Faculty of Manufacturing Engineering

TENSILE PROPERTIES AND WELD DIMENSION OF DIS-SIMILAR MATERIAL JOINT BETWEEN AA5083 AND AA6061 WITH COLDARC GAS METAL ARC WELDING

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A thesis submitted

in fulfilment of the requirements for the degree of Master in Manufacturing Engineering (Industrial Engineering)

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DECLARATION

I declare that this thesis entitled “Tensile properties and Weld Dimension of Dissimilar Material Joint between AA 5083 and AA6061 with ColdArc Gas Metal Arc Welding” 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 candidate of any other degree.

Signature : GOGULAN

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Date : 01 / 02 / 2021

APPROVAL

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality as a partial fulfilment of Master of Manufacturing Engineering (Industrial Engineering).

Signature : ……

Supervisor Name : ……

Date : …….....

DEDICATION

TO MY DEAREST PARENTS,

Mr P. Manickavelu and Ms M. Jayanthi

TO MY BELOVED SIBLINGS

TO MY SUPPORTIVE FRIEND,

THANA KRISHNAN

TO MY HONOURED SUPERVISOR,

PM.DR. NUR IZAN SYAHRIAH BINTI HUSSEIN

For her support, guidance and advices dur-

ing accomplishment of this project

TO ALL STAFF & TECHNICIANS

ABSTRACT

AA 5083 and AA6061 dissimilar Aluminium Alloy are joined by ColdArc GMAW. Both aluminium from 5XXX and 6XXX series which commonly used in high strength products. The welding carried out by using EWM Robot Welding. ColdArc setting used in the EWM Robot Welding for this experiment. The joint type used was butt joint with 3mm material thickness. Furthermore, the design matrix for parameters obtained from the Taguchi method. The parameters are taken as factors and output are tensile testing and hardness test. Finally, the Taguchi Method method utilised in analysing the data or result obtained from the experiment. ColArc GMAW utilised in this experiment to identify the difference in the strength of welded joints and Heat-Affected Zone (HAZ). This is because normal fusion welding exerts a high rate of heat input while colArc reduces heat input at the arc. The heat input from the welding has a severe effect on the coarse grain structure and inter-metallic development in the weld zone. The high and low heat input influences the strength of the HAZ of the material. Besides, the tensile properties of the material face severe changes according to the level of heat input and other parameter settings. Parameters such as current, voltage, arc travel speed and type of filler wire can affect this strength of the material. Besides, heat input also can influence the dimension of weld bead on the weldment and penetration of the weldment. The high and low of bead width and bead height are affected by the heat input from the setting of parameters. Therefore, to ensure this problem can be solved by using optimised parameters.

ABSTRAK

AA 5083 dan AA6061 Aluminium Alloy yang berbeza disatukan oleh ColdArc GMAW. Kedua-dua aluminium dari siri 5XXX dan 6XXX yang biasa digunakan dalam produkyang kekuatan tinggi. kolArc GMAW digunakan dalam eksperimen ini adalah untuk mengenal pasti perbezaan kekuatan sendi yang dikimpal dan kawasan yang terpengaruh dengan haba (HAZ). Ini kerana kimpalan peleburan normal memberikan kadar input haba yang tinggi sementara ColArc mengurangkan input haba pada arka. Input haba dari kimpalan mempunyai kesan yang teruk terhadap struktur butiran kasar dan pengembangan antara logam di zon kimpalan. Input haba tinggi dan rendah mempengaruhi kekuatan HAZ bahan. Selain itu, sifat tensile bahan menghadapi perubahan teruk mengikut tahap input haba dan tetapan parameter lain. Parameter seperti arus, voltan, kelajuan perjalanan arka dan jenis wayar pengisi boleh mempengaruhi kekuatan bahan ini. Selain itu, ketinggian dan lebar manik kimpalan juga menunjukkan pengaruh parameter. Bentuk dan ukuran manik kimpalan yang baik menunjukkan kualiti pengelasan pada bahan. Oleh itu, untuk memastikan masalah ini dapat diselesaikan dengan menggunakan parameter yang dioptimumkan. Kimpalan dilakukan dengan menggunakan EWM Robot Welding. Jenis sendi yang digunakan adalah sambungan butt dengan ketebalan bahan 3mm. Selanjutnya, matriks reka bentuk untuk parameter yang diperoleh dari kaedah Taguchi. Parameter diambil sebagai faktor dan output adalah ujian tegangan dan kekerasan. Akhirnya, kaedah Taguchi Method digunakan dalam menganalisis data atau hasil yang diperoleh dari eksperimen.

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LIST OF ABBREVIATIONS AND SYMBOL

AA	Aluminium Alloy
HAZ	Heat-Affected Zone
ANOVA	Analysis of Variance
GMAW	Gas Metal Arc Welding
FSW	Friction Stir Welding
SMAW	Shielded Metal Arc Welding
FCAW	Flux Cored Arc Welding
TIG	Tungsten Inert Gas
DOE	Design of experiment
MIG	Metal Inert Gas
MAG	Metal Active Gas
CMT	Cold Metal Transfer
MPa	Mega Pascal
DCEP	Direct Current Electrode Positive
AlSi	Aluminium Silicon
BM	Base Metal
NZ	Nugget Zone
FZ	Fusion Zone
gm/cm³	Gram per Cubic Centimetre
mm	Millimetre
%	Percentage
max	Maximum
UTS	Ultimate Tensile Strength

CHAPTER 1

INTRODUCTION

1.1 Background

Welding has been widely used as a method of joining similar and dissimilar of various types of metals such as copper and brass, magnesium alloy, aluminum alloy, steel and stainless steel, cast iron and titanium. In these, Aluminum Alloy (AA) is commonly used in welding process in most of the manufacturing and industries sector for instant automobiles, automotive, aircraft, marine, rail, buildings, constructions, energy distribution and etc.

Welding process, welding technology and the use of materials for weldment continue to evolve according to the high demand from marine applications including subsea installations, underwater naval requirements and deep-sea mining, including shipyard constructions and shipbuilding. Welding technology and welding process are crucial for produce high quality of joint in marine applications that are watertight and oil-tight.

The AA has become the most broadly used material in marine due to its great corrosion resistance. AA5xxx series and AA6xxx series are widely being used and accepted as the most suitable materials in marine applications due to the mechanical properties. The AA5xxx series has magnesium and the AA6xxx series contains magnesium-silicon. According to various scholars, the advantages of aluminium used in marine applications are as follow.

a. Aluminium alloys are light in weight.

b. The easy formability of aluminium alloy makes it more unique.

c. The resistivity of aluminium alloy towards corrosion in marine environments.

d. Aluminium also a metal that environmental compatibility.

e. Usage of aluminium alloy are cost-effective.

f. Aluminium are recyclable.

Guo *et al.* (2014) stated that Friction Stir Welding (FSW) is most commonly used welding techniques for joining the dissimilar materials. There are vast amount of studies and researches on dissimilar materials welding that are mainly discussed on FSW techniques. Mvola *et al.* (2015) claimed that Gas Metal Arc Welding (GMAW) techniques have great potential in welding dissimilar material of ferrous, non-ferrous or combination of ferrous and non-ferrous metals of different grades.

Meanwhile, in under water, Shielded Metal Arc Welding (SMAW), Tungsten Inert Gas (TIG) and Flux Cored Arc Welding (FCAW) were used as a conventional welding technique. Underwater welding is divided into wet welding and dry welding.

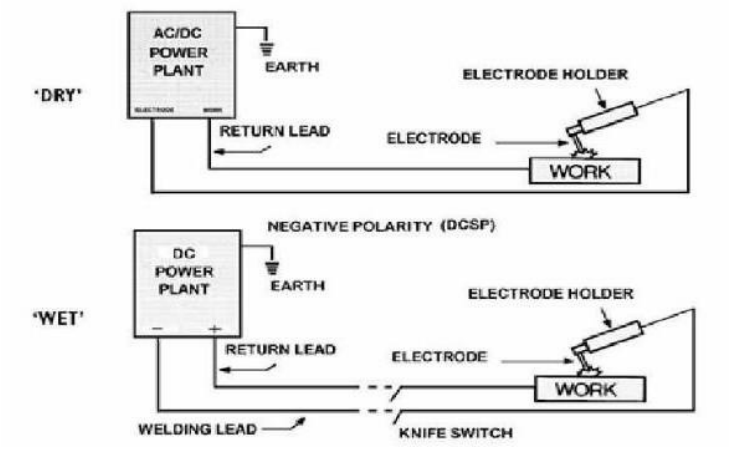

Figure 1.1: Systematic Diagrams of Dry and Wet Welding Process (Sundarapandiyan et al., 2017)

1.2 Problem Statement

Aluminum Alloys is the most commonly used material in marine applications. Even, aluminium alloys is considered as a marine material (sea metal) (Alcan Marine, 2017) due to its corrosion and wear resistant behavior. In fact, aluminum need moreheat input to weld the aluminum alloy due to the greater thermal conductivity of the aluminum alloy (Luijendijk, 2000).

Welding is used to joint similar and dissimilar material. Dissimilar aluminium alloys have different composition. Hence, in dissimilar aluminium alloys welding, the weldment can yield to undesirable or unfavourable conditions due to the variation in thermal conductivity (Luijendijk, 2000).

It has been proven that FSW is an effective welding process that able overcome the weaknesses of conventional welding techniques such as TIG and MIG (GMAW). There are vast number of researches and studies on FSW of dissimilar material joint in marine environment. Several scholars and researchers have explored and researched GMAW of dissimilar metal joint but as yet there is still gap to investigate the cold arc GMAW in welding applications. The cold arc GMAW still not explore which has excellent potential to perform welding process at lower heat input.

Nazemi (2015) explained that when aluminium alloy is undergo welding process the tensile properties and weld bead dimension of the material will change especially in Heat-Affected Zone (HAZ). The high heat input from the welding will lower the mechanical strength in the HAZ. The final material properties will be different compared to before welding properties. By above phenomenon the material will be affected at zones that the heat has been absorbed during the process. Moreover, the width of HAZ on the material are influence by the rate of heat input and heat reduction. Concurrently, few parameters

of the GMA welding will affect the rate of heat input and heat reduction. The few parameters such as voltage, current and travel speed.

ColdArc is an arc welding process that weld material in low-heat with short arc for high dimensional stability welding. ColdArc is an innovative welding process of GMAW (De Dompablo, 2013). The conventional GMAW can be upgraded and improvised to low heat energy potential for welding thin plates or any type of materials. Arc in conventional GMAW can be balanced and controlled for low heat input. Low heat energy input can lower the burn-through exposure, lesser the distorting, improve melt pool control and reduce sparks (Kolarik *et al.*, 2012). For this reason, welding manufacturers have taken advantage of this and explored the potential of low heat welding processes. The exploration has led to the new discovery of heat reduces the welding process, for instance, ColdArc and Cold Material Transfer (CMT).

Since this is a new property of material, there are few types of research only available using AA5083 and AA6061 along with coldArc GMA welding. Therefore, suitable and optimized parameter need to be identified and stated before doing a further experiment. Therefore, in this context, the quality of welding in terms of tensile properties and weld bead dimension of dissimilar material joint of AA5083 and AA6061 will be investigated using coldArc GMAW techniques.

1.3 Research Objectives

Concerning the preceding problem statements, the objectives of this research are:

i. To analyse the weld bead dimension of the AA5083 and AA6061.

ii. To investigate the effect of coldArc GMAW parameters on tensile properties of Aluminium Alloy 5083 and 6061 weldment using ER 5356 and ER 5183 filler wire.

iii. To suggest the best set of parameters for AA5083 and AA6061 butt joint using coldArc GMAW.

1.4 Scope of Study

The scope of work explained how the objectives of this project to be achieved. This research focuses on welding using coldArc GMAW on dissimilar material which is AA5083 and AA6061. The EWM machine will be used for this research along with filler wire chosen for this material is ER5356 and ER5183. The type of joint that will be used is butt joint on the material with a thickness of 3mm. The design will be generated by using Minitab software. The welding inspection is tensile testing, and weld bead dimension of the dissimilar material joints.

At the beginning of the research, the AA5083 and AA6061 need to be cut into a specific dimension (200mm×80mm×3mm) using a shearing machine. The result of the inspections will be further optimized to find the optimum parameter using the design of experiment (DoE) that has been selected.

CHAPTER 2

LITERATURE REVIEW

2.1 Gas Metal Arc Welding (GMAW)

Innovation has transformed the processes and technology of welding which is cost-effective, durable and produce higher weld quality. Therefore, conventional GMAW can be improvised and upgraded to coldArc GMAW. ColdArc GMAW processes able to control the high heat input of welding materials. Innovations in GMAW are wildly unknown and rarely used (Kah et al. 2013).

It is necessary to investigate conventional GMAW to get a clear picture of ColdArc GMAW. GMAW developed and pioneered by N.G. Slavianoff in 1888. GMAW, is also known as a Metal Inert Gas (MIG) or Metal Active Gas (MAG) welding, is an arc welding process that has a consumable filler known as an electrode. The electrode is applied to the base metal during the welding process. GMAW uses inert gas which acts as shielded gas. GMAW is the process of joining the metals by heating to a melting point.

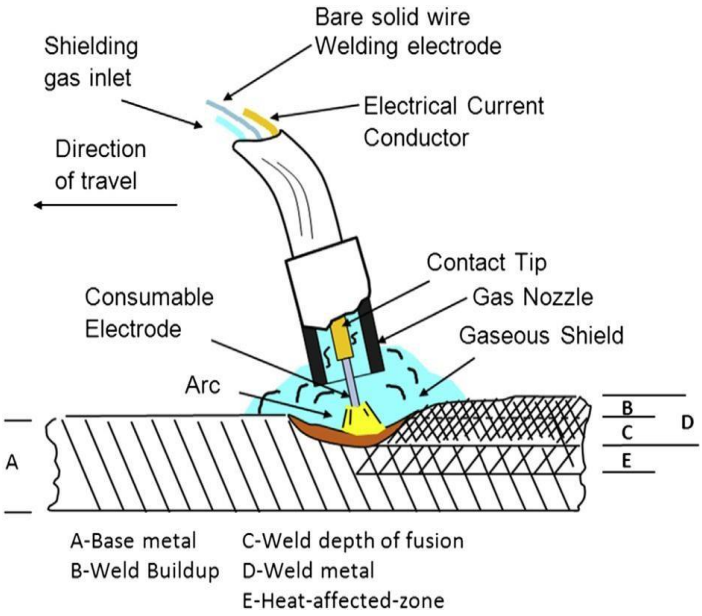

Figure 2.1: GMAW process (Welding Handbook Welding Science and Technology, 2001)

GMAW can be obtained in Semiautomatic welding, Machine welding and Automatic welding. Semiautomatic welding is controlled by hand and known as hand-held welding; Machine welding is not handheld welding but the process requires manpower to control and adjust the machine; Automatic welding process uses some equipment and the operator or welder are not required to controls and adjust the weldment process.

At first, GMAW is used to joint aluminium and at a later stage, it widely used for weld another type of metals such as steels, copper, titanium, and nickel alloys. Briefly, GMAW process can be used for welding ferrous and non-ferrous metals in most of the manufacturing and industries applications. GMAW able to weld metal in all position with a significant fusion of electrodes, shielding gas and welding variables.

According to Ajit Hooda (2012), GMAW process of welding is most commonly used in industries for joining similar and dissimilar materials. Welding dissimilar materials are complicated due to the compositions of the two materials is different. Nevertheless, the demand for dissimilar metals join is constantly rising in welding industries.

Conventional welding processes (arc welding) such as GMAW have been used for weld metals in marine environments. On the other hand, Gyasi (n.d) claimed that shortcomings arise in the use of arc welding of GMAW in marine applications. Alternatively, modern welding processes, friction stir welding (FSW) take over conventional welding processes mainly in the marine environment for the joining purposes.

Although GMAW is widely used in the welding industry, that particular arc welding process is unpopular in the underwater welding process due to the usage of shielding gas (Ajit Hooda, 2012). Consequently, this situation leads to research and development in the welding industry. Welding process and technology have been explored and the innovative welding industry has discovered ColdArc GMAW. The new innovative welding technology offers a potential solution for conventional GMAW.

2.1.1 ColdArc GMAW

ColdArc welding process was pioneered and invented by EWM Hightec Welding GmbH and introduced the innovative welding process in 2004. The ColdArc is well known as a short arc process resulting from the variation of cyclical between the arc and phases of short circuit (Rosado et al. 2011) & (Dompablo 2013). To sum up, ColdArc welding process is a modification of conventional GMAW. ColdArc GMAW processes able to fulfil the basic requirement in welding to the joint metal which is crack-free and without effect any mechanical and metallurgical properties of the two materials. Sabdin et al. (2018) conveyed that ColdArc is an alternative welding method to conventional short-circuit welding that provides adaptation to the electric current process.

ColdArc GMAW process was accepted and used for similar and dissimilar metals welding. The study of Sabdin et al. (2018) confirmed that ColdArc welding process can be used to join dissimilar thin sheet metals. The study further emphasised that it is necessary to establish proper and suitable welding speed to ensure low porosity and reduce distortion

on the welding metals.

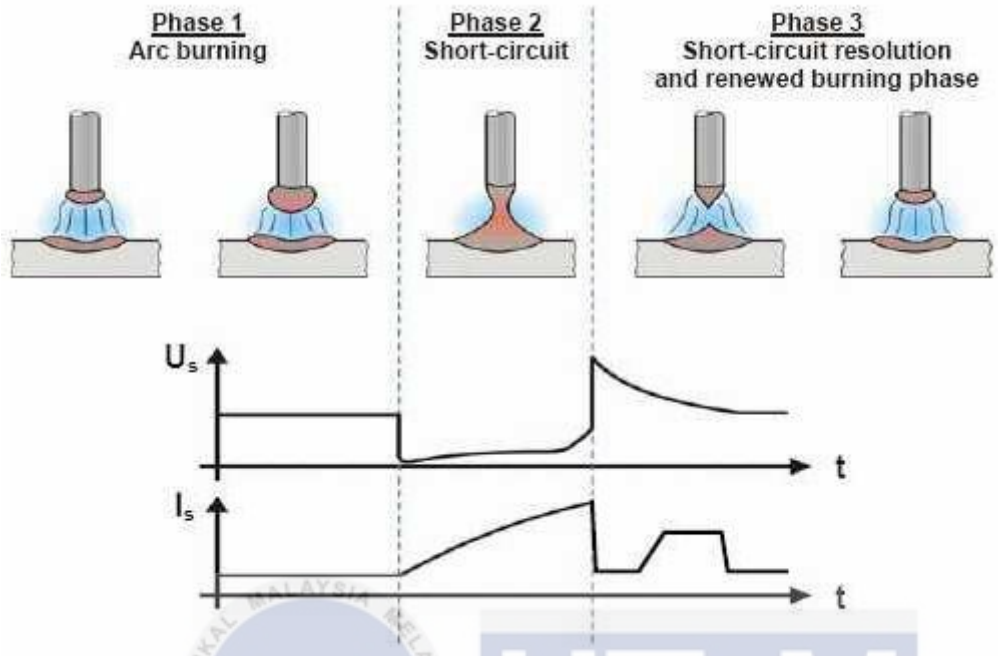

Figure 2.2: Phases of ColdArc (Rosado *et al.*, 2011)

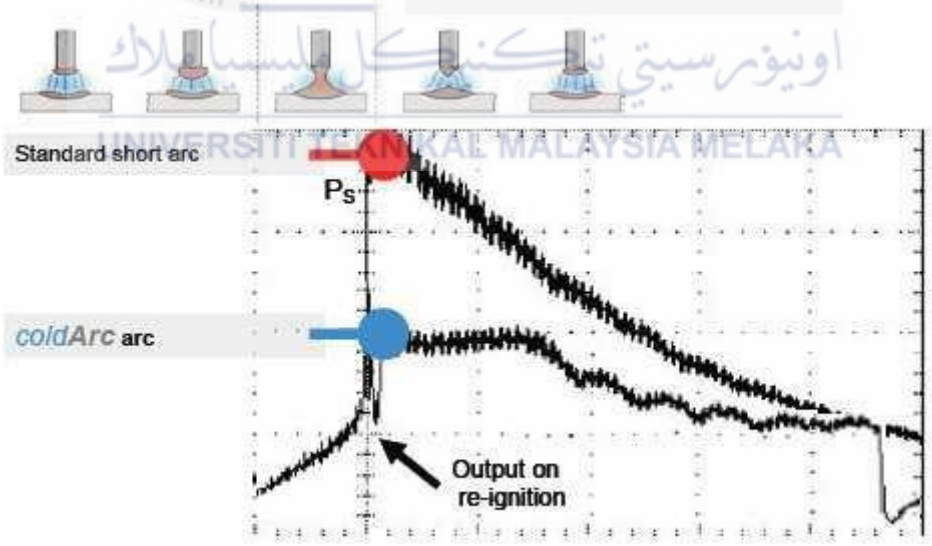

Figure 2.3: Comparison of Cold Arc process and standard short arc (Rosado *et al.*, 2011)

Figure 2.3 and 2.4 shows the difference between coldArc process and standard short

arc process when the arc re-ignition happens. The output of both processes showed clearly in Figure 2.4. Adamiec et al. (2011) remarked that ColdArc welding process can provide high quality welded connections of the thin sheet for all type of metal joint. Adamiec et al. (2011) additionally argued that cold arc welding processes have the potential to expand and provide butt joint of thin sheets metals which is considered as impractically welded by any conventional welding process. The result of the study shows that ColdArc welding process can be adopted for thin sheets and butt joints. The study further pointed out that Cold Metal Transfer (CMT) has similar potential as ColdArc welding process.

The CMT was developed and patented by FORNIUS in 2004, it is a GMAW (MIG/MAG) welding process which utilized high-speed digital control, inverters and processor that adjusts the whole process such as the current, voltage and arc length (Furukawa 2006 & Kah et al. 2013)

Technology *et al.*, (2017) concluded that ColdArc GMAW and CMT GMAW are a new form of welding technologies specially designed for thin plates. Both this welding technology cost-effective. Technology *et al.*, (2017) further documented that ColdArc and CMT GMAW technology has high demand in producing lower manufacturing cost and offering high welding quality.

Figure 2.4: The principal phases in the new CMT (from left to right) (Technology *et al.*, 2017)