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Study the Effects of Welding Parameters on TIG Welding of Aluminium Plate

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ABSTRACT

To enhance the Mechanical properties and welding quality of Aluminum (Al) plate an automated TIG welding system has been developed, by which welding speed can be controlled during welding process. Welding of Al plate has been performed in two stages. During 1st stage of welding, single side welding performed over Al plate and during 2nd stage both side welding performed for Al plate by changing different welding parameters. Effect of welding speed and welding current on the tensile strength of the weld joint has been investigated for both type of weld joint. An analysis through Optical microscopic has been done on the weld zone to evaluate the effect of welding parameters on welding quality. Micro-hardness value of the welded zone has been measured at the cross section to understand the change in mechanical properties of the welded zone.

Keywords: tungsten inert gas welding, Aluminum plate, mechanical properties and Optical microscopic.

1. INTRODUCTION

Welding is a permanent joining process used to join different materials like metals, alloys or plastics, together at their contacting surfaces by application of heat and or pressure. During welding, the work-pieces to be joined are melted at the interface and after solidification a permanent joint can be achieved. Sometimes a filler material is added to form a weld pool of molten material which after solidification gives a strong bond between the materials. Weld ability of a material depends on different factors like the metallurgical changes that occur during welding, changes in hardness in weld zone due to rapid solidification, extent of oxidation due to reaction of materials with atmospheric oxygen and tendency of crack formation in the joint position.

1.1 Different *type of welding processes*

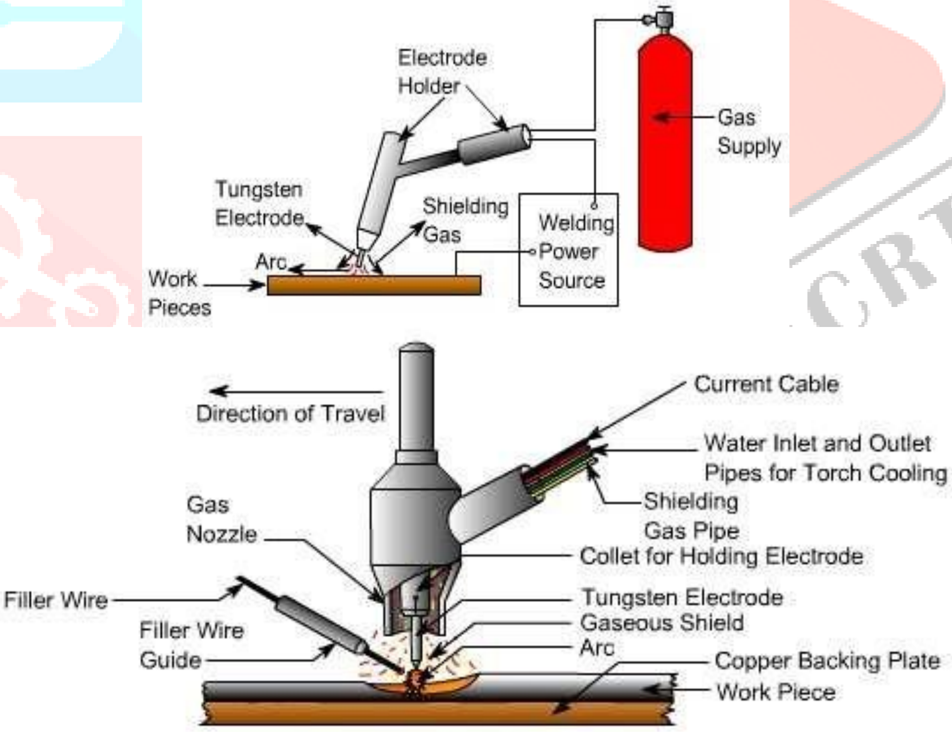
Based on the heat source used welding processes can be categorized as follows:

1. *Gas Welding*
2. *Resistance Welding*
3. *High Energy Beam Welding*
4. *Solid-State Welding*
5. *Arc Welding*: In arc welding process an electric power supply is used to produce an arc between electrode and the work-piece material to joint, so that work-piece metals melt at the interface and welding could be done. Power supply for arc welding process could be AC or DC type. The electrode used for arc welding could be consumable or non-consumable. For non-consumable electrode an external filler material could be used.

a) Shielded metal Arc Welding.
b) Gas metal arc welding.
c) Gas tungsten arc welding or Tungsten Inert welding**:** *GTAW or TIG* welding process is an arc welding process uses a non consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere with a shielding gas generally Argon or Helium or sometimes mixture of Argon and Helium. A filler metal may also feed manually for proper welding. GTAW most commonly called TIG welding process was developed during Second World War. With the development of TIG welding process, welding of difficult to weld materials e.g. Aluminium and Magnesium become possible. The use of TIG today has spread to a variety of metals like stainless steel, mild steel and high tensile steels, Al alloy, Titanium alloy. Like other welding system, TIG welding power sources have also improved from basic transformer types to the highly electronic controlled power source today.

Basic mechanism of TIG welding:

TIG welding is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere by an inert shielding gas (argon or helium), and a filler metal is normally used. The power is supplied from the power source (rectifier), through a hand-piece or welding torch 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 work piece using a constant-current welding power supply that produces energy and conducted across the arc through a column of highly ionized gas and metal vapours [1]. The tungsten electrode and the welding zone are protected from the surrounding air by inert gas. The electric arc can produce temperatures of up to 20,000^{o}C and this heat can be focused to melt and join two different part of material. The weld pool can be used to join the base metal with or without filler material.



Schematic Diagram of TIG Welding System and Principle of TIG Welding

Tungsten electrodes are commonly available from 0.5 mm to 6.4 mm diameter and 150 - 200 mm length. The current carrying capacity of each size of electrode depends on whether it is connected to negative or positive terminal of DC power source. The power source required to maintain the TIG arc has a drooping or constant current characteristic which provides an essentially constant current output when the arc length is varied over several millimeters. Hence, the natural variations in the arc length which occur in manual welding have little effect on welding current. The capacity to limit the current to the set value is equally crucial when the electrode is short circuited to the work piece, otherwise excessively high current will flow, damaging the electrode. Open circuit voltage of power source ranges from 60 to 80 V.

1.2 Types of welding current used in TIGwelding:

a. DCSP (*Direct Current Straight Polarity)*: In this type of TIG welding direct current is used. Tungsten electrode is connected to the negative terminal of power supply. This type of connection is the most common and widely used DC welding process. With the tungsten being connected to the negative terminal it will only receive 30% of the welding energy (heat). The resulting weld shows good penetration and a narrow profile.
b. DCRP *(Direct Current Reverse Polarity):* In this type of TIG welding setting tungsten electronde is connected to the positive terminal of power supply. This type of connection isused very rarely because most heatison the tungsten, thus the tungsten can easily overheat and burn away. DCRP produces a shallow mainly wide profile.
c. AC*(AlternatingCurrent):*Itisthepreferredweldingcurrentformostwhitemetals, 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. On the half cycle, where the tungsten electrode is positive, electrons will flow from base material to the tungsten. This will result in the lifting of any oxide skin on the base material. This side of the wave form is called the cleaning half. As the wave moves to the point where the tungsten electrode becomes negative the electron will flow from the welding tungsten electrode to the base material. This side of the cycle is called the penetration half of the AC-wave.
d. *Alternating Current with 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 better control and each side of the wave can give a more cleaning half of the welding cycle and more penetration.

Advantages of TIG welding

TIG welding process has specific advantages over other arc welding process as follows -

I. Narrow concentrated arc
II. Able to weld ferrous and non-ferrous metals
III. Does not use flux or leave any slag (shielding gas is used to protect the weld-pool and tungsten electrode)
IV. No spatter and fumes during TIG welding.

Applications of TIG Welding

I. Nuclear industry
II. Aircraft
III. Food processing industry
IV. Maintenance and repair work
V. Precision manufacturing industry
VI. Automobile industry.

Process parameters of TIG welding: The parameters that affect the quality and outcome of the TIG welding process are given below.

a) Welding Current: Higher current in TIG welding can lead to splatter and work piece become damage. Again lower current setting in TIG welding lead to sticking of the filler wire. Sometimes larger heat affected area can be found for lower welding current, as high temperatures need to applied for longer periods of time to deposit the same amount of filling materials. Fixed current mode will vary the voltage in order to maintain a constant arc current.

b) Welding Voltage: Welding Voltage can be fixed or adjustable depending on the TIG welding equipment. A high initial voltage allows for easy arc initiation and a greater range of working tip distance. Too high voltage, can lead to large variable in weldingquality.

c) Inert Gases: The choice of shielding gas is depends on the working metals and effects on the welding cost, weld temperature, arc stability, weld speed, splatter, electrode life etc. it also affects the finished weld penetration depth and surface profile, porosity, corrosion resistance, strength, hardness and brittleness of the weld material. Argon or Helium may be used successfully for TIG welding applications. For welding of extremely thin material pure argon is used. Argon generally provides an arc which operates more smoothly and quietly.

d) Welding speed: Welding speed is an important parameter for TIG welding. If the welding speed is increased, power or heat input per unit length of weld is decreases, therefore less weld reinforcement results and penetration of welding decreases. Welding speed or travel speed is primarily control the bead size and penetration of weld. It is interdependent with current. Excessive high welding speed decreases wetting action, increases tendency of undercut, porosity and uneven bead shapes while slower welding speed reduces the tendency to porosity.

Properties and advantages of Al:

Aluminium is a very light weight metal (specific weight of 2.7 g/cm^3). Use of aluminium in automobile and aerospace reduces dead-weight and energy consumption. Strength of Aluminium can be improved as per the required properties for various applications by modifying the composition of its alloys. Aluminium is a highly corrosion resistant material. Different types of surface treatment can further improve its corrosion resistance property. Aluminium is an excellent heat and electricity conductor and in relation to its weight is almost twice as good a conductor as copper. This has made aluminium the most commonly used material in major power transmission lines. Aluminium is ductile and has a low melting point. In a molten condition it can be processed in a number of ways. Its ductility allows products of aluminium to be basically formed close to the end of the product's design.

LITERATURE SURVEY:

Tseng {2011}[5]:investigated the effect of activated TIG process on weld morphology, angular distortion, delta ferrite content and hardness of 316 L stainless steel by using different flux like TiO_2, MnO_2, MoO3, SiO2 and Al_2O_3. To join 6 mm thick plate author uses welding current 200 Amp, welding speed 150 mm/min and gas flow rate 10 l/min. From the experimental results it was found that the use of SiO_2 flux improve the joint penetration, but Al_2O_3 flux deteriorate the weld depth and bead width compared with conventional TIG process.

Sakthivel {2011}[6]:studied creep rupture behavior of 3 mm thick 316L austenitic stainless steel weld joints fabricated by single pass activated TIG and multi-pass conventional TIG welding processes. Welding was done by using current in the range of 160-280 A, and welding speed of 80-120 mm/min. Experimental result shows that weld joints possessed lower creep rupture life than the base metal. It was also found that, single pass activated TIG welding process increases the creep rupture life of the steel weld joint over the multi-pass TIG weld joints.

Wang {2011}[7]:studied the influences of process parameters of TIG arc welding on the microstructure, tensile property and fracture of welded joints of Ni-base super-alloy. For welding plate width of 1.2-1.5 mm, welding current in the range of 55-90 A, with variable welding speed in the range 2100-2900 mm/min was used. From experimental result it was observed that, the heat input increases with increase of welding current and decrease of welding speed.

Narang {2011}[8] :performed TIG welding of structural steel plates of different thickness with welding current in the range of 55 -95 A, and welding speed of 15-45 mm/sec. To predict the weldment macrostructure zones, weld bead reinforcement, penetration and shape profile characteristics along with the shape of the heat affected zone (HAZ), fuzzy logic based simulation of TIG welding process has been done

Indira Rani {2012}[9] :investigated the mechanical properties of the weldments of AA6351 during the GTAW /TIG welding with non-pulsed and pulsed current at different frequencies. Welding was performed with current 70-74 A, arc travel speed 700-760 mm/min, and pulse frequency 3 and 7 Hz. From the experimental results it was concluded that the tensile strength and YS of the weldments is closer to base metal. Failure location of weldments occurred at HAZ and from this we said that weldments have better weld joint strength.

Karunakaran {2012}[10]:performed TIG welding of AISI 304L stainless steel and compare the weld bead profiles for constant current and pulsed current setting. Effect of welding current on tensile strength, hardness profiles, microstructure and residual stress distribution of welding zone of steel samples were reported. For the experimentation welding current of 100- 180 A, welding speed 118.44 mm/min, pulse frequency 6 Hz have been considered. Lower magnitude of residual stress was found in pulsed current compared to constant current welding. Tensile and hardness properties of the joints enhanced due to formation of finer grains and breaking of dendrites for the use of pulsed current.

Ahmetdurgutlu {2012}[11]: investigated the effect of hydrogen in argon as shielding gas for TIG welding of 316L austenitic stainless steel. They used current 115 A, welding speed 100 mm/min and gas flow rate 10 l/min for welding of 4 mm thick plate. For all shielding media, hardness of weld metal is lower than that of HAZ and base metal. Penetration depth, weld bead width and mean grain size in the weld metal increases with increasing hydrogen content. The highest tensile strength was obtained for the sample welded under shielding gas of 1.5%H2–Ar.

Wang Rui {2012}[12]:investigated the effect of process parameters i.e. plate thickness, welding heat input on distortion of Al alloy 5A12 during TIG welding. For welding they used current (60-100) A, welding speed (800-1400) mm/min and thickness of w/p (2.5-6) mm. The results show that the plate thickness and welding heat input have great effect on the dynamic process and residual distortion of out-of-plane.

Dongjie Li {2012}[13]:proposed a double-shielded TIG method to improve weld penetration and compared with the traditional TIG welding method under different welding parameters.

Lu {2012}[14] : proposed a double-shielded TIG welding process for the welding of 9 mm thick Cr13Ni5Mo stainless steel by using pure He as inner shielding layer and mixture of He and CO2 gas as the outer shielding layer. Welding current and welding speed considered for the experimentation in the range of 120-140 A and 90-300 mm/min respectively. The double– shielded TIG welding process display efficiency 2-4 times greater than that of traditional TIG welding. A change in the direction of the surface tension affects the fusion zone profile which results a larger weld depth. This process allows a high welding efficiency comparing with traditional TIG welding.

Urena{2013}[15]:investigated the influence of the interfacial reaction between the Al alloy (2014) matrix and SiC particle reinforcement on the fracture behaviour in TIG welded Al matrix composites. TIG welding was carried out on 4 mm thick AA2014/SiC/Xp sheets using current setting in the range of 37-155 A and voltage of 14-16.7 V. From experimental results it was found that, the failure occurred in the weld metal with a tensile strength lower than 50% of the parent material. Fracture of the welded joint was controlled by interface deboning through the interface reaction Layer. Probability of interfacial failure increases in the weld zone due to formation of Aluminium-carbide which lowers the matrix/reinforcement interface strength.

Raveendra{2013}[16]:done experiment to see the effect of pulsed current on the characteristics of weldments by GTAW. To weld 3 mm thick 304 stainless steel welding current 80-83 A and arc travel speed 700-1230 mm/min. More hardness found in the HAZ zone of all the weldments may be due to grain refinement. Higher tensile strength found in the non-pulsed current weldments. It was observed that UTS and YS value of non-pulsed current were more than the parent metal and pulsed currentweldments.

Amir hosseinfaraji{2015}[17]:The effects of three important welding parameters including laser power, welding current and welding speed on the weld pool characteristics, shape and dimensions in hybrid laser-TIG welding of AA6082 aluminum alloy are studied by numerical, experimental, and statistical approaches. For this aim, first, a 3D numerical model is used to simulate heat transfer and fluid flow in the weld pool and then resultant weld shape for various welding conditions. Besides, a set of experiments are performed to validate and calibrate the model. Finally, analysis of variance (ANOVA) method is applied to investigate more precisely how welding parameters affect weld dimensions. The simulation results show with increasing the laser power and welding current and decreasing the welding speed, the Marangoni and buoyancy forces increase. With increasing the laser power, the weld depth increases more significantly than the weld width. The weld half width increases with increasing the welding current, whereas the weld pool depth is relatively unchanged. Furthermore, with increasing the welding speed, both weld pool depth and half width decrease with similar slope. Generally, the presented model showed a good capability to predict the weld geometry and characteristics under various applied welding conditions which can reduce number of needed experimentsRishi Kumar {2017}[30]:To improve Welding quality of aluminum (Al) plate, the TIG Welding system has been prepared, by which Welding current, Shielding gas flow rate and Current polarity can be controlled during Welding process. In the present work, an attempt has been made to study the effect of Welding current, current polarity, and shielding gas flow rate on the tensile strength of the weld joint. Based on the number of parameters and their levels, the Response Surface Methodology technique has been selected as the Design of Experiment. For understanding the influence of input parameters on Ultimate tensile strength of weldment, ANOVA analysis has been carried out. Also to describe and optimize TIG Welding using a new metaheuristic Nature – inspired algorithm which is called as Firefly algorithm which was developed by Dr. Xin-She Yang at Cambridge University in 2007. A general formulation of firefly algorithm is presented together with an analytical, mathematical modeling to optimize the TIG Welding process by a single equivalent objective function.

Sanjay kumar {2019}[18]: The present investigation focused on the optimization of the various process parameters of tungsten inert gas welding operation. AISI 304 stainless steel has been taken as the base metal. Taguchi's L27 orthogonal array has been chosen for the design of experiment. The selected input parameters are current, voltage, root gap and gas flow rate. Further, the mechanical testing was performed. Bending strength and micro-hardness values are chosen as the response values. The regression relation between input parameters and response values are designed with the help of response surface methodology.

Amirreza KHOSHROYAN {2020}[19] :The distribution of temperature and then the distribution of residual stress and distortion in the stiffened aluminum alloy Al6061-T6 plates under the metal inert gas (MIG) welding process were investigated by three dimensional thermo-mechanical coupled finite element model using Ansys software. The properties of materials were considered temperature-dependent and the filler metal was added to the workpiece by the element birth and death technique. In three modes of current, two different speeds and two various sequences, the distribution of residual stress and distortion were calculated and analyzed. The results showed that increase in welding speed decreased the vertical deflection in the plate, transverse shrinkage and angular distortion of plate and the lateral deflection of stiffener, but increased the maximum longitudinal tensile stress in the plate and stiffener. Furthermore, increase in current increased the residual stress and deformation in the plate and stiffener, and the change in the welding sequence changed the distribution of the distortion in the plate and the stiffener without significant change in the distribution of the longitudinal residual stress

Problem identification and objective of thework

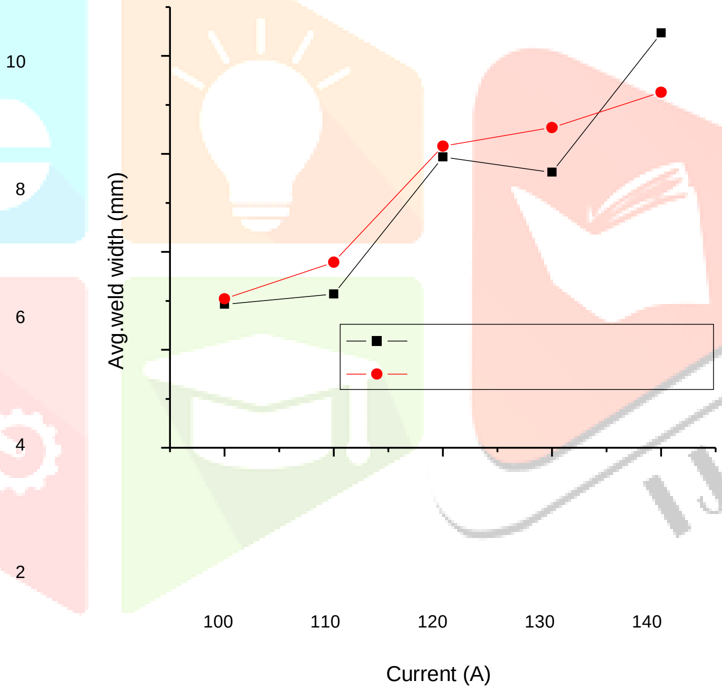
From the literature review, it is found that welding of Aluminium is a big challenge by conventional arc welding process. Again repeatability of welding depends on its control on welding speed and other processingparameters.

In this work to perform welding of 3 mm Aluminium plate, an automated TIG welding setup was made. Welding of the Aluminium plate was done by changing the welding current and welding speed to get a high strength joint. To get better strength welding of the Aluminium plate also done from both side. Effect of welding speed and applied current on the tensile strength of weld joint, micro hardness of the weld pool and macrostructure of the joint was analysed.

RESULT AND DISCUSSION:

Welding width for all the samples were measured and calculated average welding width as shown in table 4. Average value of welding width then plotted against the applied welding current for different welding speed as shown in Fig. 5. From the plot it is clearly seen that welding width increases almost linearly with increase of welding current.

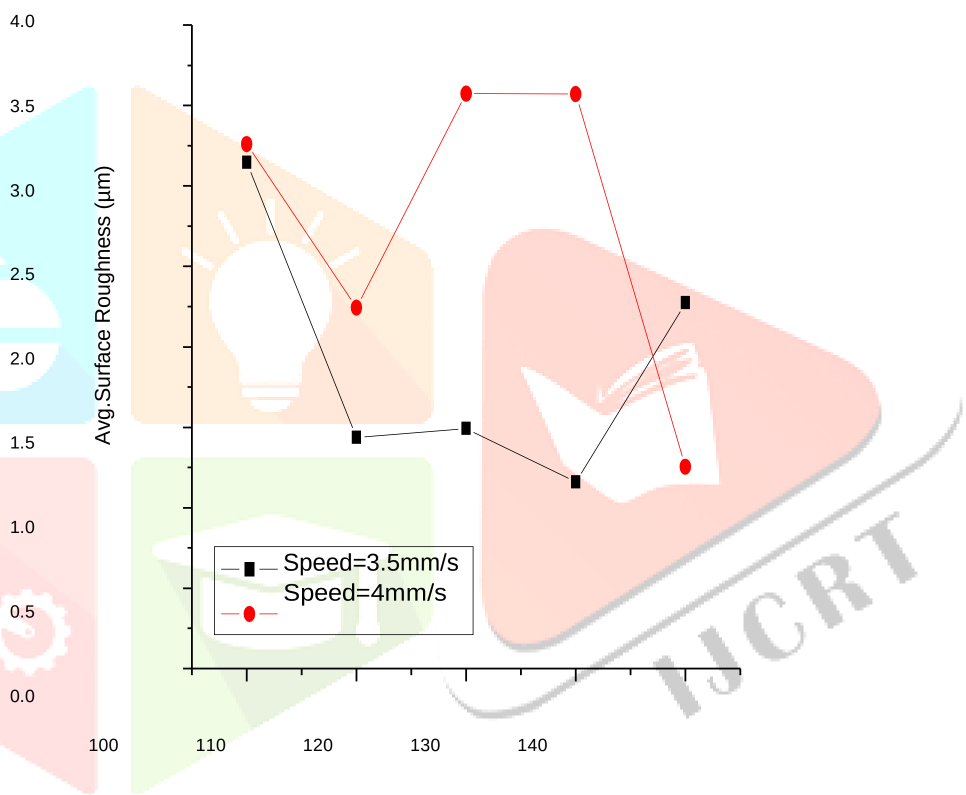
Sample no	Reading 1 (mm)	Reading 2 (mm)	Reading 3 (mm)	Avg. width (mm)
1	5.43	4.85	4.51	4.93
2	7.35	6.83	7.22	5.14
3	8.95	7.58	7.29	7.94
4	7.24	7.82	7.82	7.626
5	10.92	10.45	10.04	10.47
6	5.03	5.18	4.92	5.042
7	5.53	5.85	5.99	5.79
8	8.57	8.05	7.86	8.16
9	9.27	8.06	8.27	8.54
10	9.13	10.07	8.57	9.256



welding width of the samples with different welding speed and welding current

Surface roughness of the weld zone for all the samples were measured and average surface roughness value was calculated from three reading which is tabulated. Roughness value found in the range of 1.1 to 3.5 micron, is quite low for a welded specimen. Therefore it can be say that using an automated system good quality of welding is possible which may not require any further finishing operation. These roughness values are again plotted against applied current in But no specific effect of applied current on the surface roughness value has been observed

Sample No	Reading1 (μm)	Reading2 (μm)	Reading3 (μm)	Avg. Value (μm)
1	3.411	3.358	3.034	3.145
2	1.929	1.190	1.189	1.436
3	1.720	1.381	1.376	1.492
4	0.704	1.382	1.395	1.160
5	2.812	2.791	1.220	2.274
6	1.900	4.615	3.258	3.258
7	2.363	2.192	2.174	2.243
8	3.563	3.575	3.583	3.574
9	3.248	3.311	4.151	3.57
10	1.311	1.236	1.210	1.252



Avg. surface roughness of the sample with different welding current and welding speed condition

Conclusion:

From the experiment of TIG welding of Aluminium plate following conclusion can be made

- With the automated welding system uniform welding of Aluminium plate can bepossible.
- Welding strength or tensile strength of the weld joint depends on the welding parameters like welding speed and weldingcurrent.
- With the increase in current, tensile strength of the weld jointincreases.
- Hardness value of the weld zone change with the distance from weld centre due to change ofmicrostructure.
- At lower welding speeds strength is more due to more intensity ofcurrent.
- For both side welding tensile strength is found almost equivalent to the strength of basematerial.
- For both sided welding performed with high current (180 A), welding speed have no specific effect on tensile strength of the weldjoint.

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