Silicon
SiC	-	Silica Carbide
SMAW	-	Shielded Metal Arc Welding
SMSS	-	Sequential Model Sum of Squares

SS	-	Stainless Steel
STEM	-	Scanning Transmission Electron Microscopy
STS	-	Stainless Steel Grades
TEM	-	Transmission Electron Microscopy
TIG	-	Tungsten Inert Gas
TNB	-	Tenaga Nasional Berhad
TO	-	Tailored Orbital
TOW	-	Tailored Orbital Welding
TWB	-	Tailor Welded Blanks
US	-	United States
UTM	-	Universal Testing Machine
UTS	-	Ultimate Tensile Strength
V	-	Welding voltage
volts	-	Voltage
Y	-	Yield Stress

LIST OF PUBLICATIONS

Ayof, M.N., Hussein, N.I.S., Noh, Z.M., and Mohd Pauzi, M.F., 2013. Tailored Orbital Welding of Dissimilar Stainless Steels Material. *Proceeding of Malaysian Technical Universities Conference on Engineering and Technology (MUCET 2013),* 3-4 December. Pahang: Universiti Malaysia Pahang (UMP).

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CHAPTER 1

INTRODUCTION

1.0 Background Study

Welding is a versatile joining process which is applicable to almost all types of materials. It is one of the permanent joining processes that produce coalescence of the material by heating workpiece to the melting temperature with or without the existence of pressure or by the application of pressure itself and with or without the use of filler material for metal or non-metallic materials. Welding technique has been widely used in various industries such as automotive, oil and gas, aerospace, and many others. There are various types of welding and it differs according to the heat source, process and type of welded material such as, shielded metal arc welding (SMAW), gas metal arc welding (GMAW), gas tungsten arc welding (GTAW) and laser welding.

In many industries, welding plays an important role in reducing the production cycle time, thus reducing the delivery time (Vandewynckéle et al., 2013). Orbital welding is a joining process of tubes of similar thickness. It was one of the major improvements in pipe welding technology since 1980s. The orbital arc welding produces high quality of welded seams and has good repeatability. It is an alternative to manual welding process as it increases speed and ensure repeatability (Vandewynckéle et al., 2013).

Tailored orbital (TO) is welded tubular product made of tube from different materials of different thickness or coatings to component or other tubes, depending on the application in taking advantages in cost, weight and function (Goppelt, 2006). If the material joint is different to each other, it is also known as dissimilar metal joint (DMJ).