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Experimental Investigation of AL6061 THIN Sheets by using Gas Tungsten Arc Welding

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Abstract: In recent times, aluminum and its alloys have been used for their light weight, moderate strength and good resistance to corrosion. Due to the high thermal conductivity, the aluminum alloys require special equipment and ability to weld. In this paper, the mechanical properties of the single V butt joints welded using ER4043 filler metal with a gas tungsten arc welding (GTAW) 6061 aluminum alloy were studied. A 6 mm thick aluminum alloy plate was chosen as a specimen. Various welding parameter values were used to prepare the aluminum welded joint specimens using the (GTAW) process. According to the complete experimental design, the input parameters welding speed, filler rod diameter, bevel angle, gas flow rate were variated. By using the macro examination and Radiography test, Pin hole and porosity were observed. Nondestructive testing or non-destructive testing (NDT) is a wide range of analysis techniques used in science and technology industry to determine the properties of a material, device or system without using it causing any physical damage. In the present work the defects occurred during welding process primarily discussed. Materials used in present welding process are Al-6061. The defects are examined using radiography processes. The welding process used is Gas Tungsten Arc Welding (GTAW). Application of this project is in major fields of Aerospace, Aircrafts, Pipeline industry, Automobile sector, manufacturing units.
Keywords: Aluminium Plate, ER4043, GTAW, Macroexamination, Radiography test

I. INTRODUCTION

Welding is a method used to join metal to metal by using electricity to produce ample heat to melt metal, and the melted metals when cool result in metal binding. It is a form of welding that uses a welding power supply to produce an electric arc at the welding point between an electrode and the base material for melting the metals. Either direct (DC) or alternating (AC) current, and consumable or nonconsumable electrodes may be used. The welding area is usually protected by some form of gas, vapor, or slag sh ielding. Processes for arc welding may be manual, semiautomatic, or fully automated. Arc welding first developed in the late part of the 19th century during the Second World War became commercially important in shipbuilding. It remains today an important process for producing steel structures and vehicles.

Welding is a manufacturing process used to tie together materials, usually metals or thermoplastics. The pieces to be joined are melted at the joining interface during welding, and typically a filler material is added to form a pool of molten material (the weld pool) which solidifies into a strong joint. Soldering and Brazing, by comparison, do not require melting the work piece but rather a substance with a lower melting point is melted between the pieces of work to tie them together.

However, Russell Meredith, working for Northrop Aircraft, was the first to produce a device that in January 1941 became a true manufacturing method that applied for a patent. It states in the first paragraph of the patent; "My invention concerns welding magnesium and its alloys-so relatively low melting point materials can be welded efficiently by an electric arc". AC TIG is commonly used for welding aluminum and magnesium materials. AC TIG welding is the method of choice for the best look, highest quality and leak-free welds on aluminium.

The primary gas used is argon, and an argon / helium mixture or pure helium is used in some applications on thick aluminum when additional penetration is needed. TIG welding offers the user the best amount of flexibility to weld the widest range of fabric and thickness. AC TIG welding is additionally the cleanest weld with no sparks or spatter DC TIG is commonly used for welding exotic materials such as stainless steel, nickel alloys, copper, titanium and critical welds that must be perfect, such as parts of aircraft engines. The main gas used is argon, and an argon / helium mixture or pure helium is used in some applications. TIG welding offers the user the best amount of flexibility to weld the widest range of fabric and thickness and its kinds. DC TIG welding is also the cleanest weld without spatters or sparks

II. EXPERIMENTAL PROCEDURE

A. *Sample Preparation*

The pieces of work were made of 6061aluminum alloy of different thicknesses i.e. 2 mm and 3 mm. The test specimens were machined to 50 mm X 100 mm in size and welded using current GTAW process. During the welding, filler wire material from ER4043 was used which reduced the weld cracks and provided the good strength and ductility compared to other filler metals.

B. *Gas Tungsten ARC Welding Procedure*

The Gas Tungsten Arc Welding process–commonly known as Tungsten Inert Gas (TIG)–uses the heat generated by an electric arc struck between a non-consumable tungsten electrode and the workpiece to fuse metal in the joint region and create a molten weld pool. To secure the weld pool and the non-consumable electrode, the arc region is enclosed in an inert or reduced gas shield. The process could also be operated autogenously (without filler), or filler could also be added by feeding a consumable wire or rod into the established weld pool.

1) Filler add-on is available
2) Also inert or reduced gasses can be used as the shielding gas
3) TIG welding is a high-quality, flexible and widely used process
4) TIG is ideal for welding ferrous and non-ferrous materials
5) Can run the TIG cycle on DC, DC+, or AC

The TIG process can deliver very high quality welds in a wide range of materials and up to around 8 or 10 mm in thickness. It is particularly suitable for welding the sheet material and for placing the pipe butt welds in the root track. The method appears to be very clean, producing little particulate fume, although it is capable of producing ozone in appreciable quantities and is not considered a process of high productivity. To supply the welding current, direct or alternating power sources with constant current output characteristics are usually employed. The tungsten can be attached to either output terminal for DC operation but most often is connected to the negative end.

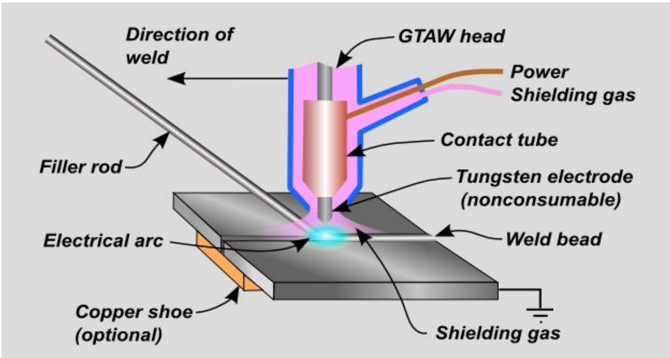

Fig 2.1. Gas Tungsten Arc Welding (GTAW)

As shown in the chemical composition and mechanical characteristics of working material and filler wire. The work pieces of aluminum alloy were chemically cleaned for 10 minutes in hot sodium hydroxide, then dipped for about 15 minutes in nitric acid solution and then washed in water. Lincoln Electrical square wave TIG 355 GTAW system with AC was used to weld 6061 aluminum alloy test specimens. Tungsten electrode selection depends on the type of welding current chosen for application. Zirconated tungsten (EWZr) electrodes are best suited for AC where hemispheric form is retained and ground to taper thoriated tungsten electrodes (EWTh-2) should be used for DCSP welding to this end.

Fig 2.2. Tungsten electrodes (EWTh-2)

This welding process was conducted with 3.0 mm diameter 2% Zirconated tungsten electrode for 6061aluminiumThe welding parameters used for this welding for two different thicknesses of the above material are given in. The edge preparation of the tested 6061aluminium alloy specimens are shown in After welding process is over, the radiography, liquid penetrant test were carried out on the weldments, according to the ASTM standards . Parameters used for pulsed GTAW: peak current.

Fig 2.3. Lincoln Electrical square wave TIG 355 GTAW machine

C. Parameters Used In GTAW

The values of the process parameters are chosen according to the thickness of the material. The following Experimental welding parameters.

1) Welding current
2) Welding Voltage
3) Pulsed current, Frequency and Waveform
4) Gas flow rate
5) Filler rod

The figure 2.4 represent the might cause cracking of current with respect to time.

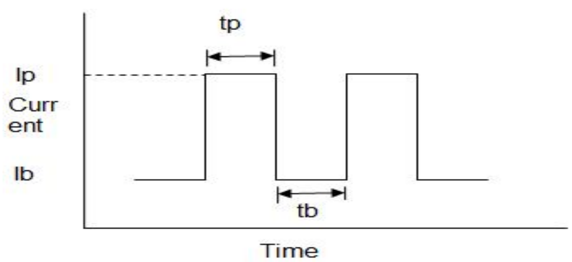

Fig 2.4. Might cause cracking.

The table 2.1.1 and table 2.1.2 represent the Mechanical properties and Chemical properties of Aluminium alloy 6061

Table 2.1.1.Mechanical properties of 6061Aluminium alloy

Material	UTS (MPa)	0.2% Y.S (MPa)	% Elongation
6061 Aluminium Alloy	260	170	11

Table 2.1.2. Chemical Compositions of work material 6061 Aluminium alloy

Material	Chemical Composition % wt								
	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
6061 Al Alloy	0.7-1.3	0.5	0.1	0.4-1.0	0.6-1.2	0.2	0.1	0.25	balance

D. Filler Rod

Aluminum welding wire ER4043 is an aluminum welding wire of a general purpose form. It contains silicon additives, resulting in enhanced weld pool fluidity (wetting action) and also provides a less cracking-sensitive weld. Its luminous weld finish makes it a famous welders choice. It may be used for welding various aluminum grades. The properties of filler rod are tabulated below

Table 2.1.3. Chemical Compositions of filler wire

Material	Chemical Composition % wt							
	Si	Fe	Cu	Mn	Mg	Ti	Cr	Al
6061 Al Alloy	4.5-6.0	0.05	0.17	0.24	0.05	0.05	0.05	balance

E. Radiography Test

Radiography is used in a wide variety of applications including medicine, engineering, forensics, health and so on. Radiography is one of the most important methods in NDT and is widely used. Radiographic testing (RT) offers a number of advantages over other NDT methods but one of its major drawbacks is the radiation-related health risk. In general, RT is the method of testing materials for secret defects by using the power of electromagnetic short wavelength radiation (high-energy photons) to penetrate different materials. A radiation sensitive film (Film Radiography) either measures the intensity of the radiation that penetrates and passes through the material and via a planer array of sensors sensitive to radiation (Real-time Radiography). Film X-rays are the oldest method, yet they are still the most frequently used in NDT

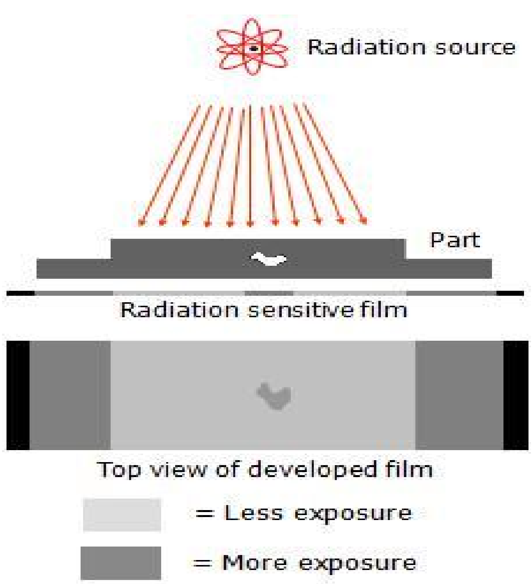

Fig 2.4. Radiography test

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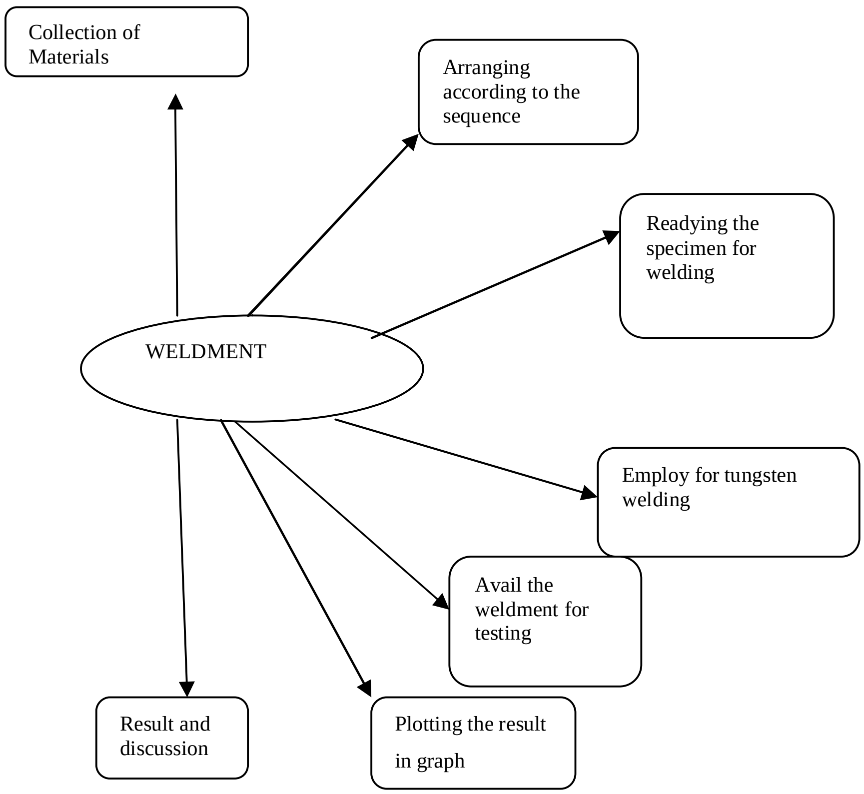
III. METHODOLOGY

The methodology are expressed in the form of flowchart from the collection of material (Initial stage) to the result and discussion (Final stage)



IV. RESULT AND DISCUSSIONS

A. *Chemical Analysis Test*

Precise analyzes of a material's chemical composition can provide useful information, assist in solving chemical problems, promote R&D and ensure the consistency of a product's chemical formulation. The analysis of chemical compositions can require the application of a variety of analytical methods to obtain a complete picture of the chemical structure and component concentrations in a sample. An observation or experiment that determines one or more characteristics of a given sample product may be called a test. Testing object requires a prior assessment of the desired observation and a comparison of that prediction to what one is actually observing.

1.Chemical Analysis:

Elements	Symbol	Unit	Specified Values	Observed Values
Silicon	Si	%	0.40 - 0.80	0.616
Iron	Fe	%	0.70 max	0.175
Copper	Cu	%	0.15 - 0.40	0.219
Manganese	Mn	%	0.15 max	0.053
Magnesium	Mg	%	0.8 - 1.2	0.978
Chromium	Cr	%	0.04 - 0.35	0.098
Zinc	Zn	%	0.25 max	0.002
Titanium	Ti	%	0.15 max	0.021
Aluminum	Al	%	Remainder	97.743

Remarks: The above chemical composition meets the requirements of ASTM B221, Grade 6061

Fig 4.1.1. Chemical Test report of Aluminium 6061

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1.Chemical Analysis:

ELEMENTS	SYMBOL	UNITS	OBSERVED VALUES
Silicon	Si	%	1.1
Iron	Fe	%	0.5
Copper	Cu	%	0.1
Manganese	Mn	%	0.8
Magnesium	Mg	%	1.0
Zinc	Zn	%	0.2
Titanium	Ti	%	0.1
Chromium	Cr	%	0.3
Aluminum	Al	%	95.9

Fig 4.1.2. Chemical Test report of Electrode 4043

B. Macro Examination Test

Macro Inspection, tests a test sample's quality and consistency using only low magnification or no. Macro metal testing can be used to determine consistency by measuring the macrostructural characteristics of a sample, which may include grain flow, porosity, and cracks. The test sample must be prepared to the specification before macroscopic analysis begins. A etching is often needed after cutting, grounding and polishing of the sample. Etching is a chemical reaction on the test sample surface, which enables visualization of the material's flow properties. The samples that consist of ingots, casts, plates, bars, sheets, or finished products. The macro etched sample examined visually and followed by stereo microscope under 10X magnification reveals, complete fusion between weld and base metal. Pin hole were observed at weld area 1C, 1D, 2A, 2B, 2C and 2D. The macro etched sample examined visually and followed by stereo microscope under 10X magnification reveals, incomplete root fusion between weld and base metal. Pin hole were observed at weld area 1A and 1B

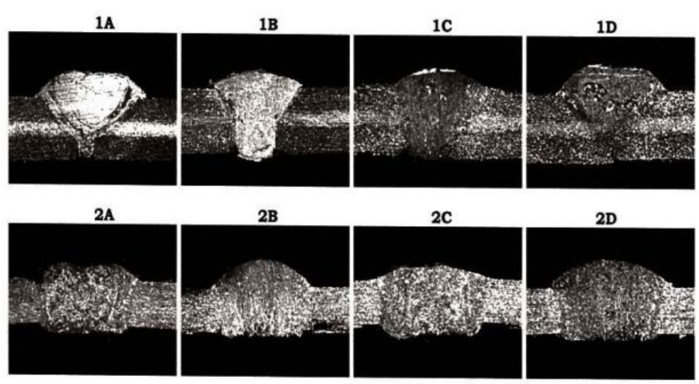

Fig 4.2.1. Macro examination Test Report

C. Radiography Test

This welding test method uses X-rays, created by an X-ray tube, or gamma rays, produced by a radioactive isotope. The fundamental principle of weld radiographic testing is the same as that for medicalx-ray. Penetrating radiation is transmitted onto a photographic film by a solid object, in this case a weld rather than the part of the human body, resulting in a picture of the internal structure of the object being deposited on the film. The amount of energy which the object absorbs depends on its thickness and density. The energy not absorbed by the material will cause the radiographic film to become exposed. When the film is made these areas will be dark. Film areas which are subjected to less energy remain lighter. So areas of the surface where discontinuities have modified the thickness, such as porosity or cracks, will appear on the film as dark outlines. Low density inclusions, such as slag, will appear as dark areas on the film while high density inclusions, such as tungsten, will appear as light zones. Both discontinuities are observed by observation of the processed film's shape and density variance.

Radiographic testing can provide a permanent weld quality film record which is relatively easy for trained personnel to interpret. Typically, this test method is ideal for viewing all sides of the welded joint (with the exception of double wall signal picture techniques used in some pipework). Although this is a slow and expensive method of non-destructive testing, it is a successful method of detecting porosity, inclusions, cracks, and voids within welds. It is vital that trained staff conduct radiographic interpretation because misinterpretation of radiographs can be costly and seriously interfere with productivity. There are significant health problems when conductingx-ray testing. X-ray and gamma radiation are invisible to the naked eye and can have serious implications for heath and safety that the porosity is noted.

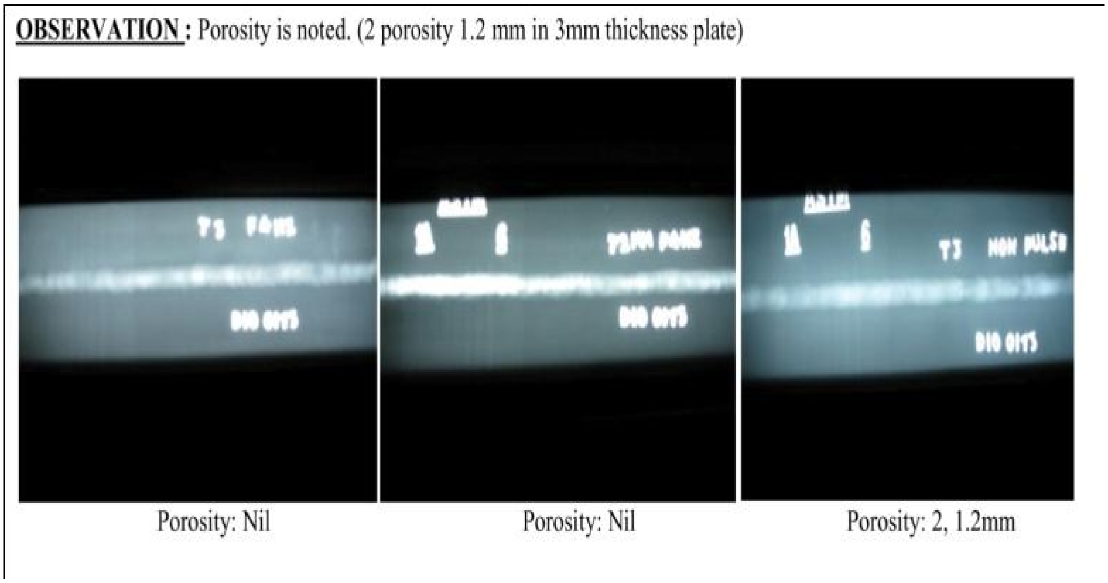

Fig 4.3.1. Radiography Test Report

V. CONCLUSION

Aluminum alloy weldability characteristics vary widely from alloy to alloy framework. The most important factor regulating the weldability of aluminum alloys is hot cracking or solidification cracking propensity. Sadly almost all heat treatable alloys are vulnerable to hot cracking. The susceptibility to solidification cracking is greatly influenced by weld metal composition, and therefore the correct choice of filler material is an important aspect in regulating cracking solidification. For produce the joints the pulsed current TIG welding system was used. Argon (pure at 99.99 per cent) was used as shielding gas.

This investigation was conducted to determine the influences of pulsed current parameters and optimize the parameters to achieve better mechanical and metallurgical properties of TIG welded aluminum alloy Al 6061.

Findings from this inquiry were collected as follows:

A. Current pulsing results in a comparatively finer and more optimized grain structure in TIG welds
B. A method has been suggested to improve the pulsed current TIG welding parameters to achieve maximum grain precision in the fusion zone
C. In general, peak current and pulse frequency are directly proportional to the welded joints, i.e. if the peak current is raised, then the frequency is directly proportional to the welded joints.
D. Evaluation of the variance approach is more suitable to find out the main and interaction factors of the current pulsed TIG welding process.

Analysis of the variance approach is more suitable to find out the major and interaction factors of the current pulsed TIG welding process. The sample was macro engraved in macro examination, and visually examined shows complete fusion between weld and base metal. Pin hole was found at the 1C, 1D, 2A, 2B, 2C and 2D weld regions. Incomplete root fusion between weld and base metal is exposed by the macro etched sample tested visually and accompanied by stereo microscope under 10X magnification. Pin hole at weld region 1A and 1B was observed.

VI. PHOTOGRAPHY OF WELDED SPECIMAN

The below diagram shows the Photography of welded specimen in the thickness of 2mm in the figure 11. Similarly figure 12 shows the thickness of 3mm welded specimen

Fig 6.1 Photography of 2mm welded specimen

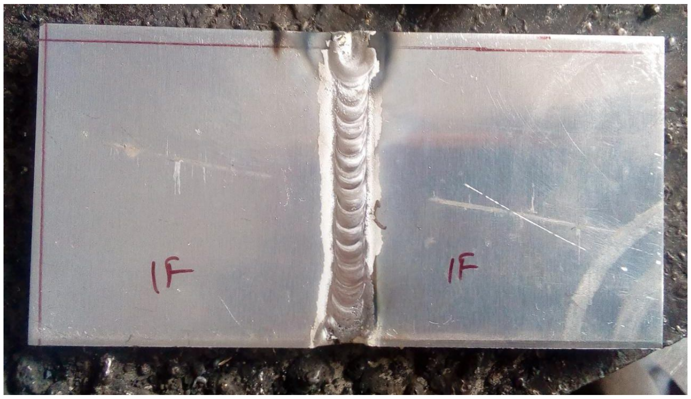

Fig 6.2. Photography of 3mm welded specimen

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