INVESTIGATION ON THE STEEL PREHEATING EFFECTS ON THE ALUMINIUM-STEEL WELDING

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ABSTRACT

Dissimilar welding or Tailor Welded Blanks (TWBs) joint is defined as two or more sheets with equal or different materials, thickness, strength, or surface coatings are welded together. The objective of this project is to investigate the effect of heat treatment on the weld joints quality and determine the mechanical properties of the steel-aluminium weld joint. Aluminium alloy AA 6061 was welded with stainless steel SUS 304 in the thickness range of 2mm in lap joint configuration. Among the process parameters varied were filler metal and preheating temperature. By metallurgy cross sections, hardness test and tensile test, the effect of those process parameters on joint properties such as welding joint hardness, macrostructure defect and tensile strength could be elucidated. Based on the results, the penetration of stainless steel with aluminium alloy occurs when the preheating process is applied. Sample C yield the best result in hardness with value at 830HV and 19.91 Mpa in tensile test. The optimum temperature for preheating is 85ºC and by using ER 4043 filler metal.

ABSTRAK

Kimpalan berbeza atau Tailor Welded Blanks (TWBs) sambungan didefinisikan sebagai dua atau lebih kepingan dengan sama atau berbeza bahan, ketebalan, kekuatan, atau lapisan permukaan yang dikimpalkan bersama. Objektif projek ini adalah untuk menyiasat kualiti kesan dari pemanasan dan sifat-sifat mekanikal sambungan aluminium keluli. Aloi aluminium AA 6061telah di kimpal dengan keluli tahan karat SUS 304 dalam julat ketebalan 2mm dengan tata rajah sambungan tindih. Antara parameter yang dipelbagaikan merupakan logam pengisi dan suhu pemanasan awal. Dengan keratan rentas metalurgi, ujian ketahanan, kesan dari parameter yang pelbagai, kecacatan makrostruktur dapat dilihat dan dijelaskan. Berdasarkan keputusan kajian, penembusan keluli tahan karat terhadap aloi aluminium terjadi semasa proses pemanasan awal di aplikasikan. Sampel C menunjukkan keputusan terbaik melalui ujian kekerasan dengan nilai 850HV dan nilai ujian ketahanan iaitu 19.91 Mpa. Suhu pemanasan awal yang optimum adalah 85ºC dan dengan menggunakan logam pengisi ER 4043.

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LIST OF SYMBOLS

ε	Strain
σ	Stress
A	Area
A	Ampere
F	Force
Kg	Kilogram
mm	Millimeter
Mpa	Mega pascal (10x6)
N	Newton
Lo	Initial length
L	Final length
HV	Hardness value
°C	Degree celcius
T	Temperature
To	Initial temperature
V	Welding speed
Π	Pi (3.142)
K	Thermal conductivity
Q	Heat density
U	Voltage

I	Current
s	Seconds
%	Percentage

LIST OF ABBREVIATIONS

TIG	Tungsten Inert Gas
AC	Alternating current
DC	Direct current
TWBs	Tailor Welded Blanks
GTAW	Gas Tungsten Arc Welding
HAZ	Heat Affected Zone
UMP	Universiti Malaysia Pahang
IMC	Intermetallic compound
PPE	Personal protective equipment
ASTM	American Standard Test Method

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Welding is the most common method of joining two or more pieces of metal to make them act as a single piece. It allows us to produce a monolithic structure (formed a single structure) that is strong in all directions (Helzer, 2005). Welding is used to join all the commercial metals, alloys and to join metals of different types and strength. Welding and joining process can be divided into 7 main types. There are arc welding (AW), resistance welding (RW), soldering (S), solid state-welding (SSW), oxyfuel gas welding (OFW), brazing (B), other type of welding and joining process (adhesive bonding, flow brazing, flow welding). Nowadays, we are trying to produce an improvement in welding process known as Tailor Welded Blanks (TWBs).

TWBs is the process where two or more materials with similar or different strengths or thicknesses joined together to form a single part before the forming operation. TWBs can be performed in any type of welding process. The common method used to perform this dissimilar welding is arc welding (AW). Gas tungsten arc welding (GTAW) is one type of arc welding that can be use in order to perform this task. GTAW uses a non consumable electrode that does not melt in the arc, and filler metal is added separately to the welding.

1.2 PROBLEM STATEMENT

There are so many advantages of TWBs. Automakers are using tailor-welded blanks to make cars safer, lighter, and more environmentally efficient and tailored blanks have become the future of automaking. Vehicle weight savings, part-count reduction, an improved stiffness/weight ratio, enhanced crash energy management, and an overall reduction in manufacturing costs are the results of TWBs (Sierra, 2008). Even so, the dissimilar welding still has the drawbacks. The main problem that most of the welder faces in order to performed TWBs is that the joints obtained between the stainless steel-aluminium alloys are not strong enough. This problem happened due to the different mechanical properties that is melting point of each material and most of all because the near zero solubility of iron in aluminium (Sierra, 2008). This two major problem has lead to the formation of brittle intermetallic compound (IMC) inside the transition zone which increased the weakness of the joint. In order to overcome these problems and produce a sound joint between these materials, a method of preheating the material and different type of filler metal is proposed.

Preheating involves raising the temperature of the parent material (stainless steel) on the joint side to a value above ambient temperature (Croft, 2003). Based on previous research formed by Aida Syamsiah bt Mohd Yusof (ME 08061), this preheating method had showed us a promising results to achieve a sound joint between stainless steel-aluminium alloys dissimilar welding joint (Aida, 2011). This research had been continued to improve the results obtained by Aida by making some modification regarding on the temperature of the preheating involved. This research looks into the effect of preheating of the stainless steel and its effect on the joints quality. This research also will investigate the relationship between different type of filler metal used and the mechanical properties gained. All specimens will be investigating regarding on the mechanical properties of the weld joint.

1.3 OBJECTIVES

The main objectives of this study are as follows:

i. Fabrication of welded stainless steel to aluminium alloys sheets using different fillers and with the help of steel preheating.

ii. To investigate the mechanical properties of dissimilar stainless steel to aluminium alloys lap joint welding with the preheating of steel.

iii. To investigate the microstructure of the welded part formed between stainless steel-aluminium alloys weld.

1.4 PROJECT SCOPE

The main scopes of this study are as follows:

i. Fabrication of welded stainless steel to aluminium alloys sheets using different fillers and with the help of steel preheating.

ii. Investigate the heat treatment (preheat) and type of filler metal used on the strength of the welded part joints by using Vickers hardness test and also tensile test.

iii. Investigate the microstructure of the welded part by using optical microscope and to compare the mechanical properties of the welded part relation with the type of filler metal used.

CHAPTER 2

LITERATURE REVIEW

2.1 AUTOMOTIVE INDUSTRY

Nowadays, the automotive are trying to produces cars that has a very low fuel consumption in order to follow the anti pollution standard and also to attract the buyers. This goal can mostly be achieved by producing lightweight vehicles. But, the car needs to maintain their body strength and must be high in endurance. No wonder that automotive industries nowadays are using several methods for example like high strength steel and light metal such as aluminium to make car are being investigated. Automakers are using tailor-welded blanks to make cars safer, lighter, and more environmentally efficient and tailored blanks have become the future of automaking TWBs is the process where two or more materials with similar or different strengths or thicknesses joined together to form a single part before the forming operation. Figure 1 shows the usage of TWB in automotive industry.

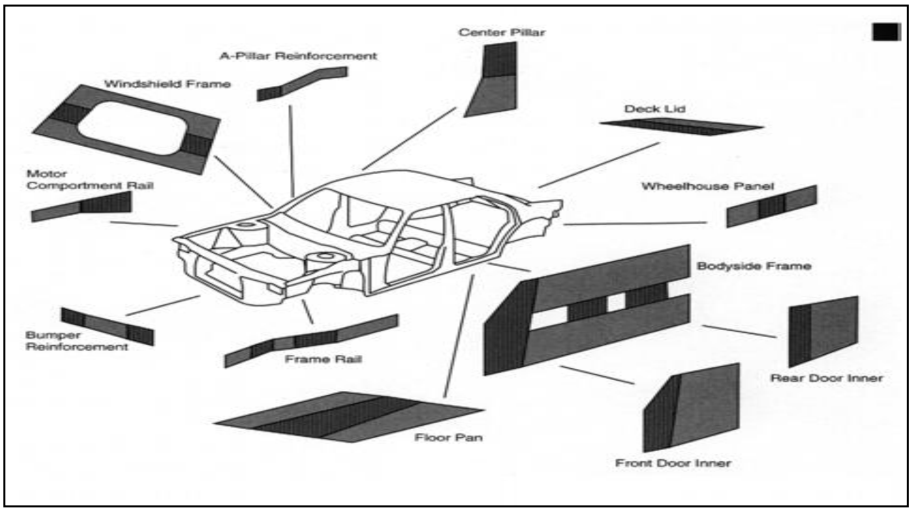

Figure 1: Exploded view of current or potential tailor welded blanks body

Source: (Kinsey, Viswanathan, Cao, 2001)

This implies the joining of dissimilar metal such as steel and also aluminium. The steel to aluminium welding is not an easy way to achieve due to their great difference in both of their properties especially melting temperature and near zero solubility of iron in aluminium which lead to the creation of brittle intermetallic compound (IMC) (Sierra, 2008).

2.2 WELDED PART

Welded joints normally consist of several parts. Normally, a part that had been welded contains weld leg, weld face, weld toe, actual throat, theoretical throat, effective throat, weld root and also joint root (Miller, 2010). Each of these parts plays an important role in making the joint to be strong. Weld leg is actually the distance from the joint root to the toe of a fillet weld. Weld toe is the junction of the weld metal and the weld face. Weld face is the exposed surface of the weld, bounded by the weld toes on the side which the welding was done. Weld root is the area where the filler metals intersect the base metal and extends the furthest into the weld joint. The actual throat is the shortest distance from the face of a fillet weld to the weld root after welding. The theoretical throat is the distance from the joint root, perpendicular to the hypotenuse of the largest right-angle triangle that can be inscribed within the cross section of a fillet weld. The effective throat on the other hand is the minimum distance, minus the convexity between the weld face and the weld root. Lastly, joint root is the portion of a weld joint where joint members are the closest to each other. Figure 2 shows the parts of a fillet weld.

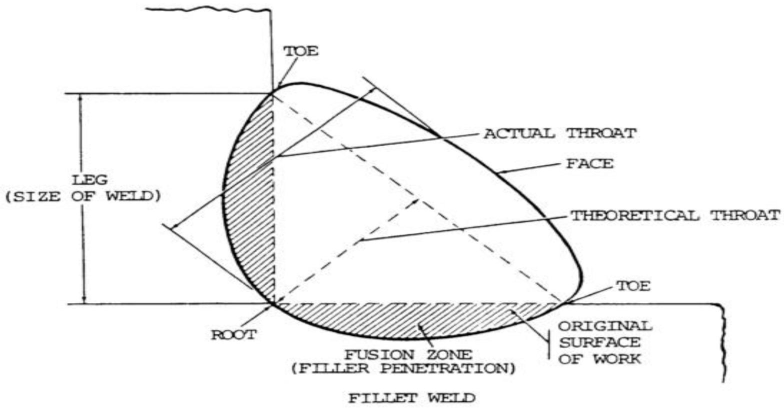

Figure 2: Parts of a fillet weld

Source: (http://www.weldguru.com/SMAWNomenclatureandJoints)

2.3 WELDING TYPES

Till nowadays, both of this steel and aluminium were only be joined by using mechanical means such as screwing or riveting and also using solid state welding process like explosion welding (Andrews, 1962) or friction stir welding (Bel'chuk, 1961). Welding is the most common method of joining two or more pieces of metal to make them act as a single piece. It allows us to produce monolithic structure that is strong in all direction. Welding and joining process can be divided into 7 main types. Figure 3 below shows AWS master chart of welding and joining process.

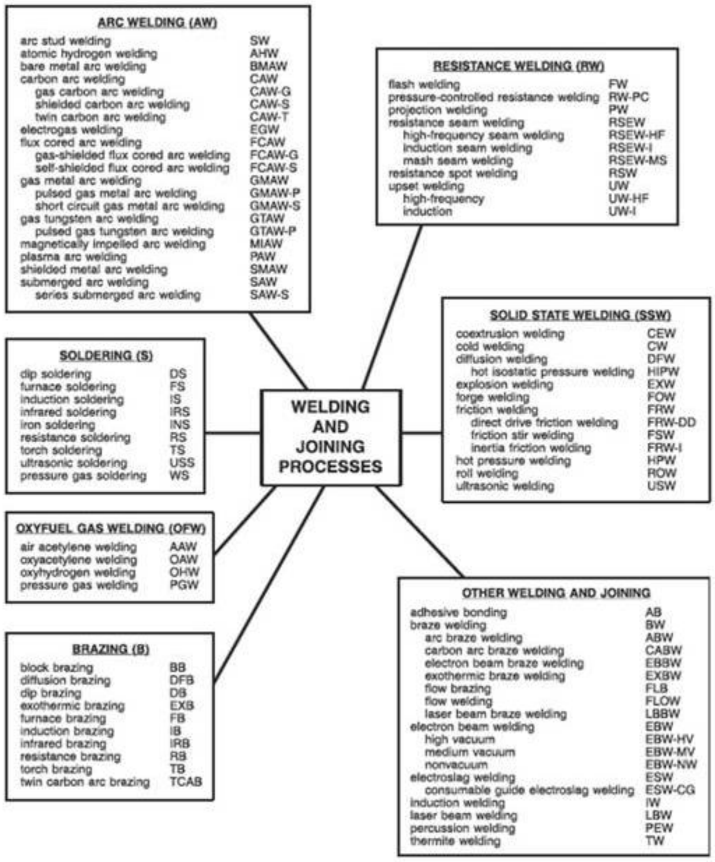

Figure 3: AWS master chart of welding and joining process.

Source: (http://www.lbl.gov/ehs/pub3000/CH33)

2.4 GAS TUNGSTEN ARC WELDING (GTAW)

The method that will be used to perform this task is by using the gas tungsten arc welding (GTAW) process. GTAW uses a non consumable electrode that does not melt in the arc and filler metal is added separately to the welding. GTAW process will supply the inert gasses (usually argon gas) in order to protect contaminants and oxidation process from happen which will cause defect to the joints area. GTAW welding uses torch as the main heat source in order to fuse the filler with the material. GTAW torches are available water cooled or air cooled. The heat transfer efficiency for GTAW welding may be as low as 20%. This means that 80% of the heat generated does not enter the weld but stay in the torch. To avoid damage to the torch, the heat must be removing. (Jeffus, 2010)

a) Following are some of the advantages of air cooled GTAW torch:

- Lighter weight for the same amperage range
- More portable
- Easier to maintain
- No water supply required
- No water leakage danger

b) But there are also disadvantages of air cooled GTAW torch:

- Cannot continuous operation without over heating
- High torch temperature means more tungsten erosion
- More torch handle temperature in the welder’s hands

Figure 4 shows the Tungsten Inert Gas (TIG) welding machine

Figure 4: Tungsten Inert Gas (TIG) Welding

Source: (Jeffus, 2010)

2.5 HEAT TREATMENT (PREHEATING)

Although that TIG welding process have a lot of advantages, a sound dissimilar welding between aluminium alloys to stainless steel are still hard to be obtained. This is due to high differences of the melting points between these materials. Heat treatment (preheat) is one of the methods that can be done in order to solve this major problem. Preheating involves raising the temperature of the parent material (stainless steel) on side of the joint to a value above ambient temperature. Normally, there are 4 main functions of preheat (Funderburk, 1997). Firstly, preheating is applied because it can slow down the cooling rate in the weld metal and base metal, producing a more ductile metallurgical structure with greater resistance to cracking. Secondly, the slower cooling rate that had been obtained can provide an opportunity for hydrogen that may present to diffuse out harmlessly, reducing the potential for cracking to happen. Thirdly, preheat can helps to reduce shrinkage stresses in the weld and adjacent base metal. Lastly, it can raise some steels above the temperature at which brittle fracture would occur in fabrication.

This research was designed to investigate so that the function of preheating can be added with another one more unique purpose. This research will investigate the effect of preheating in order to raise the initial temperature of the stainless steel so that the melting temperature of the steel can be obtained at the time the aluminium alloys melt. When this happen, a sound joint between these two materials since both of the metal had exist in molten state and fusion can be performed during this liquid state. As we know, the melting point of aluminium is between 550°c - 660°c while the melting temperature of stainless steel is between 1300°c - 1400°c. When the welding process starts, the temperature of both materials will increase. At 550°c - 660°c, the aluminium starts to melt and perform the bonding. Unfortunately, the steel still did not achieve the melting temperature and exist in solid state. So, the bonds that form between these two materials are still not strong enough. By using preheat; we want to increase the initial temperature of the stainless steel so that when the aluminium reaches its melting temperature, the steel reach a near melting point.

Besides that, aluminium to steel welding will produce the brittle IMC at the welded area due to near zero solubility and extreme different in melting point. This compound can cause the bonding between the aluminium alloys and stainless steel to be weak due to its brittle behavior. This research will investigate two type of different filler metal that is Al-5%Si (ER 4043) and Al-12%Si (ER 4047) on the strength of the weld area and also the formation of the IMC. Each filler metal can affect the thickness formation of the IMC. Normally, the formation of the IMC layer is due to the reaction between the Fe (Ferum) and the Al (Aluminium) atom inside the welding area. The formation of the IMC need to be avoided since this compound can weaken the joint between those steel and aluminium due to its brittle behavior. So, because of this problem, this research will investigate the most suitable filler metal in order to decrease the thickness of the IMC formation on the weld area (Sierra, 2008).

H. Dong (Dong, 2011) had obtained a result of TIG dissimilar welding between galvanized steel and aluminium alloys until 136Mpa of tensile strength at the joint area by using ER 4047 filler metal. The research said that the addition of Si (Silicon) into the weld could suppress the diffusion of Fe from the steel base metal into the weld, reduce the thickness of IMC and improve the tensile strength of the joint. Based on that research, the thickness of the IMC layer could be controlled with using of ER 4047 filler metal. For the ER 4043 filler wire has a result of 134Mpa of tensile strength at the joint area. In this research, we will investigate the effect of these filler metal on the joint formation and compare the results between these two experiments.

2.6 ALUMINIUM 6061

In this experiment, aluminium 6061 and galvanized steel will be used. The unique combination of light weight relatively high strength makes aluminum the second most popular metal that is welded. Aluminum is not difficult to joint, but aluminum welding is different from welding steels. A system of four digit numbers has been developed by Aluminum Association, Inc., and adopted by the American Society for Testing Materials (ASTM) designate the wrought aluminum alloy types. The series that used for this project is 6XXX series which designates magnesium and silicon as the major alloys (The Virtual Machine Shop website, 2006).

Aluminum possesses a number of properties that make welding different than welding steel, these are:

- Aluminum oxide surface coating
- High thermal conductivity
- High thermal expansion coefficient
- Low melting temperature
- The absence of color change as temperature approaches the melting point (dull red)

Figure 5 shows the sheet of aluminium 6061 that will be used in the experiment.

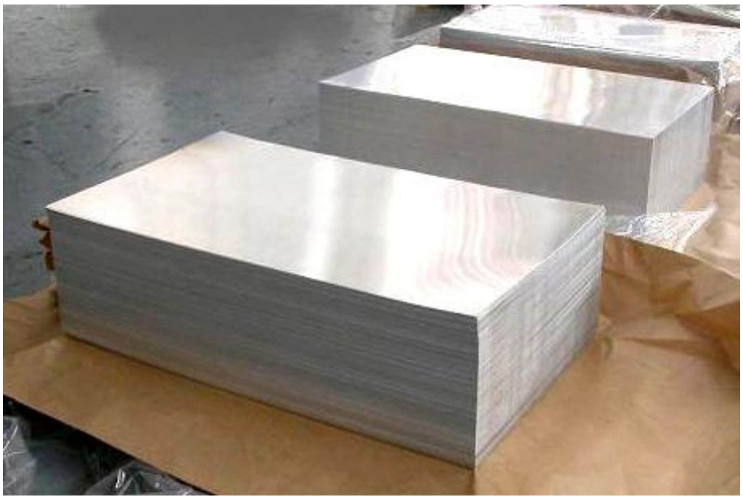

Figure 5: Sheet of aluminium 6061

Source: http://image.made-in-china.com/2f0j00bCLEReWsZBzS/Sheet-of-Aluminium-6061