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13 – 18

Influence of Welding Current and Welding Speed on Tig Welding of Aluminium Plate

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Abstract— in this research work an automated TIG welding setup was made and welding is performed on 3 mm thick aluminium plate. Welding parameters such as welding speed and current are changed to get a better strength joint and for this reason only welding is done on both the sides of aluminium plate. The tensile strength of the obtained weld joint, microstructure and micro hardness of weld pool was analysed by changing welding speed and current applied

Keywords-*TIG welding; automated; aluminium plate;microstructur.*

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I. INTRODUCTION

Now the bonding force between the two metallic atoms decreases very sharply with the interatomic distance. When the distance is more than a few atomic spacings (i.e, a few angstorms), the interacting atomic forces reduces to almost zero. But the force increases sharply and attains a very large value when the distance is reduced. Thus, if it is possible to bring together two metallic surfaces so that nothing but the grain boundaries seprate them, the two bodies will adhere with a very large force resulting in the process of what we call as welding.

In simple words we can say that welding is the process of joining similar or dissimilar metals with or without the application of heat and pressure. Weldability of a material depends upon the various factors like the metallurgical changes that occur due to welding, changes in hardness in and around the weld, extent of oxidation and extent of cracking tendency of the joint

II. DIFFERENT TYPES OF WELDING PROCESSES

Based on the type f heat source welding process is characterized as

- Arc Welding

Arc welding is a method of permanently joining two or more metal parts. It consists of combination of different welding processes wherein coalescence is produced by heating with an electric arc, (mostly without the application of pressure) and with or without the use of filler metals depending on the thickness of base plate metal.

- Resistance welding

Resistance Welding is produced by means of electrical resistance across the two components to be joined. In this process coalescence is produced by the heat obtained from the resistance of work to the flow of electric current in a circuit of which the work is a part and by application of pressure. Filler metal is not needed in this process.

- Solid State Welding

The principal of this operation is changing mechanical energy into heat energy. Two samples are joined together along their axis by this process. Spindle is rotated with a very high speed around 5900 rpm. Both the pieces are allowed to rub against each other and as a result of that heat will be produced.

- Radiant Energy Welding

In this process a beam of electrons is used to melt the metal where it has to be welded. These electrons are converged to field by creating magnetic field with the help of field electrodes. This electron beam has highly concentric energy and can melt the metal within with in no time. Workpiece experiences deep penetration and very insignificant heat affected zone.

- Thermit welding

Thermit is a mixture of aluminium powder and metal oxide. This mixture is placed in a crucible and ignited by means of fire cracker, this action is continued throughout the mass of mixture and enormous heat is released since the reaction is exothermic. The aluminium combined with oxygen forms iron oxide, iron oxide gets reduced to iron releasing intense heat.

- Allied Process

If the parent metal cannot withstand high temperature, or the parts to be joined are delicate intricate or metals with different properties, thickness etc. then to weld with those processes is difficult so to weld with those allied processes are introduced.in this additional metal is deposited on a substrate either by spraying or by some welding processes.

- Gas welding

This process is also known as oxy-acetylene welding. Heat is supplied by the combustion of acetylene in a stream of oxygen. Oxygen and acetylene is supplied by the torch having flexible hoses. Heat from this torch is less concentrated as compared to electric arc.[2]

III. TIG WELDING

Tungsten Inert Gas Welding is an arc welding process in which tungsten electrode is used which is non consumable in nature to produce weld. An inert shielding gas such as argon or helium along with a filler metal is used to protect the weld area from atmosphere. A rectifier is used as a power source from which power is supplied, with the help of a welding torch or a hand piece. This power is delivered to the tungsten electrode which is already fitted into the hand piece. An electric arc is

ISSN: 2349-7947
13 – 18

created between the base metal and the tungsten electrode with the help of a constant current welding power supply from which energy is produced and this energy is conducted through out the arc with a column of highly ionised gas and metal vapours[2].

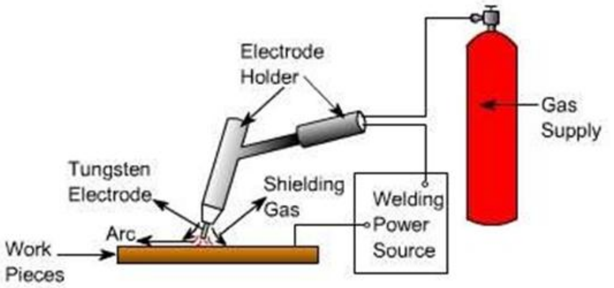

Figure 1 : TIG WELDING SYSTEM (Reference 1)

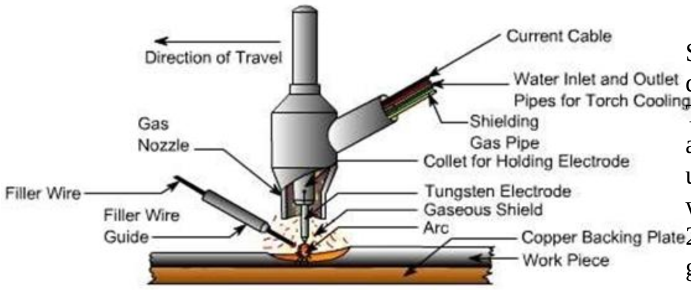

Figure 2: PRINCIPLE OF TIG WELDING (Reference 1)

IV. LITERATURE REVIEW

A. Kumar and Sundarrajan [6] He investigated about pulsed TIG welding process parameters on how they can be optimised to increase the mechanical properties of the weld using Taguchi method and also Regression models were developed. This method is used to design and analyse the experiments for improving quality characteristics. Taguchi method evaluates the effects of individual parameters which are not dependent on other and the quality characteristics are identified such as Ultimate tensile strength, Yield strength, hardness etc. Taguchi method is used since it is a practical tool which helps to improve the quality of output without increasing the experiment cost and also it decreases the number of experiments to be performed. Microstructures of all the welds were studied and correlated with the mechanical properties. Welds obtained are then subjected to cold planishing process due to which the internal stresses are relieved and grains are reformed thereby increasing the mechanical properties.

Harmish Bhatt [7] He investigated about the effects of process parameters such as gas flow rate and welding current during TIG welding of aluminium alloy 7075 for which he performed the 2 sets of experiments. In first he studied about the mechanical properties such as Ultimate Tensile Strength and hardness. In 2 set of experiment he tried to optimize the process parameters by limiting the values of gas flow rate and welding current to get maximum Ultimate Tensile Strength.

B Ravindar and K Gururaj [8] He adopted pulsed current TIG welding method. The material used is aluminium alloy 5053 sheets, with thickness of 4mm. The required dimension of the final workpiece is 100x100x4 mm. The filler metal used was ER 5356 of different diameter and weld samples of weld at different conditions by changing the process parameters i.e., welding current, gas flow rate and filler rods. The impact test was conducted and Vickers Hardness value is obtained for the process parameters such as welding current of 180 A, gas flow rate 10l /min and filler rod diameter is 1.6 mm. The Vickers hardness value obtained was very low due to lack of fusion which is obtained good when the above process parameters values are changed such as welding current 240A , gas flow rate 12l/min and filler rod diameter 3.2 mm. Hardness value of weld zone altered with the distance from the weld centre due to change of microstructure. The basic reason for the improvement in Vickers Hardness and microhardness properties is the refinement produced in fusion zone grain size by pulsed current welding.

Surendhiran. S et. al [9] TIG welding of sheets having dimensions 250x150x2.4 mm is carried out using AA 5456. The micro hardness was measured at an interval of 0.5 mm across the weld, 1mm across the HAZ and 1.5 mm across the unaffected base metal. Fine equated grain structure is obtained with peak current of 80 A, base current 4 A, welding speed 230mm/minute and pulse frequency 2 Hz results in coarse grain structure. The benefit of this study is with the use of obtained optimum condition, the mechanical properties improve and the regression models so developed are helpful for the automation of process.

Yashwant Thakur et. al [10] He investigated the welding parameters for TIG welding of AA 7005, as it possess good welding characteristics and resistance to corrosion. He observed that the strength and profile of the welded joint is greatly influenced by the material and technique to be selected for welding. Experiment design is determined by Taguchi method. Study of microstructure at different zones of weldment gives a comparative outcome between TIG welding and base material to differentiate the effect of temperature distribution.

Ahmed Khalid Hussain et. al [13] Aluminium alloy AA6361 is used to prepare the test specimen. Universal Testing Machine is used to test the strength of the welded joint. The dimension of the base metal used are 4x50x200 mm. The filler metal used was AA6063. Shielding gas contains 18% CO_2 and 82% argon. The design of weld joint, bevel angle and bevel height influence the tensile testing of weld. No remarkable change is there in tensile strength of weldment at welding speed of 0.3 cm/s. However there is unanticipated decrease in strength, when welding speed is 1.2 cm/s due to lack of weld bead penetration on to the root gap of weldment. Linear correlation is observed between bevel height and welding speed.

Shailesh Kumar [14] Specimen with size 100x20x3 mm is used for welding of Al 5083 series plate. Process parameters used are welding current of 118-134A, gas flow rate 6-7 l/min and welding speed of 90-105 mm/min. As per ASTM standard, welded specimen is cut by wire EDM and tensile

ISSN: 2349-7947
13 – 18

strength is tested on UTM machine. The maximum tensile strength is obtained at welding current of 134A, gas flow rate of 7l/min and corresponding welding speed is 100 mm/min. Microstructural analysis of weld pool shows refinement in grain structure. Since, the pulses in welding tends to rapid solidification in the weld pool and welding joints are fused well and structure is tight. So the highest tensile strength of 127 MPa is achieved.

Song et. al [15] AISI 321 stainless steel plate of thickness 3mm is joined with 5A06 Aluminium alloy by TIG welding-brazing with different filler materials. The experiment is carried out by AC-TIG welding source with arc length of 3-4 mm, welding speed 120mm/min and argon gas flow 8-10l/min. Due to heat addition Inter Metallic Layer will not be formed and thus thickness is reduced. Microstructural analysis and the spreading behaviour of filler metal on the groove surface for butt joint was studied. For the plate of 2 mm thickness welding speed is 100-220mm/min and current ranges from 90-270A.

K Srinivas et al. [17], have carried out TIG welding for AA 6063.The Dimensions of plate are (150x60x6) mm3. By varying weld current and maintaining all parameters constant hardness, impact and tensile strength was found. The Process Parameters are Weld current, Argon Shielding Gas. Two plates of same dimensions are joined as a square butt joint giving the resultant dimensions of (150x100x6) mm3. Welding is done in forward direction using pulsed A.C current. The increase of welding current will increase the welding heat input in AA 6063. Accordingly, the chance of defect formation such burns in Welded metal also increases. It effects on the mechanical properties and the quality of welded metal badly.

V. PROBLEM IDENTIFICATION

- Aluminium forms an oxide layer over it which is very hard and needs to be removed otherwise it will not allow proper fusion to take place. So welding should be done with reverse polarity or AC so that current flow strips off the oxide as it forms.
- Due to high thermal conductivity of aluminium it needs more current at the start of welding than at the end. Since welds are susceptible to cold start at the beginning and high penetration at the end.
- Welds of aluminium are susceptible to cracking, improper penetration and sudden cooling.
- Filler alloys are not flowing well and care is needed to create a consistent bead.
- Grinding of aluminium is difficult since it clogs the abrasives and milling cutters.

VI. EXPERIMENTAL WORK AND METHODOLOGY

Figure 3: Automated TIG welding setup

The main components of a TIG welding setup are

i. Power Source- The power source in TIG welding can be DC or AC, since in both the cases the output obtained is of constant current characteristic. In TIG welding arc length varies linearly with the arc voltage and variation of 3-4 mm in arc length can vary the voltage upto 5V. DC power source is generally used for welding since it produces concentrated arc but with metals like aluminium AC power supply is used because it forms an oxide film over its surface. So, by changing the polarity from positive to negative the cleaning and the welding actions are performed alternately.

ii. Speed Control Unit- A speed control unit is there which runs with the prior decided speed. Welding torch is also fixed with it with the help of a clamp in a particular angle so as to produce a stable arc during welding. Regulator is there to change the welding speed. An adjustable knob is there to maintain a constant distance between torch and the workpiece.

iii. Welding Torch- It is connected with the speed control unit and the tungsten electrode is attached to it and argon gas flows with this torch.

iv. Gas Shielding- A gas lens is attached to the nozzle of the welding torch so that the flow of gas is laminar. The selection of the gas nozzle depends on the electrode diameter.

v. Gas Cylinder- A gas cylinder filled with the argon gas is there which is supplied with welding torch at a fixed flow rate so as to form inert atmosphere and stable arc. A regulator and a valve is there to control the gas flow rate.

vi. Work Holding Table- A plate made of cast iron is used for holding the workpiece so as to maintain proper gap between the tungsten electrode and the workpiece.

CALIBRATION OF SPEED

To get the required welding speed, speed of the control unit is calibrated before the start of experiment.

 ISSN: 2349-7947
13 – 18

EQUIPMENT NUMBER	SPEED VALUE (MM/S)
1	2
1.5	3
2	4
2.5	5
3	6
3.5	7
4	8

Table 1: value of speed on speed control unit

VII. RESULT

Average value of welding width is calculated by measuring the welding width of all the samples and is shown in table 2. For different welding speeds, a graph is plotted between average welding width and the applied welding current. which shows that welding width increases in linear proportion with welding current? Figure 5 shows the welded butt joint specimen where welding is performed with varying welding speed and current.

Figure: 4 a) Welded specimen performed with welding speed 3mm/s and welding current 100, 105, 110, 120 and 130A for sample number 1 to 5.

b) welded specimen performed with welding speed 4mm/s and welding current 100, 105, 110, 120 and 130A for sample number 6-10 respectively.

Sample no	Reading 1 (mm)	Reading 2 (mm)	Reading 3 (mm)	Avg. width (mm)
1	5.53	4.67	4.31	4.83
2	7.38	6.78	7.45	7.20
3	8.83	7.67	7.37	7.95
4	7.36	7.75	7.85	7.65
5	10.87	10.59	10.09	10.51
6	5.12	5.08	4.88	5.026
7	5.67	5.76	5.88	5.77
8	8.43	8.17	7.79	8.13
9	9.38	8.03	8.78	8.73
10	9.19	10.09	8.52	9.26

Table 2- Weld Width

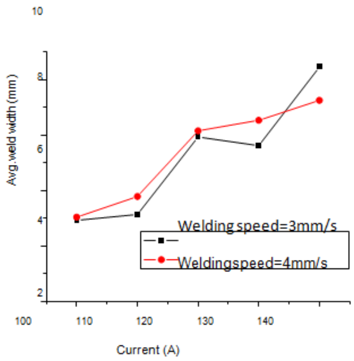

Figure 5 specimens welding width with varying welding speed and current

Average surface roughness value for all the samples of weld zone was measured from the readings in Table 3. Roughness value ranges from 1 to 6 micron approximately which is somewhat low for a welded specimen. Thus we conclude that by using automated system finishing operation is not required further on. The roughness values so obtained are plotted against the applied current. But the current does not have any effect on the surface roughness..

Sample No	Reading1 (µm)	Reading2 (µm)	Reading3 (µm)	Avg. Value (µm)
1	3.442	3.385	3.034	3.287
2	1.896	1.157	1.123	1.392
3	1.768	1.299	1.476	1.514
4	0.865	1.297	1.379	1.180
5	2.835	2.896	1.233	2.321
6	1.876	4.654	3.312	3.280
7	2.398	2.145	2.234	2.259
8	3.567	3.498	3.612	3.559
9	3.229	3.411	4.121	3.587
10	1.345	1.178	1.276	1.266

Table 3: Surface roughness value for different welded samples

MICRO HARDNESS TEST

To understand the change in mechanical property of the welded zone micro hardness value of all the welded specimens at the cross section is measured.

TENSILE TEST

Universal tensile testing machine is used to perform the tensile test of welded joint having maximum load capacity of 600kN. Load is applied with the speed of 1mm/min.

At different welding speed and current setting, tensile strength values of all the welded joints is obtained which is shown in table 6. These values so obtained are much lesser than the values of pure aluminium. The tensile strength of the aluminium is found to be 132 Mpa. For welding speed of 3mm/s, tensile strength of welded joints are plotted against applied current as shown in figure 10. Thus, it can be concluded that tensile strength value is increasing in direct proportion with the increasing current setting except when welding current ranges from 120 to 130 A.

Sample no	Load at tensile strength (N)	Actual tensile strength (MPa)
1	1718.31465	23.94286
2	1963.50763	25.19435
3	2877.47628	37.37904
4	2312.59820	31.81012
5	2927.53077	38.03435
6	1311.63805	18.41884
7	1285.71786	16.13438
8	3307.39748	45.06890
9	2258.41971	31.12126
10	1386.85181	19.42809

Table 4: Tensile strength value for all the welded joints produced at different welding speed and current setting

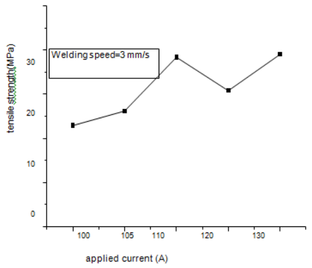

Fig. 6: Tensile strength of the welded joint against applied current for welding speed of 3 mm/s.

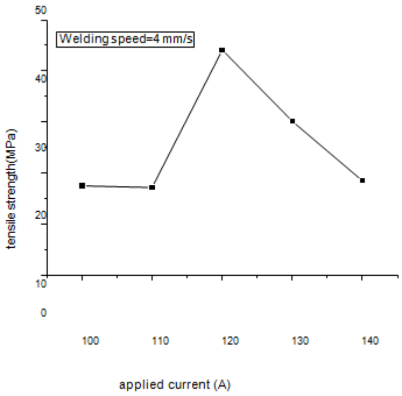

Fig. 7: Tensile strength of the welded joint against applied current for welding speed of 4 mm/s.

Optical Image at The Cross Section For Both Sided Weld Joints

By using optical microscope, optical images at the cross section of weld is taken after proper polishing. Figure 13 shows the optical photograph at the cross section of welded samples. From these images we can conclude that when welding is done on both sides of welded joints, it takes place throughout the thickness of the Aluminium plate.

Fig. 8: Optical microscopy image of the welded zone at the cross section of both sided TIG welded Aluminium samples with current setting of 140 A and welding speed(a) 3 mm/s (b) 3.5 mm/s (c) 4 mm/s (d) 4.5 mm/s

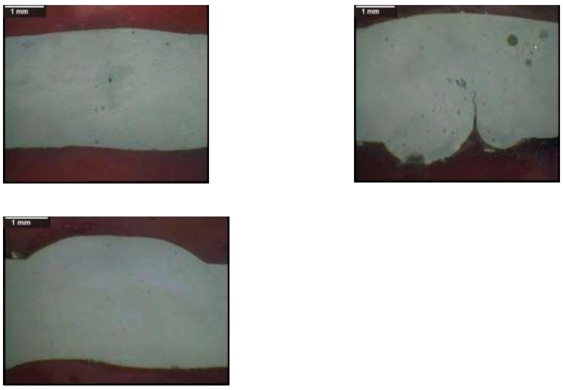

Fig. 9: Optical microscopy image of the welded zone at the cross section of both sided TIG welded Aluminium samples with current setting of 170 A and welding speed(a)5 mm/s (b)5.5 mm/s (c) 6 mm/s (d) 6.5 mm/s

Sample No	Load at tensile strength(N)	Tensile strength (MPa) UTS
1	6712.37688	112.8559
2	5537.16367	91.3029
3	4836.28344	81.58724
4	4516.36769	74.28996
5	5963.54783	98.37641
6	5751.49897	96.87498
7	6290.76234	105.8289
8	5994.42478	100.90709

Table 5: Maximum load at tensile strength and tensile strength value of different welded samples (both side welding)

 ISSN: 2349-7947
13 – 18

For welding current of 150 A, tensile strength of welded specimen are plotted against welding speed which is shown in figure 10. The figure also shows that tensile strength of the welded joint decreases approximately from 110 to 75 Mpa when welding speed increases from 3.5 to 5 mm/s. When welding current is 180 A, the tensile strength value ofof the welded joint is in the range of 95 to 105 Mpa and there is no variation in tensile strength values when welding speed is changed.

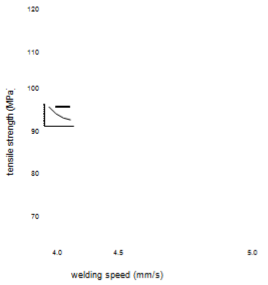

Fig. 10: Tensile strength of welded joint against different welding speed for applied current

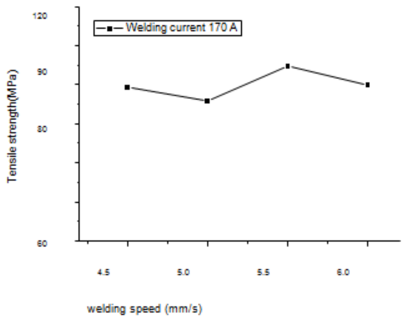

Figure 11: Tensile strength of welded joint against different welding speed for applied current of 170 A

VIII. CONCLUSION

The following conclusions are made with the TIG welding of aluminium.

- It is possible to uniformly weld aluminium with the automated TIG welding.
- Welding speed and welding current affect the parameters such as welding and the tensile strength.
- Strength of welded joint increases in linear proportion to increase in welding current.
- Due to change in microstructure, hardness value changes as the distance from weld centre change.
- For both side welding Tensile strength is almost equal to strength of base material.
- For both sides of welding, welding speed does not have any notable effect on tensile strength of the weld joint.

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