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RESEARCH ARTICLE

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EXPERIMENTING NON DESTRUCTIVE TESTING TECHNIQUES ON WELDING JOINTS

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ABSTRACT

The present work deals with the identification of the best combination of welding parameters, in TIG welding of Aluminium alloy 5083. In this study two level full factorial experimental design is considered which consists of two factors and two levels. In order to avoid experimental errors eight replications are performed for each experimental combination. The working ranges of welding parameters for conducting experiments are initially obtained by trial and from literature survey. After the experiment, various tests like Dye penetrant inspection and Ultrasonic non-destructive testing are conducted to the welded specimens. The analysis of the test results is conducted and the combination of welding parameter ranges that gives best result is found. This combination can be considered as good working ranges for TIG welding of Aluminium alloy 5083.

Keywords:NDT Technique, Welding Joints, Aluminium alloy 5083, TIG Welding

1. INTRODUCTION

1.1. Tungsten Inert Gas Welding:

Tungsten Inert Gas (TIG) Welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld.

1.1.1. HISTORY OF GTAW (TIG WELDING):

TIG welding was, like MIG/MAG developed during 1940 at the start of the Second World War.

TIG's development came about to help in the welding of difficult types of material, e.g. aluminium and magnesium. The use of TIG today has spread to a variety of metals like stainless mild and high tensile steels.

GTAW is most commonly called TIG (Tungsten Inert Gas).

The development of TIG welding has added a lot in the ability to make products that before the 1940's was only thought of.

Like other forms of welding, TIG power sources have, over the years, gone from basic transformer types to the highly electronic power source of the world today.

1.1.2. OVERVIEW:

TIG welding is a welding process that uses a power source, a shielding gas and a TIG hand piece. The power is fed out of the power source, down the TIG hand piece and is delivered to a tungsten electrode which is fitted into the hand piece. An electric arc is then created between the tungsten electrode and the workpiece. The tungsten and the welding zone is protected from the surrounding air by a gas shield (inert gas). The electric arc can produce temperatures of up to 19,400oC and this heat can be very focused local heat.

The weld pool can be used to join the base metal with or without filler material.

The TIG process has the advantages of -

1) Narrow concentrated arc
2) Able to weld ferrous and non-ferrous metals
3) Does not use flux or leave a slag
4) Uses a shielding gas to protect the weld pool and tungsten
5) A TIG weld should have no spatter
6) TIG produces no fumes but can produce ozone

The TIG process is a highly controllable process that leaves a clean weld which usually needs little or no finishing. TIG welding can be used for both manual and automatic operations.

The TIG welding process is so good that it is widely used in the so-called high-tech industry applications such as

1) Nuclear industry
2) Aircraft
3) Food industry
4) Maintenance and repair work
5) Some manufacturing areas

1.1.3. POWER SOURCES

TIG welding power sources have come a long way from the basic transformer types of power sources which were used with add-on units to enable the power source to be used as a TIG unit, eg high frequency unit and/or DC rectifying units, the basics of TIG welding has almost remained the same, but the advent of technology TIG welding power sources have made the TIG processes more controllable and more portable in some cases.

The TIG power source uses main power connected to a suitable power for the TIG process being used. This can be either AC or DC.

The one thing that all TIGs have in common is that they are CC (Constant Current) type power sources. This means only output adjustment will control the power source amps. The voltage will be up or down depending on the resistance of the welding arc.

A TIG power source can be of the AC or DC type. The principle of electric circuits will apply to only DC power sources. This means 70% of the heat is always on the positive side. So when a DC power source is used whatever is connected to the positive side will have 70% of the energy output (heat). When using an AC power source, which has an output of a wave form, the average on both terminals will be the same. This is because for one half of the wave form (cycle) the positive terminal will have 70% of the energy, but as the wave form moves to the other half of the cycle it will move to the negative terminal, which will then have the 70% of the energy.

Other things to check on TIG power sources are –

1) Amperage to do the job. Will it be sufficient?
2) Doesthe amperage go low enough for light material and high enough for thick material?
3) Power supply - 400 Volt, 230 Volt - single or three phase. Is there enough main power to do the job?
4)) Is weight a problem? If so, is the inverter type power source more suitable
5) Will an engine driven power source be better to do the job? (Must have CC range). Might need suitable extra add-ons to do the eg, HF unit
6) Would a multi-process type power source be better to do the job? Must have CC range.
7) Doesthe TIG welding need an AC power source or DC power source, as different material will need a different power type

1.1.4. TYPES OF WELDING CURRENT USED FOR TIG

1) DCSP - Direct Current Straight Polarity - (the tungsten electrode is connected to the negative

terminal). This type of connection is the most widely used in the DC type welding current connections. With the tungsten being connected to the negative terminal it will only receive 30% of the welding energy (heat). This means the tungsten will run a lot cooler than DCRP. The resulting weld will have good penetration and a narrow profile.

2) DCRP - Direct Current Reverse Polarity - (the tungsten electrode is connected to the positive terminal). This type of connection is used very rarely because most heat is on the tungsten, thus the tungsten can easily overheat and burn away. DCRP produces a shallow, wide profile and is mainly used on very light material at low amps.

3) AC - Alternating Current is the preferred welding current for whitest metals, e.g. aluminium and magnesium. The heat input to the tungsten is averaged out as the AC wave passes from one side of the wave to the other.

4) AC - Alternating Current - Square Wave -With the advent of modern electricity AC welding machines can now be produced with a wave form called Square Wave. The square wave has the benefit of a lot more control and each side of the wave can be, in some cases, controlled to give a more cleaning half of the welding cycle, or more penetration.

1.1.5.CHARACTERISTICS OF CURRENT TYPES FOR GAS TUNGSTEN ARC WELDING:

- Uses a non-consumable tungsten electrode during the welding process,
- Uses a number of shielding gases including helium (He) and argon (Ar),
- Is easily applied to thin materials,
- Produces very high-quality, superior welds,
- Welds can be made with or without filler metal,
- Provides precise control of welding variables (i.e. heat),
- Welding yields low distortion,
- Leaves no slag or splatter.

The most common TIG welds are illustrated below. They include the:

- butt joint,
- lap joint,
- T-joint, and
- Fillet weld.

The TIG welding process utilizes a number of shielding gases including:

- argon
- argon/helium, and
- helium

Even though TIG is a commonly used welding process, there are a number of limitations. These include:

- TIG requires greater welder dexterity than MIG or stick welding,
- TIG yields lower deposition rates,
- TIG is costlier for welding thick metal sections.

1.1.6 .TIG HANDPIECE (TIG TORCH)

The function of the TIG hand piece is to

1) Hold the electrode tungsten
2) Deliver welding current to the tungsten via a welding power cable
3) Deliver shielding gas to the TIG torch nozzle. The nozzle then directs the shielding gas to cover the weld pool protecting it from contamination from the surrounding air.
4) Often will be the way of getting the welder control circuit to the operation, eg on/off and/or amperage control.
5) TheTIG hand piece can be water-cooled. Hoses in the TIG lead will supply cooling water to the TIG torch head assembly.
6) TheTIG torch length will allow a distance from the TIG power source and work piece.

TIG torches come in different styles depending on the brand being selected. But they all have things in common –

1) Air-cooled or water-cooled
2) Current rating. The operator must select the correct amperage rating TIG torch. Using a TIG torch that is not sufficiently rated for the machine may result in the TIG torch overheating. A TIG torch with an excessive rating may be larger and heavier than a lower amperage TIG torch.

The TIG torch is made up of

1) Leads - The lead will be set up for either air-cooled or water-cooled. It will be at a length suitable to do the job, e.g. 4 metre, 8

metre, etc. The lead will be made up of a power cable, gas hose and water leads in and out if the TIG torch is water-cooled. The lead may also include a control lead.

2) Tungsten Holders - Holders may vary with different brands of TIG torches.
3) Nozzles - The nozzle's job is to direct the correct gas flow over the weld pool.
4) Back Caps - The back cap is the storage area for excess tungsten. They can come in different lengths depending on the space the torch may have to get into (eg. long, medium and short caps).

Please make sure when ordering a TIG torch to tell the supplier the amperage rating, whether water- or air-cooled, and the fitting that is to go on the end of the TIG torch lead suitable to fit the TIG power source it will be used from. This may include power cable fit up, gas fittings and control plug fitting

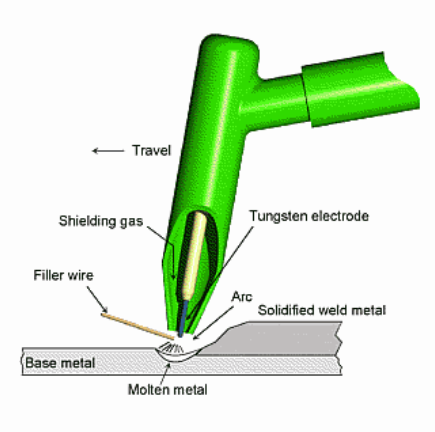


Fig : 1.1.6.1

1.1.7. TIG WIRES

The selection of the TIG wire to be used in the TIG process is a decision that will depend on

1) The composition of the material being welded
2) Mechanical properties of the weld material and those that are a match for the base material
3) Corrosion resistance should match
4) Joint design
5) Thickness of the base material

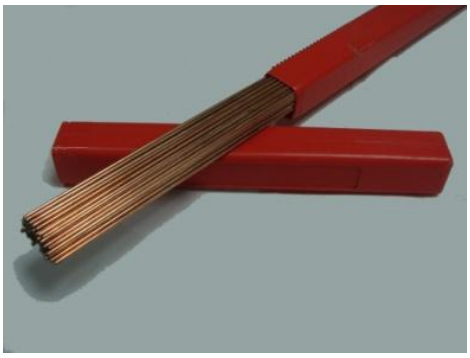


Fig: 1.1.7.1

1.1.8. SHIELDING GAS

Like other welding processes the job of the shielding gas is to protect the weld pool from contamination from air, which can cause porosity and defects in the weld. The shielding gas is a pathway for the welding arc and will help in the starting and running of the welding arc.

In New Zealand the most common gas being used for TIG welding is Argon gas.

Overseas Helium is also being used and in days gone by in some countries the weld process was called Heli arc welding.

Each of these two gases has advantages.

Argon

1) Better arc starting
2) Good cleaning action
3) Lower arc voltage
4) Low gas flows needed

Helium

1) Faster travel
2) Better penetration
3) Higher arc voltages

Because of the cost of Helium, we are now seeing mixtures of Argon and Helium. This is to gain the best part of each gas. Please see your local gas.

1.1.9. SHIELD GAS SELECTION AND USE

Table-1.1.9.1-Shielding gas types

Thickness Range	Weld Type	Shield Gas Type	Characteristics
Thin	Manual	Pure Argon	Best arc starts, control of penetration, cleaning and appearance on thin gauges.
Thick	Manual	75 Ar - 25 He	Increase heat input with good arc starts of argon, but with faster welding speeds.
General Purpose	Manual	Pure Argon	Best overall for good arc starts, control of penetration, cleaning and appearance.
Thin	Mechanised	50 Ar - 50 He	Higher weld speed under 20mm thick, with good arc stability and starting.
Thick	Mechanised	Pure Helium	Highest weld speeds, deeper penetration with DCSP, demanding arc starting and fixturing requirements, high flow rates needed.

1.1.10. WELDING ALUMINIUM

The use of TIG welding for aluminium has many advantages for both manual and automatic processes. Filler metal can be either wire or rod and should be compatible with the base alloy. Filler metal must be dry, free of oxides, grease, or other foreign matter. If filler metal becomes damp, heat for 2 hours at 120oC before using. Although ACHF isrecommended, DCRP has been successful up to 2.4mm, DCSP with helium shield gas issuccessful in mechanised applications.

Table-1.1.10.1- Advantages for both manual and automatic processes and usage of shielding gas

1.1.11. CORRECT TORCH AND ROD POSITIONING

The suggested electrode and welding rod angles for welding a bead on plate. The same angles are used when making a butt weld. The torch is held 60o -75o from the metal surface. This is the same as holding the torch 15o - 30o from the vertical.

Take special note that the rod is in the shielding gas during the welding process.

Metal Gauge	Joint Type	Tungsten size	Filler Rod Size	Cup Size	Shield Gas Flow			Welding Amperes	Travel Speed
					Type	CFH (L/Min)	PSI		
1.6 mm	Butt	1.6 mm	1.6 mm	4, 5, 6	Argon	15 (7)	20	60-80	307 mm
	Fillet							70-90	256 mm
3.2 mm	Butt	2.4 mm	2.4 mm	6, 7	Argon	17 (8)	20	125-145	307 mm
	Fillet		3.2 mm					140-160	256 mm
4.8 mm	Butt	3.2 mm	3.2 mm	7, 8	Argon/ Helium	21 (10)	20	190-220	258 mm
	Fillet							210-240	230 mm
6.4 mm	Butt	4.8 mm	3.2 mm	8, 10	Argon/ Helium	25 (12)	20	260-300	256 mm
	Fillet							280-320	205 mm

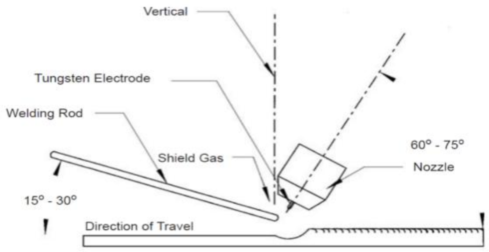


Image-1.1.11.1- Correct Torch and Rod Positioning

1.1.12. PULSED TIG

Pulsed TIG has the advantages of

1) better penetration with less heat
2) less distortion
3) better control when welding out of position
4) easy to use on thin materials

The down side is - more set-up cost and more operator training.

Pulsed TIG consists of

Peak Current - This is set up higher than for non-pulsed TIG.

Background Current - This is set lower than peak current and is the bottom current the pulse will drop to, but must be enough to keep the arc alive.

Pulses Per Second - This is the number of times per second that weld current reaches peak current.

% on Time - This is the pulse peak duration as a percentage of the total time, which controls how long the peak current is on for before dropping to the background current.

Down Slope - This is the way and the time taken for the welding current to wind down at the end of the TIG weld. Down slope will help prevent the uneven cooling of the final weld pool and will help stop pinholes forming at the completion of a TIG weld.

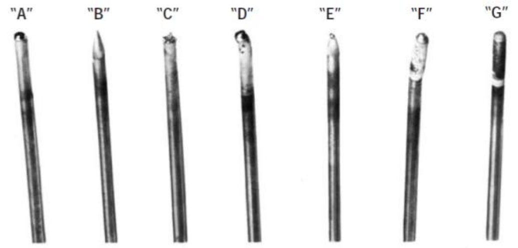
Post Flow - Post flow is the time taken for the shielding gas to stay on after the welding current has stopped. This time will

1) Protect the end of the weld
2) Protect the cooling down of the tungsten (the oxidation of the tungsten).

Pre-Flow– Pre-flow is used at the start of the welding process to help protect the start of the weld from contamination and to make sure the shielding gas is flowing before the welding current starts up.

1.1.13. RECOGNISING YOUR TUNGSTEN

Image-1.1.13.1-Electrodes



Electrode "A" has the "ball" end. This pure tungsten was used with alternating current on aluminium. Notice the end is uniform in shape and possesses a "shiny bright" appearance.

Electrode "B" is a 2% throated tungsten ground to a taper and was used with direct current straight polarity.

Electrode "C" is a 2% throated tungsten which was used with alternating current on aluminium. Note that this electrode has several small ball shaped projections rather than a round complete "ball end" like the pure tungsten.

Electrode "D" is a pure tungsten used with alternating current on aluminium. This electrode was subjected to a current above the rated capacity. Notice the "ball" started to droop to one side. It becomes very molten during operation and continuing to operate would have caused the molten end to drop into the weld puddle.

Electrode "E" is a pure tungsten that was tapered to a point and used on direct current straight polarity. Notice the "ball" tip characteristic of the pure tungsten. Pointing of pure tungsten is not recommended as the extreme point will always melt when the arc is established. The electrode in this illustration melted back, however, often times the point may melt and drop into the weld puddle.

Electrode "F" was severely contaminated by touching the filler rod to the tungsten. In this case the contaminated area must be broken off and the electrode reshaped as desired.

Electrode "G" did not have sufficient gas "post-flow". Notice the black surface which is oxidized because the atmosphere contacted the electrode before it cooled sufficiently. If this electrode were used the oxidized surface will flake off and drop into the weld puddle. Post-flow time should be increased so the appearance is like electrode "A" after welding.

1.2 NDT Techniques:

The use of non-invasive techniques to determine the integrity of a material, component or structure or quantitatively measure some characteristic of an object.i.e. Inspect or measure without doing harm.

1.2.1. History

Although history does not provide a precise starting date for non-destructive testing, its use dates back many, many years.

It is said that that flour and oil were used during Roman times to find cracks in marble slabs. For centuries, blacksmiths used sonic NDT when listening to the ring of different metals as they were being hammered into shape; a technique also used by early bell makers.

One of the first recorded uses of NDT was in 1868, when Englishman S.H. Saxby relied on the magnetic characteristics of a compass to find cracks in gun barrels.

Liquid Penetrant Testing (LPT)

According to Inspectioneering.com, one of the first methods of NDT was an early form of liquid penetrant testing called the "Oil and Whiting Method," which came into use in the second half of the 19th century.

Primarily used by the railroad industry, early inspectors relied on this method to increase the "see ability" of defects not typically seen visually.

Ultrasonic Testing (UT)

Ultrasonic testing was the latest NDT technique to come into industrial use.

In 1847, methods of "exciting" ultrasound were discovered by James Prescott Joule and then later in 1880 by Pierre Curie and his brother Paul Jacques.

The first "industrial" application was recommended following the tragic sinking of the Titanic, and, in 1929, a Russian named Sokolov proposed the use of ultrasound for testing castings.

NDT has come a long way since the early years, and those of us involved in the industry today owe a debt of gratitude to these pioneers, many of whom never lived to see the fruit of their labour. Had it not been for their efforts, non-destructive testing as an industry might not even exist.

1.2.2. Some Uses of NDT Methods

- Flaw Detection and Evaluation
- Leak Detection
- Location Determination
- Dimensional Measurements
- Structure and Microstructure Characterization
- Estimation of Mechanical and Physical Properties
- Stress (Strain) and Dynamic Response Measurements
- Material Sorting and Chemical Composition Determination

There are NDE application at almost any stage iin the production or life cycle of a component.

- To assist in product development
- To screen or sort incoming materials
- To monitor, improve or control manufacturing processes
- To verify proper processing such as heat treating
- To verify proper assembly

To inspect for in-service damage

1.2.3. Liquid Penetrant Inspection

A liquid with high surface wetting characteristics is applied to the surface of the part and allowed time to seep into surface breaking defects. The excess liquid is removed from the surface of the part. A developer (powder) is applied to pull the trapped penetrant out the defect and spread it on the surface where it can be seen. Visual inspection is the final step in the process. The penetrant used is often loaded with a fluorescent dye and the inspection is done under UV light to increase test sensitivity.

1.2.4. Ultrasonic Inspection (Pulse-Echo)

High frequency sound waves are introduced into a material and they are reflected back from surfaces or flaws. Reflected sound energy is displayed versus time, and inspector can visualize a cross section of the specimen showing the depth of features that reflect sound. High resolution images can be produced by plotting signal strength or time-of-flight using a computer-controlled scanning system.

1.2.5. Applications of NDT

- Inspection of Raw Products
- Inspection Following Secondary Processing
- In-Services Damage Inspection
- Power Plant Inspection
- Wire Rope Inspection
- Storage Tank Inspection
- Jet Engine Inspection
- Pressure Vessel Inspection
- Rail Inspection
- Bridge Inspection
- Pipeline Inspection

1.3. OBJECTIVE

The objective of the project is to conduct Tungsten Inert Gas Welding specimens of Aluminium alloy 5083 and the welded specimens will be tested using Non-Destructive testing techniqueslike Dye penetrant inspection to detect surface defects and Ultrasonic testing to detect sub-surface defects in specimens.

2. LITERATURE SURVEY

Kohyama et.al studied he Microstructural changes in welded joints of 316 SS by dual-ion irradiation was analysed in this study. They welded the specimens at three different parameters Current, Voltage, Flow Rate. They used the welding specimen have dimensions 500Lx 300w x 15t and finally conclusion of Microstructure evolution in welded joints is emphasized to be very sensitive to He/dpa ratio, especially in HAZ. Thus, mechanical and corrosion property changes m welded joints under fusion environment, should be very carefully evaluated. And the I-butt welding of 15 mm thickness plate, may produce the least swelling resistant zone m the HAZ. Ahmet Durgutlu studied the experimental investigation of the effect of hydrogen in argon as a shielding gas on TIG welding of ss material by changing the parameters Shielding gas 1.5%H2–Ar and 5%H2–Ar and pure Argon. Tensile strength and Penetration on plate specimen have dimensions 200L x 80w x 4 mm. They find the shielding gas of 1.5%H2–Ar the sample welded highest tensile strength was obtained. And it can be observed that increasing hydrogen content in the shielding gas reduces the mechanical properties. P. Liu et.al worked on microstructure characteristics in TIG welded joint of Mg/Al dissimilar materials using the welding plate specification of 100Lx40Wx3thk mm on parameters of welding velocity, wire feed velocity. And they find out the Microstructure, Hardness and Fracture and conclusion of there is an obvious fusion zone between the Mg substrate and weld metal. The structure close to the weld metal is columnar crystals, which grow into the weld metal. The Mg substrate close to the fusion zone was largely affected by the welding thermal cycle, and the crystals were small. The weld metal was mainly composed of dendrite crystal. M. Ahmad et.alAnalysed the microstructure and characterization of phases in TIG welded joints of Zircaloy-4 and ss 304L on the plate specimen on 2 x 1 x 0.3 cm.Input process parameter range of voltage 30–60 V, current 12–15 and Gas flow rate 15 l/min using the X-ray diffraction (XRD) technique. They finally find Zr(Cr, Fe)2 intermetallic compound and Zr2Fe–Zr2Ni eutectic phases have been observed in the molten zone of the TIG welded joints of the Zircaloy-4 and stainless steel 304L. The density of Zr(Cr, Fe) is about twice as compared to Zr2Fe–Zr2Ni eutectic phase. Hardness of the Zr (Cr, Fe)2 intermetallic compound is about three times higher eutectic phase. Density of Zr (Cr, Fe)2 intermetallic compound is low on the side of Zircaloy-4 as compared to SS 304L.compared to Zr2Fe–Zr2Ni. B.Y. Kang et.al study the effect of alternate supply of shielding gases in austenite stainless steel GTA Welding on the material of Stainless Steel 304 by used the specimen of 200L x 100w x 12 thk weld and apply the both Conventional and Alternate method. The input parameter of Shielding gas, welding ampere (A) and welding voltage (V). The result of under similar welding conditions, the alternate method with Ar and He compared with the conventional methods of Ar and Ar + 67% He produced the lowest degree of welding distortion. Compared with the conventional method of Ar + Prashant Kumar Singh et al. Int. Journal of Engineering Research and Applications www.ijera.com ISSN : 2248-9622, Vol. 5, Issue 2, (Part -5) February 2015, pp.125-128 www.ijera.com 127 | P a g e 67% He, the alternate method with Ar and He under similar welding conditions showed similar welding speed without largely deteriorating the weld shape. The alternate method with Ar and He presented the possibility of solving the problem of the increase in gas cost and welding distortion with the use of He in stainless steel welding. S. P. Gadewar et.al [11] analyzed of the experimental investigations of weld characteristics for a single pass tig welding with SS304 using the specimen of 100L x 25w x (1or 2 or 3) thickness of welding plate. They used the input parameters of Welding current (15-180 Amp), Shielding Gas Flow (1-18 LPM), Work Piece thickness (1-3mm) and apply the Regression analysis technique. And the final result of it is observed that as thickness of the work piece increases the Front width and Back width value across the weld also increases. Rui-Hua Zhang et.al study of the mechanism of penetration increase in A-TIG welding used the stainless steel materials plate which specimen are 150Lx 40w x 10 t and 300L x 40w x 20 t mm. They used the input parameters which are flux- Al2O3, Fe2 O3, SiO2, Cr2O3, TiO2, MnO, and B2O3 to find the result of penetration simulation by the PHOENICS software. The final result of that experiments are Arc construction and increase in voltage can cause the width of the weld to become narrower but have little effect on penetration. Stronger inward fluid flow patterns leading to weld beads with narrower width and deeper penetration could be apparently identified in the case of A-TIG welding. C. Balaji et.al have studied on evaluation of mechanical properties of SS 316 L weldments using tungsten inert gas welding. They consider the stainless steel 316 L rod specimen which have dimensions of 25 mm diameter and 75 mm length. They changed the input parameters range which are current (90,100,110 amp) bevel angle (60, 70, 800) gas volume (1.1, 0.9, 0.7 lpm) uses the Taguchi L-9 orthogonal array technique and they find the result are The tensile test has showed that the Current of 110A, Bevel Angle of 600 and a gas flow of 0.7 lpm offers the maximum tensile strength. The tensile test has also showed that the Current of 100A, Bevel Angle of 600 and a gas flow of 0.9 LPM offers the minimum tensile strength. The micro hardness has showed that the sample with the minimal tensile strength has the maximum micro hardness, which concludes that, the increase in micro hardness results in the decrease of the tensile strength. Dheeraj Singh et. Alstudied on parametric optimization of TIG process parameters using Taguchi and Grey Taguchi analysis. They used the Stainless Steel 304 grade plate which dimensions are 1.2 t x 250 l x 30 w and changed the process parameters which are Current (40-85A), Gas flow rate (5-20 lit./ min), Welding speed (8-14m/min) and Gun angle (500 -800). And they applied the Taguchi method L16 orthogonal array for optimization the result. Finally they find results which are If the optimal setting for steel with a current 40 A, gas flow rate 5 ltr/min, welding speed 12 m/min and gun angle 800, for stainless steel, the final work piece give the Tensile load (294.1Mpa), Area of penetration (13.05 mm2), penetration (2.215 mm) maximum Bead width (5.22 mm) and Bead height (0.055 mm) are minimum. Cheng-HsienKuo et.al studied on the effect of activated TIG flux on performance of dissimilar welds between mild steel and stainless steel and they used the dissimilar plate which have the dimensions of 100l x 50w x 6 t and they use the Austenitic stainless steel (SUS 316L) and hot-roll mild steel (JIS G3131) for weld. They changed the process parameters which are different flux CaO, Fe2O3, Cr2O3, and SiO2. Finally they find the conclusion of the surface appearance of TIG welds produced with oxide flux tended to form residual slag. The SiO2 powder can give the greatest improvement in joint penetration and also a satisfactory surface appearance of G3131 mild steel to 316L stainless steel dissimilar welds. TIG welding with SiO2 powder can increase weld depth-to-width ratio, which indicates a high degree of energy concentration during welding process, and tends to reduce angular distortion of the weldment. Furthermore, the defects susceptibility of the welds can also be reduced.

3. EXPERIMENTAL WORK

Welding Process

The experimental design consists of eight sets of experiments including the replication. The ranges of welding current and shielding gas flow rate are obtained by conducting trial and error and from the literature survey. The experiment is performed according to the order of the experimental design matrix. The specimen after welding is used for tensile testing.

Table-3.1

Sl. No.	WELDING CURRENT (A)	SHIELDING GAS FLOW RATE (1/min)
1	250	15
2	200	10
3	250	15
4	200	10
5	250	10
6	200	15
7	200	15
8	250	10

Min and Max values of TIG Welding for Aluminium (Hand book of welding)

In the Hand book of welding by Wilhelm Sen Ships Service it was stated that:

Aluminium Pure aluminium (Al) is a soft, easily shaped metal with low strength. It is characterized by low weight, excellent corrosion resistance and good electrical conductivity. The strength of aluminium can be considerably improved by the addition of small quantities of alloy elements. As an alloy, aluminium retains the same appearance as pure aluminium and approximately the same low weight, but strength can be compared to mild steel. Only a limited number of aluminium alloys are considered suitable for use on board ships. AIMg 3 and AIMg 1 are seawater resistant aluminium alloys. When alloyed with copper and silicon, aluminium can be used for the manufacture of cast components (silumin). When aluminium and its alloys come into contact with air, a refractory skin of oxide quickly forms on the surface. The melting point of aluminium oxide is over, 1000°C, considerably higher than that of aluminium, which melts at 660°C. Unless this layer of oxide is effectively removed during the welding operation, the difference in melting temperatures will make it difficult for the metal of the work piece to bind with the filler.

Included oxides will also reduce the strength of the weld. Thorough cleaning and the use of flux is therefore essential when gas welding aluminium. Welding should be done immediately after cleaning, before a new oxide film has time to develop. Other characteristic properties of aluminium are a high coefficient of expansion, good electrical and heat conductivity, and the absence of colour change when heated to melting point. Filler materials for Aluminium in the Unitary range are:

Coated electrode: ALUMIN-351N
Gas welding rod: ALUMAG-35
Wire welding: ALUMAG-W-35

For gas welding of aluminium it is required to use a flux that removes oxides.

Use Unitary ALU FLUx-34F.

Inspection of welded joints Inspection indicates whether the prescribed standard of quality has been met. This function may be the responsibility of the superintendent or other representative of the ship owner.

Prior to welding Visual inspection should begin before the first arc is struck. The materials should be examined to see if they meet specifications for quality, type, size, cleanliness, and freedom from discontinuities. Foreign matter grease, paint, oil, oxide film, heavy scale – that should be detrimental to the weld shall be removed. The pieces to be joined should be checked for straightness, flatness, and dimensions. Warped, bent, improperly cut or damaged pieces should be ordered for repair or rejected. Alignment and fixtures should be scrutinised. Joint preparation should be checked. Often little more than a passing glance is required as a preliminary inspection, but, despite its almost casual nature, it can be a significant factor in weld quality. A good joint design will provide access for the welder, adequate root opening to permit full fused penetration and correct groove angle to minimise volume of weld metal. The joint preparation must be correct before welding is started, not only to meet the specifications, but also to give assurance of weld quality.

Inspection of welded joints Inspection indicates whether the prescribed standard of quality has been met. This function may be the responsibility of the superintendent or other representative of the ship owner: Visual inspection from start to finish Visual inspection is the best buy in Non Destructive Testing (NDT) but it must take place constantly, prior to, during and after welding. In a sense, everyone involved in the job, as well as the appointed inspector, participate in visual inspection. A conscientious worker does not knowingly pass on work in which he recognises discontinuities of his own making. Nevertheless, it is usually desirable that someone is assigned the responsibility for quality checking each operation. In addition to good eyesight and proper light, the tools for visual inspection are simple a pocket rule, a weld-size gauge, a magnifying glass, and sometimes a straight edge and square for determining straightness, alignment, and perpendicularity. Inspection prior to welding also includes verification of correct process and procedures are to be employed – that the electrode type and size and the equipment settings for voltage and amperage are as specified – and that provisions are made for required preheat or post heat. Each welding process has its advantages and limitations, and each introduces problems affecting joint preparation, welding procedures and operator training. In most inspection situations the welding process is decided beforehand. So are the welding consumable (filler metals), but it is important that they have been stored properly in unopened containers unharmed by moisture. To ensure uniform results the welder's procedures must be spelled out in detail and followed rigorously during welding. Only qualified people must be assigned to the job.

What to look for PRIOR TO WELDING:

- Type/state of base material
- Joint design
- Welding process
- Consumables
- Welding procedure
- Welder's qualifications

During welding Assuming the preliminary requirements are met, the productive inspection will take place while the weld is being done. Examination of a weld bead and the end crater may to a competent inspector reveal quality deficiency such as cracks, inadequate penetration, and gas and slag inclusions. On simple welds, inspection of a specimen at the beginning of the operation and periodically as the work progresses may be adequate. When more than one layer of filler metal is deposited, however, it may be desirable to inspect each layer before the next. The root pass in a multiphase weld is the most critical one with regard to weld soundness. Check that the welding parameters match the parameters laid down in the approved welding procedure.

What to do DURING WELDING:

- Compare welding parameters with procedure
- Inspect each layer before the next

After welding Visual inspection after welding has been completed is also useful in evaluating quality, even if ultrasonic, radiographic, or other methods are to be employed. As welding progresses, surface flaws such as cracks, porosity, and unfilled craters can be detected, leading to repairs or rejection of the work. There is no point in submitting an obvious bad weld to sophisticated inspection methods. Dimensional variations from tolerances, warping, and faults in appearance are detected visually at this stage. The extent and continuity of the weld, its size, and the length of segments in intermittent welds can be readily measured or recorded. Welds must be cleaned from slag to make inspection for surface flaws possible. A 10x magnifying glass is helpful in detecting fine cracks and other faults. Shot blasting should not be used prior to examination, since the peening action may seal fine cracks and make them invisible. The objective of visual inspection at this stage is not only to detect non permissible faults, but also to give clues as to what may be wrong in the entire repair /fabrication process. If the inspector has a sound knowledge of welding, he can read much from what he sees. Thus, the presence of excessive porosity and slag inclusions may be an indication of insufficient current even if the dial readings on the machine tell otherwise. Subsequent tests will also give clues to faults in equipment or procedures, but the information acquired through visual examination allows corrections to be made before results from more sophisticated methods become available

What to look for After WELDING:?

- The final weld result
- Size of weld (measuring)

Tungsten Inert Gas Welding, also known by its acronym as TIG welding, is a welding process that uses the heat produced by an electric arc created between no consumable tungsten electrode and the e weld pool. This electric arc is produced by the passage of current trough aa conductive ionized inert gas that also provides shielding of the electrode, molten weld pool and solidifying weld metal from contamination by the atmosphere. The process may be used with or without the addition of filler metal us sing metal rods. Electric arc: The process can be used with either direct o alternating current, the choice is depending largely on the metal to be welded. Direct current with electrode negative offers the advantage of deep penetration and faster welding speeds.

A Brief Description of NDT Techniques in Insight NDT Paper by Mark Wilcox & George Downes have stated that use of non-invasive techniques to determine the integrity of a material, component or structure or quantitatively measure some characteristic of an object. The Die Penetration Test is frequently used for the detection of surface breaking flaws in no ferromagnetic materials. The subject to be examined is first of all chemically cleaned, usually by vapour phase, to remove all traces of foreign material, grease, dirt, etc. from the surface generally, and also from within the cracks. Next the penetrant (which is a very fine thin oil usually dyed bright red or ultra-violet fluorescent) is applied and allowed to remain in contact with the surface for approximately fifteen minutes. Capillary action draws the penetrant into the crack during this period. The surplus penetrant on the surface is then removed completely and thin coating of powdered chalk is applied. After a further period (development time) the chalk draws the dye out of the crack, rather like blotting paper, to form a visual, magnified in width, indication in good contrast to the background. The process is purely a mechanical/chemical one and the various substances used may be applied in a large variety of ways, from aerosol spray cans at the simplest end to dipping in large tanks on an automatic basis at the other end. The latter system requires sophisticated tanks, spraying and drying equipment but the principle remains the same.

This technique is used for the detection of internal and surface (particularly distant surface) defects in sound conducting materials. The principle is in some respects similar to echo sounding. A short pulse of ultrasound is generated by means of an electric charge applied to a piezo electric crystal, which vibrates for a very short period at a frequency related to the thickness of the crystal. In flaw detection this frequency is usually in the range of one million to six million times per second (1MHz to 6 MHz). Vibrations or sound waves at this frequency have the ability to travel a considerable distance in homogeneous elastic material, such as many metals with little attenuation. The velocity at which these waves propagate is related to the Young's Modulus for the material and is characteristic of that material. For example, the velocity in steel is 5900 meters per second, and in water 1400 meters per second. Ultrasonic energy is considerably attenuated in air, and a beam propagated through a solid will, on reaching an interface (e.g. a defect, or intended hole, or the back wall) between that material and air reflect a considerable amount of energy in the direction equal to the angle of incidence. For contact testing the oscillating crystal is incorporated in a hand held probe, which is applied to the surface of the material to be tested.

The material used is the Aluminium. And the dimensions are:

Image-3.2 Specifications

4. Input Parameters

As discussed above the Aluminium alloy will be welded and tested for the flaws by using NDT techniques as per the design specifications are mentioned below.

Design specifications are:

Table-4.1

	MAXIMUM VALUE	MINIMUM VALUE
CURRENT (Amps)	250	100
VOLTAGE (Volts)	15	10
ELECTRODE THICKNESS (mm)	3	1.5

As per the earlier mentioned dataeight specimens will be prepared with the above mentioned dimensions and by altering specifications.

1) The fist specimen will be prepared by following specifications.

Table-4.2

	VALUE
CURRENT (AMPS)	250
VOLTAGE (VOLTS)	15
ELECTRODE (diameter in mm)	3

Figure-4.1 First Specimen

2) The second specimen will be prepared by following specifications.

Table-4.3

	VALUE
CURRENT (AMPS)	250
VOLTAGE (VOLTS)	15
ELECTRODE (diameter in mm)	1.5

Figure-4.2 Second Specimen

3) The third specimen will be prepared by following specifications.

Table-4.4

	VALUE
CURRENT 9AMPS)	250
VOLTAGE (VOLTS)	10
ELECTRODE (diameter in mm)	3

4) The fourth specimen will be prepared by following specifications.

Table-4.

	VALUE
CURRENT (AMPS)	250
VOLTAGE (VOLTS)	10
ELECTRODE (diameter in mm)	1.5

The fifth specimen will be prepared by following specifications

Table-4.6

	VALUE
CURRENT (AMPS)	100
VOLTAGE (VOLTS)	15
ELECTRODE (diameter in mm)	3

The sixth specimen will be prepared by following specifications.

Table-4.7

	VALUE
CURRENT (AMPS)	100
VOLTAGE (VOLTS)	15
ELECTRODE (diameter in mm)	1.5

5) The seventh specimen will be prepared by following specifications.

Table-4.8

	VALUE
CURRENT (AMPS)	250
VOLTAGE (VOLTS)	10
ELECTRODE (diameter in mm)	3

6) The eighth specimen will be prepared by following specifications.

Table-5.9

	VALUE
CURRENT (AMPS)	100
VOLTAGE (VOLTS)	10
ELECTRODE (diameter in mm)	1.5

5. Testing

Depth of penetration measured from sectional cross cutting of weld beads through measuring instrument after cutting all the welded specimens perpendicular to the direction of welding are shown in the table 3 and variations in the penetration are analysed with the help of graph as shown in graph no. 1,2&3. The depth of penetration increases with increasing welding speed up to 147.78 mm/min which was optimum value to obtain maximum penetration, because it begins to decrease linearly after this point. Increasing the speed of travel and maintaining constant arc voltage and current increases penetration until an optimum speed is reached at which penetration is maximum. Increasing the speed beyond this optimum result in decreased penetration and maximum depth of penetration occurs at heat input rate of 1705.23J/mm. Greater the depth of penetration, better is the weldability. So, Optimum weld ability can be obtained with heat input rate as 1705.23J/mm. So it can be concluded from experimental analyses is that for the specimen 5052 Al-alloy grade of 100mm long x 50mm wide x 2.5 mm thickness ,optimum weldability can be achieved by considering the welding parameters as welding speed, 147.78 mm/min with current 210 Amp, arc voltage 20 V and gas flow rate 12.5Lt/mm.

A. Effect of Welding Speed on Depth of Penetration: The evaluation of data of welding speed and depth of penetration which helps to analyze the variation in depth of penetration. Arc time is varied during the welding of 5052 Al-alloy specimens at constant voltage and current va20 volt and 210 amperes. It is clear from Figure 1 that describes the depth of penetration increases linearly by increasing welding speed until an optimum value which gives maximum penetration. After this optimum value, depth of penetration begins to decrease linearly. Therefore, maximum penetration of 2.02 mm is obtained for specimen 4 at welding speed of 147.78 mm/min.

B.Tensile Test : Tensile testing is conducted to determine the ultimate tensile strength and percentage elongation. The tensile sample is prepared as per ASTM standard and it is. The tensile test is conducted for all combination of the welding parameter ranges. The results of the tensile test are shown in the Table V. From the table it is found that the test result obtained is close to the standard value. The value of UTS very close to the standard value is selected from the four combinations.

According to this result microstructure and macrostructure study is conducted to find out the best welding parameter ranges in the TIG welding of Aluminum alloy.

The specimens are tested and the tested pieces have been displayed.

1) Fist test piece

2) Second test piece

3) Third test piece

4) Fourth test piece

5) Fifth test piece

6) Sixth test piece

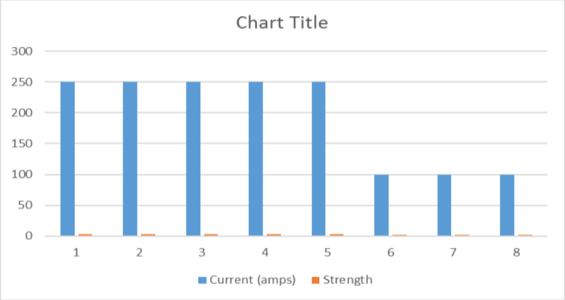
7) Seventh test piece

8) Eight test piece

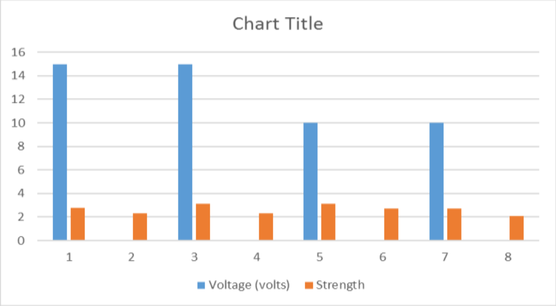
6. RESULTS

S.No.	Current (amps)	Voltage (volts)	Electrode Diameter (mm)	Elongation (mm)
1	250	15	3	2.8
2	250	15	1.5	2.3
3	250	10	3	3.1
4	250	10	1.5	2.3
5	250	10	3	3.1
6	100	15	1.5	2.7
7	100	10	3	2.7
8	100	10	1.5	2.1

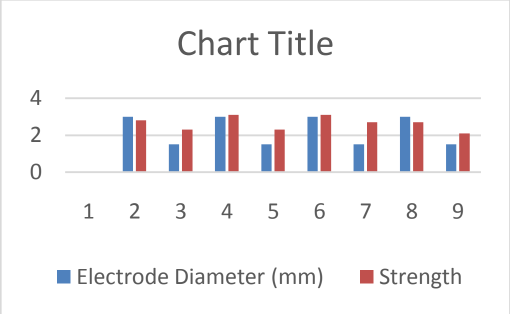
Stronger the weld is longer it elongates. The three graphs are made to display the result. The fist is current against strength (current on x-axis and strength on y-axis). The second graph is voltage against strength. And the third graph is electrode diameter against strength.



Welding current is the most influential parameter because it affects bead shape, controls the rate at which electrode is melted and therefore also controls the deposition 104 rate, heat affected zone, the depth of penetration, and the amount of base metal melted. Penetration and reinforcement increase with the increase in welding current.



The voltage principally determines the shape of the weld bead cross section and its external appearance. Increasing the welding voltage with constant current and welding speed produces flatter, wider, less penetrated weld beads and tends to reduce the porosity caused by rust or scale on steel. Higher voltage also bridges an excessive root opening when fit-up is poor. Increase in arc voltage also increases the size of droplets and hence decreases the number of droplets. The time of the movement of droplet transfer also increases. Further increase in voltage increases the possibility of breaking the arc and disrupting the normal welding process.



Electrode size affects the weld bead shape and the depth of penetration at fixed current. At any given current, a larger diameter electrode will have a higher current density and a higher deposition rate than a smaller electrode. A larger diameter electrode can carry more current than a smaller electrode, and produce a higher deposition rate at higher amperage. For the same values of current, arc voltage and welding speed, an increase in electrode diameter results in a slight increase in the spread of the bead.

7. CONCLUSION

The experimental design is done with two parameters and two levels, and the defect free working ranges (levels) of welding parameter for conducting experiment is found out by trial and error and from the literature survey. The welding of the samples is done as per the order of experimental design matrix and found that

- The strength increases as the current increase
- The strength decreases as the voltage increase

- The strength increases as the electrode diameter increase.

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