ALUMINIUM WELDING AND IT'S EFFECT ON CHANGING OF MECHANICAL PROPERTIES OF THE BASE METAL

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Universiti Malaysia Sarawak
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BORANG PENYERAHAN TESIS

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This project report attached here to, entitled **"Alulminium Welding and it`s effect on the changing of mechanical properties of the base metal "** prepared and submitted by Yu Guan Sing as a partial fulfilment of the requirement for the degree of Bachelor of Engineering with Honours in Mechanical and Manufacturing system is hereby read and approved by:

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ALUMINIUM WELDING AND ITS' EFFECT ON CHANGING OF MECHANICAL PROPERTIES OF THE BASE METAL

YU GUAN SING

This report is submitted in partial fulfillment of the requirement for the
Degree of Bachelor of Engineering (Hons.)
Mechanical Engineering and Manufacturing System from the
Faculty of Engineering
Universiti Malaysia Sarawak
2000

Dedicated to my family and love ones ……………..

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This thesis report is aim for the Faculty of Engineering Program Mechanical Engineering and Manufacturing System. It is a compulsory for the post graduate student to finish this report before graduated. The thesis report must either a new design of a product or machinery, improvement of product or machinery and research.

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ABSTRACT

Aluminium is one of the preferred metal after iron that been chosen for manufacturing industry. Aluminium or aluminium alloy are very light, stronger, corrosion resistance, etc compare with iron. In manufacturing industry, aluminium seldom been welded it is because of the difficulty on the aspect that needed to be considered first before start the welding process.

Those aspect are such as kind of parent metal that using, type of aluminium that will be used either heat treatable or non-heat treatable, group of aluminium (group of 1XXX, 3XXX, 6XXX etc), type of filler rod, type of welding technique that want to use, either the pre welding or post welding is needed or not etc.

In this research, a lot of aspect will be discussed which might be the cause of the changing of the mechanical properties of the parent metal. It is very important to know all kind of aluminium alloy and their mechanical properties and how to solve the problem facing. Even though thing only been done theoretical but this is a good beginning to know and get more understanding on aluminium welding and its' behavior.

ABSTRAK

Aluminium merupakan satu jenis bahan yang paling gemar digunakan dalam bidang pembuatan selepas besi atau ferum. Ini adalah kerana sifat mekanikalnya yang unik iaitu ringan, tidak berkarat, keras, kekenyalan yang baik dan lain-lain. Dalam bidang pembuatan, aluminium ataupun aloi aluminium jarang dikimpal kerana kerja mengimpal amat sukar.

Dalam kajian ini banyak aspek akan diselidik dan dikenalpasti akan kesannya kimpalan terhadap sifat mekanikalnya serta langkah-langkah mengelakkan masalah perubahan sifat mekanikal pada aluminium dari berlaku. Secara umumnya beberapa aspek yang perlu ditelitikan dahulu sebelum kerja mengimpal dijalankan. Kita perlu mengetahui akan jenis Aluminium atau aloi Aluminium yang digunakan, jenis kimpalan (MIG atau TIG), jenis rod penambah yang digunakan, perlunya kerja pre pemanasan (sebelum kimpalan) atau rawatan haba (selepas kimpalan).

Pengabaian aspek-aspek di atas, perubahan terhadap sifat mekanikalnya (mechanical properties) akan berubah dan menyebabkan benda kerja menjadi kurang tahan. Contohnya, nilai ketegasan aloi aluminium akan menurun dan ini menyebabkannya mudah patah atau rosak.

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CHAPTER 1

INTRODUCTION

1.1 Background

The unique combination of lightweight and relatively high strength makes aluminium the second most popular metal that is welded. Aluminium and aluminium alloys are not difficult to be joined but aluminium welding is different from welding steels.

There are a lot of condition and effect that needed to be considered, to produce a good welding result. For example, types of aluminium or parent metal, types of filler electrode, pre and post welding treatment, types of power source either A.C or D.C, gas Argon welding or Tungsten Inert Gas Welding (TIG) and Metal Inert Gas (MIG) etc.

At the beginning, an experiment planned to be made to support the title of this thesis. But because of some unexpected problem I have to do this thesis by research. This report is to investigate all the condition and effects of welding that might cause the changing of the mechanical properties of parent metal.

Research on the effect of pre and post welding heat treatment and other condition that might cause the changing of the mechanical properties of the aluminium alloy also need to be study so that a good recommendation or suggestion can be made.

1.2 State of Problem

It has been found that mechanical properties, in particular, the strength of Aluminium plate, are strongly affected by the welding condition. As we know Aluminium and Aluminium alloys is the most prefer material on offshore platform construction, cars, vessels, and others product. This is because of the mechanical properties of Aluminium such as corrosion resistant, strength and others.

But the mechanical properties of the base metal were changed effected by the incorrect welding condition. Thing become easy to brake or even erosion which will cause a lot of money to recover or to solve the problem.

1.3 Objective

The main objectives of this research is to:

(a) To establish the relationship between the welding condition and the mechanical strength of welded aluminium.

(b) To investigate the effects of post weld heat treatment on the property relationship.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter briefly explains the terms and theory of research that involves with the mechanical properties' investigations. Moreover, reviews of literature from various sources are included.

2.2 Aluminium

Aluminium was first produced in the laboratory in 1825. Aluminium does not occur in nature in the metallic form. In rocks, aluminium is present in the form of silicates and other complex compounds. The ore from which most aluminium is presently extracted, bauxite, is a hydrated aluminium oxide. Aluminium oxide is a ceramic material that extremely hard and chemically inert.

In 1886 a patent was issued to Martin Hall for a process of reducing aluminium oxide ore to aluminium by electrolysis in a molten salt. In this process, cryolite, a sodium-aluminium-fluorine compound (Na_3AlF_6), is melted, and aluminium oxide (Al_2O_3) is dissolved in the molten salt. The salt now contains aluminium ions (Al^{3+}). Carbon electrodes are put in the bath and current flow is established between the electrodes. Aluminium ions are reduced to metallic aluminium at the cathode and oxygen is produced at the anode. Since the bath is at a high temperature (about 170 ^{o}F: 953 ^{o}C), aluminium formed at the cathode melts [the melting point of pure aluminium is 1220 ^{o}F (659 ^{o}C)] and collects at the bottom of the cell. It goes to the bottom since aluminium is denser than the molten salt.

Aluminium (Al), atomic weight 26.97 of obtained chiefly from bauxite. Pure (99.99%) aluminium has a specific gravity of 2.70 or a density of 2,685 kg/m^3, electrical and thermal conductivity about two-thirds that of copper; and a tensile modulus of elasticity of 62,000 MPa. The metal is nonmagnetic, highly reflective, and has a face-centred-cubic crystal structure. Soft and ductile in the annealed

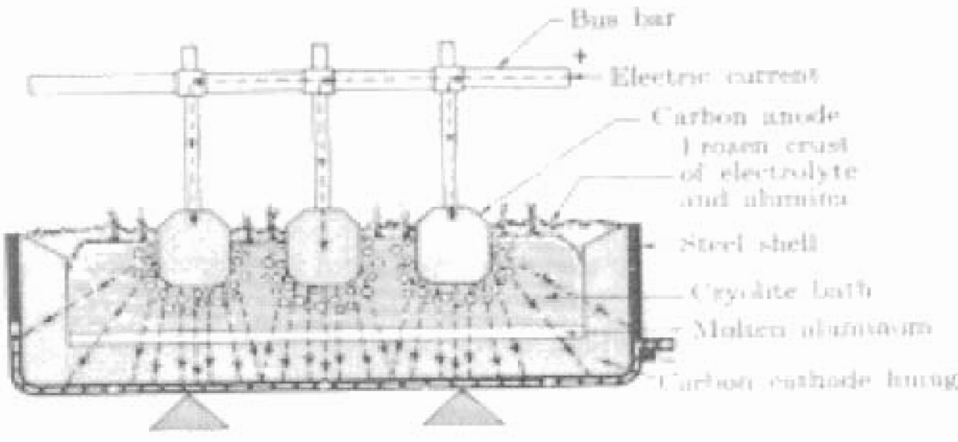

Figure 2.1 : Process Electrolysis

condition, it is readily cold-worked to moderate strength. It resists corrosion in many environments due to the presence of a thin aluminium oxide film.

Some of the more important weldable structural aluminium is shown in table 2.1, together with their nominal composition and typical mechanical properties. The four-digit designation is that of the Aluminium Association Inc and ASTM and BSI have adopted it, although not by ISO. British standards for wrought aluminium used in general engineering are BS 1470~1475. Castings are specified in BS 1490 but these are little used in structural work.

Commercially available aluminium alloys fall into three categories:

(a) Pure aluminium and non-heatable alloys;

Pure aluminium is used for its corrosion-resistance properties where strength is unimportant, and the aluminium-magnesium (3~5% Mg) and aluminium-manganese alloys for corrosion-resistant for low temperature applications where moderate tensile strength is necessary.

(b) Medium-strength heat-treatable alloys;

For example, the medium-strength heat-treatable Al-Zn-Mg alloys may be employed in applications where lightweight must be combined with strength and structural integrity in the welded joint. These alloys have been used for military bridging, for airframe elements and for cylindrical storage tanks.

(c) High-strength heat-treatable alloys;

The high-strength alloys are used in aircraft construction where high strength-to-weight ratio is of paramount importance. These alloys have poor corrosion resistance (in general they must be protected by means of an anodic coating of pure aluminium or aluminium-zinc alloy).

2.3 Alloys of Aluminium

There are small number of other elements are added to aluminium in order to modify its basic properties. The eight most important are chromium, copper, iron, magnesium, manganese, silicon, titanium, and zinc. These can be grouped into those with high solid solubility and those with low solid solubility. Pure aluminium, aluminium-manganese and aluminium-magnesium alloys may be joined by most fusion welding processes, but the weldability of some of the higher-strength alloys is limited by a susceptibility to solidification cracking and by a reduction of tensile strength in the heat affected zone. Porosity may also be a problem in shielded metal arc and gas metal arc welding.

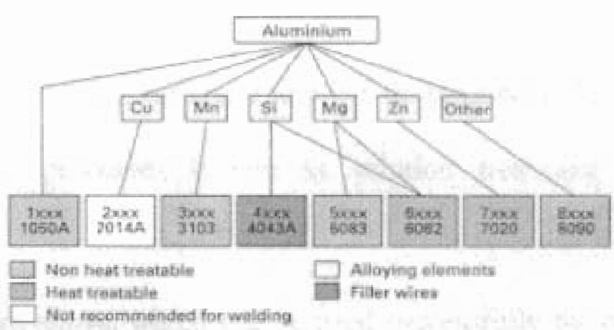

Figure 2.2 : Groups of Aluminium Alloy

Aluminium alloys are used in the wrought from; that is they are rolled to sheet, strip, or plate; drawn to wire; or extruded as rods or tubes. Other alloys are cast to shape by either a sand-casting or die-casting process. In either case, some of the alloys may receive subsequent heat treatment, in order further to improve their mechanical properties by inducing 'precipitation-hardening'.

Aluminium alloys can be divided up into four categories as shown below:

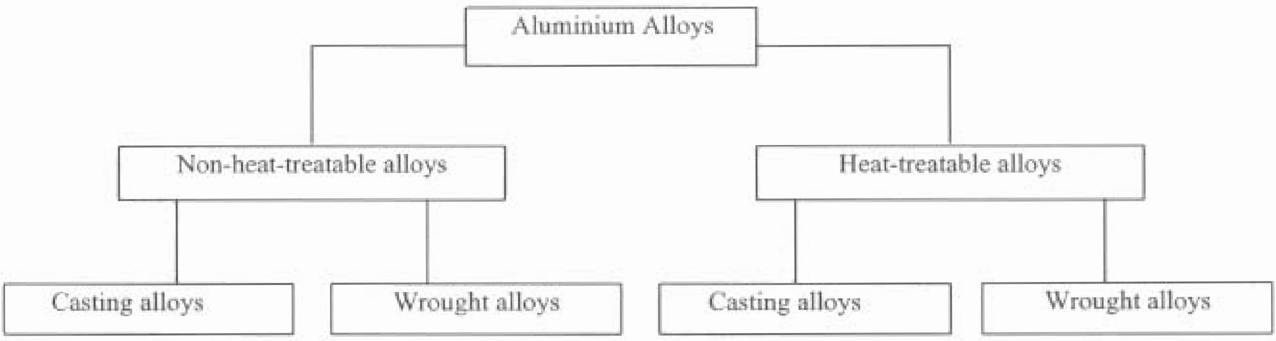

Figure 2.3 : Categories of Aluminium Alloy

- *Non-heat-treatable alloys*, as their name implies, do not respond significantly to heat-treatment processes beyond annealing and stress relief after casting or cold working.
- *Heat-treatable alloys*, as their name implies, do respond to heat treatment and in particular to the processes known as solution treatment and precipitation hardening.
- *Casting alloys* are alloys, which can be used successfully for casting by a variety of processes including sand-casting and die-casting. They may be heat-treatable or non-heat-treatable.
- *Wrought alloys* are those alloys whose mechanical properties allow them to be formed by a variety of processes including forging, rolling, extrusion and drawing. They may be heat-treatable or non-heat-treatable. The non-heat-treatable wrought alloys can have their mechanical properties enhanced considerably by a combination of hot working and cold working.

ASTM Designation	Category	Cu	Mg	Mn	Si	Zn
1060	99% pure aluminium					
3003	Non-heat-treatable			1.25		
5083			4.50			
5154			3.50			
5454			2.70			
5456			5.10			
6005	Medium-strength heat-treatable		0.50		0.75	
6061		0.30	1.00		0.60	
6063			0.60		0.40	
7005			1.40	0.45		4.50
2014	Heat-treatable	4.50	0.50	0.80	0.85	
2024		4.50	1.50	0.60	0.50	
7075		1.80	2.50			5.60
7079		0.60	3.30	0.20		4.60
7178		2.00	2.80			6.80

Composition (mass%) applies to columns Cu, Mg, Mn, Si, Zn.

Table 2.1 : Structural Alunimium Alloy

We also can refer to appendix A to see others aluminium alloy structural.

2.3.1 Group 1000 (pure aluminium)

The 1000-group contains pure aluminium alloys with various degree of purity, but with a minimum of 99,00% aluminium. The purity is defined in the alloy numbering such that the last two digits indicate the minimum aluminium percentage. Pure aluminium is often chosen for electrical conductors, in products where good corrosion resistance is necessary and where excellent formability is desired.

2.3.2 Group 6000 (AlMgSi)

Approximately 80% of the annual world production of extrusions are made of AlMgSi-alloys. The 6000-group contains magnesium and silicon additions of 0,3 to 1,2% each and sometimes smaller amounts of copper, chromium or manganese. The alloys get increased strength by precipitation of Mg2Si-particles and the mechanical properties range from "soft" to those of structural steel.

The extrudability is generally very good. The alloys are weldable, they have good corrosion resistance (for some alloys even in marine atmospheres), they are well suitable for most of the common surface treatment processes (anodising, chromating, phosphating, painting, plating etc.) and they have good strength properties to above 100°C. Typical applications range from window frames to heavily loaded structures. The most frequently used extrusion alloys are AW-6060 and AW-6063. For structural applications AW-6082 is used.

2.3.3 Group 7000 (AlZnMg)

The 7000-group contains high strength materials similar to AlCuMg, but with zinc instead of copper as the main alloying element. But copper can also be added, in smaller amounts. Compositions within this system have the highest known strength of all commercial aluminium alloys. The high strength is due to precipitation of MgZn2 particles.

The alloys without copper have a tensile strength somewhat above the strongest of the 6000-alloys. The most widely used alloy contains approximately 4,5% Zn and 1,3% Mg. This alloy has extrudability that is slightly worse than for AW-6082, but the alloy is much less quench sensitive and can be air cooled for much greater wall thicknesses.

The alloys obtain full strength after approximately one month storage at room temperature, which in turn makes the alloy attractive for welding. The alloys containing copper (AlZnMgCu) attain the highest strength of all aluminium alloys, exceeding normal structural steel. The extrudability is very poor and the alloys are not weldable under normal conditions.

The AlZnMg-alloys are used for structural applications where high mechanical strength is needed and in the automotive industry (e.g. car bumpers). The AlZnMg Cu alloys are used for particularly high stressed components in the aviation- and space industry.

CHAPTER 3

ALUMINIUM WELDING

3.1 Welding in Aluminium Alloys

Aluminium alloys may be classified generally into two categories, non-heat treatable and heat treatable. The former category is typified by the aluminium-magnesium alloys, with 3-5% Mg. Their strength is obtained through solid solution hardening and increases with magnesium content. The upper limit is a nominal 5%; above this value a second phase may be formed and the ductility is reduced. Heat treatable alloys gain their strength by precipitation hardening; for example, 6061 is hardened by an incipient precipitate of the intermetallic compound Mg_2

In GTA welding of aluminium and its alloys, two factors must be considered: the tenacious oxide films which forms rapidly on aluminium surfaces and the high thermal conductivity of aluminium. The surface oxide film interferes with wetting of molten aluminium filler metal to joint surfaces and causes poor bonding in welds even though the surfaces are properly cleaned before welding. The surface oxide will be removed by gas ion bombardment when welding DC electrode positive allowing good wetting of the joint surfaces. However, this polarity delivers the greatest portion of arc heat to the electrode, which requires a much larger electrode and greater arc current than would be required with electrode negative. AC is recommended and used for GTA welding of aluminium because it provides some of the required features of both polarity modes. The electrode positive pulse of AC provides the necessary cleaning action, and the electrode negative pulse delivers most of the heat to the work. The heating is not as great as obtained with DC electrode negative; therefore, increased current and a larger electrode are required than would be required for DC electrode negative (refer to appendix B).

Some advanced GTAW power supplies include a feature that provides a square wave AC that permits adjustment of the proportional time of the positive and negative half cycles. This allows the positive pulse to be adjusted to the lowest value needed to achieve adequate cleaning so that the maximum heat can be delivered to the work on the negative pulse. Another benefit of the square wave is that there is no need for continuous high frequency to maintain the AC arc. On sinusoidal AC the arc current drops to zero twice on each cycle and requires high frequency to restart each half cycle. The square wave current passes through zero so rapidly that the arc will restart in the opposite direction without high frequency.

The low emittance of electrons from the molten aluminium surface will cause rectification of AC when using AC power supplies, which are not designed to produce a balanced wave. In this case, the current is high when the electrode is negative and low when it is positive so that the cleaning action is greatly reduced. The power supply must have a high enough open circuit voltage or continuous high frequency to provide a balanced wave and a cleaning action.