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Optimization of Process Parameters Affecting gas Tungsten Arc Welding of AA6082

Y.Mahesh, K.V.N.V.N Rao

Abstract—**In this competitive manufacturing technology, the versatility of aluminum and its alloys makes it the most widely used metal after steel. In any structural application of aluminum alloys consideration of its Weldability is of utmost importance as welding is largely used for joining of structural components. Gas tungsten arc welding (GTAW) is most commonly used welding process for joining aluminum alloys that has produced low cost and high quality joints. The welding of aluminum and its alloys has always represented a great challenge for researchers and technologists. In this paper some important GTAW process parameters and their effects on weld quality are discussed. Taguchi method was employed to optimize the GTAW process parameters.**

Keywords— GTAW System, AA6082 plate,orthogonal array Taguchi method, Tensile test,Hardness test.

I. INTRODUCTION

In order to face the demands of today's competition, in any field a growing interest is seen for materials that combine high mechanical properties with the possibility of a quicker and easier machining (Klocke, 1998). The production of aluminium alloys represents a significant proportion in worldwide light metal manufacturing. They have low density (2.7 gcm-3) which is advantageous in many applications due to a high stiffness to weight ratio. As a result, aluminium is used in a variety of industries from food packaging to car manufacture. It is the most common metal and the third most abundant element on earth, comprising more than 8 percent of the earth's crust. Aluminium alloys offer many machining advantages such as excellent machinability and finish degree with high cutting speed, low cutting forces, outstanding tool life (Kishawy et al., 2005; Schultz & Moriwaki, 1992). Elevated thermal exchange and weight reduction, which means easier handling, compared to steels are additional characteristics that lead to increasing applications in the automotive and aerospace industry and in the field of mould production (Amorim & Weingarten, 2002; Ozcelik et al., 2010).

Aluminium alloys have been more and more extensively utilized in structural applications and transportation industry [1,2] for their light weight and attractive mechanical properties achieved by thermal treatments. The gap with steels is thus reduced or even reversed in terms of specific properties (Amorim & Weingarten, 2002; Starke & Staley, 1996).Wrought heat-treatable alloys develop high specific strength thanks to age-hardening and have been widely used for airframes. In the utilization of these alloys, one of the difficulties to overcome is the general reduction of mechanical properties of welded joints as compared to the parent material.

Gas tungsten arc welding (GTAW) is an important joining technique for high strength aluminium alloys with their increasing applications in aerospace, aircraft, automotive, aviation space shuttle, rocket propulsion for missiles automotive industries, marine engine components. A literature review has been done to study important GTAW processing parameters and their effects on weld quality.

1.1Gas Tungsten Arc welding (GTAW):

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non- consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenously welds, do not require it.

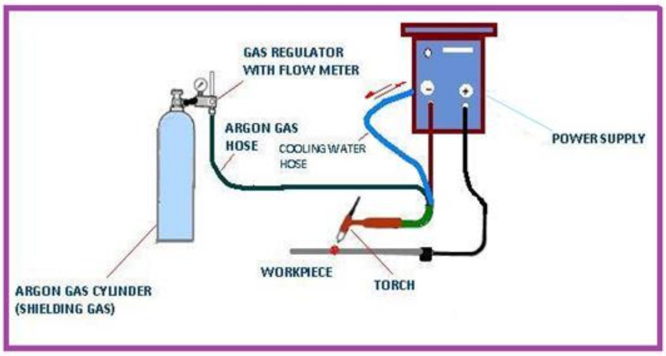

Fig 1: Set up of GTAW

II. LITERATURE SURVEY

In GTAW one of the most important aspects is the welding parameters used. A weld program consists of a list of welding parameters developed to achieve a specific weld quality and production output. A change in any parameter will have an effect on the final weld quality, so the welding variables normally are written down or stored in the welding equipment memory [5]. For welding in many precision or high-purity applications, a specification may already be written that outlines the recommended welding parameters, including the base material; part diameter(s); weld joint and part fit-up requirements; shield gas type and purity; arc length; and tungsten electrode material, tip geometry, and surface condition [4]. Welders should always follow an equipment supplier's suggested procedures first because the suppliers usually have performed a significant amount of qualifying and troubleshooting work [4]. The following are the different weld parameter that mainly determines quality of the weld.

a. Welding gun speed
b.Current.
c.Gas flow rate
d .Filler rod diameter

A. Welding gun speed

The effect of increasing the welding speed for the same current and voltage is to reduce the heat input. The welding speed does not influence the electromagnetic force and the arc pressure because they are dependent on the current. The weld speed increase produces a decrease in the weld cross section area, and consequently penetration depth (D) and weld width

(W) also decrease, but the D/W ratio has a weak dependence on travel speed. These results suggest that the travel speed does not influence the mechanisms involved in the weld pool formation, it only influences the volume of melted material. Normal welding speeds are from 100 to 500 mm/min depending on current, material type and plate thickness [5].

In TIG welding of aluminum alloy AA6082, the depth of penetration of weld bead decreases with increase in bevel height of V butt joint. Maximum Tensile strength of 230 Mpas was observed at weld speed of 0.6 cm/sec and tensile strength is higher with lower weld speed. This indicates that lower range of weld speed is suitable for achieving maximum tensile strength. Bevel angle of the weld joint has profound effect on the tensile strength of weldment. Bevel angles between 30^0 to 45^0 are suitable for maximum strength. The heat affected zone, strength increased with decreasing heat input rate [6]

B. Current

Current has direct influence on weld bead shape, welding speed and quality of the weld. Most GTAW welds employ direct current on electrode negative (DCEN) (straight polarity) because it produces higher weld penetration depth and higher travel speed than on electrode positive (DCEP) (reverse polarity).Besides, reverse polarity produces rapid heating and degradation of the electrode tip, because anode is more heated than cathode in gas tungsten electric arc [5]. Reverse polarity may be of interest in welding aluminum alloys because of the cathodic cleaning action of negative pole in the work-piece, that is the removal of the refractory aluminum oxide layer. However alternating current is better adapted to welding of aluminum and magnesium alloys, because it allows balancing electrode heating and work-piece cleaning effects.

C. Gas flow rate

Flow rates of shield in gases depend on weld thickness, being 4-10 l/min for argon and 10-15 l/min for helium, because it is lighter than argon, and consequently less effective in shielding. Gases with a purity of 99.995% are used in welding most of the metals, though reactive materials such as titanium need contaminant level less than 50ppm [6]. The gas flow must not be too high in order to allow a good shielding effect both on the weld pool and on the solidifying material. This result is also very important in terms of manufacturing costs: a low gas flow rate helps minimizing the expenses for helium which is probably the most expensive among inert gases. The inclination of the gas flow into the chamber should be perfectly horizontal or equal to at least 300 in order to guarantee good shielding results.

D.Filler rod diameter

Filler rod diameter is also having influence on mechanical properties of welding. It influences the welding speed and improves process tolerance.

III. METHODOLOGY

A.MATERIALS

Aluminum alloy AA-6082 (Composition shown in Table 1) plates of the dimension 150*60*6 mm were taken for TIG welding technique. These plates are cleaned from dirt, grease and other foreign materials by using cleansing agents, dirt remover's another re-agents. Edge preparation is carried out where single V edge is prepared for an angle of 60^0. The Aluminium plates are placed on welding table where the welding process is carried out. The filler metal selected for the process is er4043which is the standard filler rod to be used for AA-6082 alloy (According to AWS Standards).The inert gas used in this investigation is 99.9% pure argon keeping the flow rate constant.

Table 1 Chemical Composition of AA6082 & filler material

Alloy	**Al**	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Zn**
6082min	Rem	0.7	-	-	0.4	0.6	-	-
6082max	Rem	1.3	0.5	0.2	0.1	1.2	0.25	0.2
FR4043	Rem	6.0	0.8	0.30	0.05	0.05	-	0.10

In this process, all the various welding parameters such as the current, welding speed, filler rod diameter flow rate, inert gas used and the number of passes is kept constant for all the trails and study the effect of all parameters on the structural and mechanical properties of weldment. In this study, TIG welding technique was adopted with three different levels to parameters current, filler rod diameter and Gas flow rate and two levels adopted for welding gun speed. Then, the welded specimens are now tested for, mechanical strength on UTM machine and Hardness (Brinells) on hardness testing machine. The tests were conducted according to Indian standards 1501 - 2002. AA-6082 plates were subjected to tensile test followingASTM E-08 standards.

B. EXPERIMENTAL PROCEDURE

For the research purpose on aluminum alloy material GTAW welding was chosen to weld the material which is wrought and heat treatable alloy. We fabricate 36 pieces into a dimension of 150x70x6mm by hydraulic cutting machine. We fabricate 18 pieces into a dimension of 75x70x6mm by hydraulic cutting machine from 36 pieces. As the thickness of the plates is 6.0mm a V groove butt joint of 60^o groove angle was desired. Edge preparation is done as per the dimensions. Then we have made all the work pieces in to flat plate standard form with angle of 60^0. Then we had took two pieces and set it with 1.5mm root gap pieces and then we had started penetration process with desired or selected welding gun speed, current, filler rod diameter and Gas flow rate readings and done the experiment. Plate standard form with angle of 60^0. In this present study, in order to indentify the influence of process parameters with maximum distribution in the GTAW for aluminum alloy 6082 Taguchi method and Grey relational analysis along with S/N ratio and their levels are given in table2.Orthogonal arrays are helpful in arranging the control parameters.L18 orthogonal array is used for arrange the these parameters as shown in table3.

Table 2: Levels of GTAW process parameters.

variables	unit	Level-1	Level-2	Level-3
A. welding gun speed	mm/min	24	28	----
B.current	Amp	190	210	230
C.Filler rod diameter	mm	2.4	3.2	4.8
D.Gas flow rate	Lit/min	15	18	21

Table 3: Experimental layout using L18orthogonal array

Sample	Weld gun speed (mm/min)	Current (Amp)	Filler rod diameter (mm)	Gas flow rate (lit/min)
1.	24	190	2.4	15
2.	24	190	3.0	18
3.	24	190	4.8	21
4.	24	210	2.4	15
5.	24	210	3.0	18

6.	24	210	4.8	21
7.	24	230	2.4	18
8.	24	230	3.0	21
9.	24	230	4.8	15
10.	28	190	2.4	21
11.	28	190	3.0	15
12.	28	190	4.8	18
13.	28	210	2.4	18
14.	28	210	3.0	21
15.	28	210	4.8	15
16.	28	230	2.4	21
17.	28	230	3.0	15
18.	28	230	4.8	18

The specimens after GTA Welding by using the control parameters with L18 orthogonal array is shown in fig1.

Fig 2: Test specimens after welding

IV. TESING

A. *Tensile test*

The UTM machine used for tensile testing having a capacity of 10 metric tons which has been changed up to 40 tons. The machine is a hydraulic powered and water cooled. Hydraulic wedge grippers are used for the tensile tests. The UTM machine has a data acquisition system attached to it which helps record and save the data obtained during the testing process. The obtained test results are shown in table4.

B. *Hardness test*

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. The welded specimens are tested on hardness testing and the Rockwell's hardness values for each level are obtained and are tabulated in table 4.

Sample	Yield strength (MPas)	Tensile strength (MPas)	Hardness
1.	98.47	110.13	45
2.	100.58	108.83	42
3.	102.71	127.95	51
4.	111.82	123.78	50
5.	118.87	123.67	48
6.	102.75	127.96	52
7.	129.93	150.66	59
8.	156.27	158.56	62
9.	142.66	158.49	68
10.	155.08	170.55	67
11.	122.28	147.98	56
12.	136.83	151.48	61
13.	125.04	140.10	53
14.	132.34	146.15	57
15.	101.96	121.26	47
16.	105.59	118.48	46
17.	124.18	146.05	61
18.	119.69	141.26	54

IV. RESULTS & EXPERIMENTAL ANALYSIS

A. T*aguchi method*

The Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with only a small number of experiments. The greatest advantage of this method is the saving of effort in conducting experiments; saving experimental time, reducing the cost, and discovering significant factors quickly. Taguchi's robust design method is a powerful tool for the design of a high-quality system. In addition to the S/N ratio, a statistical analysis of variance (ANOVA) can be employed to indicate the impact of process parameters on mechanical properties.

a) S/N ratio

Taguchi method stresses the importance of studying the response variation using the signal – to – noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The Tensile strength, yield strength and hardness were considered as the quality characteristic with the concept of "the larger-the-better". The S/N ratio used for this type response is given by [1] and the results are shown in the table5,6&7.

The S/N ratio for the larger-the-better is:

S/N = -10*log (mean square deviation) …..(1)

Table 5: S/N ratio values for Tensile strength by factor level

level	Weld gun speed	current	Filler rod diameter	Gas flow rate
Level-1	381.09	255.33	255.26	255.04
Level-2	387.28*	253.72	256.55	257.81
Level-3	----	259.32*	256.56*	257.86*
Delta	6.19	5.6	1.3	2.77
Rank	1	2	4	3

* Optimum level

Table 6: S/N ratio values for Yield strength by factor level

level	Weld gun speed	current	Filler rod diameter	Gas flow rate
Level-1	372.10	248.43	249.33	247.72
Level-2	376.75*	245.77	248.0	250.04
Level-3	---	253.15*	251.49*	251.06*
Delta	4.65	7.38	3.49	3.34
Rank	2	1	3	4

Table 7: S/N ratio values for Hardness by factor level

level	Weld gun speed	current	Filler rod diameter	Gas flow rate
Level-1	309.42	206.85	206.70	206.97
Level-2	313.83*	204.95	208.47	206.31
Level-3	---	211.46*	208.90*	209.98*
Delta	4.41	6.51	1.77	3.67
Rank	2	1	4	3

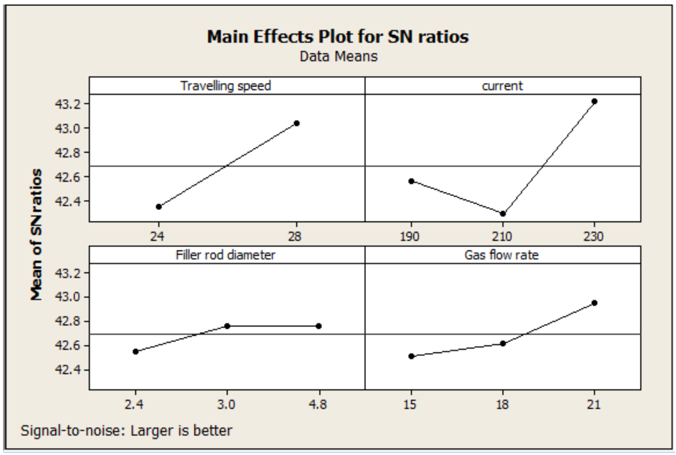

Fig 3: Main effects of plot for S/N ratio for Tensile strength

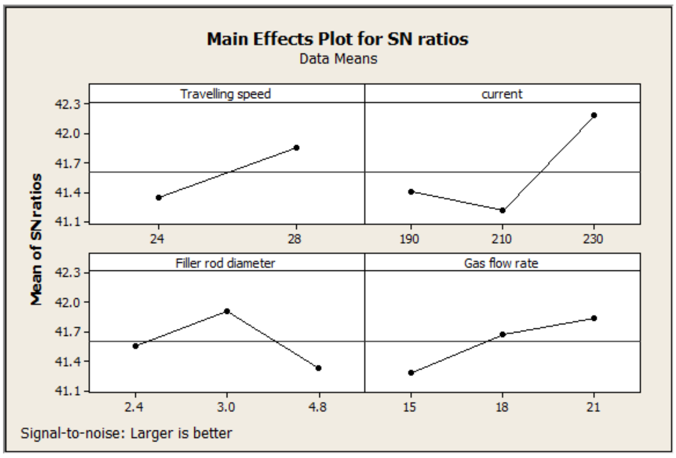

Fig 4: Main effects of plot for S/N ratio for Yield strength

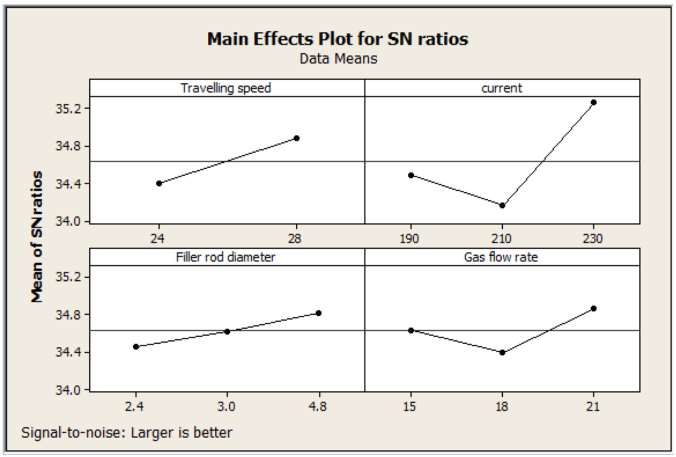

Fig 5: Main effects of plot for S/N ratio for Hardness

b) ANOVA

Analysis of Variance (ANOVA) is a hypothesis-testing technique used to test the equality of two or more population (or treatment) means by examining the variances of samples.ANOVA allows one to determine whether the differences between the samples are simply due to random error (sampling errors) or whether there are systematic treatment effects that causes the mean in one group to differ from the mean in another. Most of the time ANOVA is used to compare the equality of three or more means, however when the means from two samples are compared using ANOVA it is equivalent to using a t-test to compare the means of independent samples. ANOVA is based on comparing the variance between the data samples to variation within each particular sample.

c) Confirmation test

The experimental confirmation test is the final step in verifying the results drawn based on Taguchi's design approach. The optimal conditions are set for the significant factors (the insignificant factors are set at economic levels) and a selected number of experiments are run under specified cutting conditions. The average of the results from the confirmation experiment is compared with the predicted average based on the parameters and levels tested. The confirmation experiment is a crucial step and is highly recommended by Taguchi to verify the experimental results. In this study, a confirmation experiment was conducted by utilizing the levels of the optimal process parameters, (A2B3C2D2) for Tensile strength was obtained as 170.55Mpas,(A2B3C2D3) for yield strength was obtained as 155.08Mpas and for Hardness was obtained as (A2B3C2D3) as 68.

V. CONCLUSION

This study has discussed an application of the Taguchi method for investigating the effects of process parameters on mechanical properties such as tensile strength, yield strength and Hardness on GTAW AA6082. From the analysis of the results in the GTAW process using the conceptual signal-to-noise (S/N) ratio approach, analysis of variance (ANOVA), and Taguchi's optimization method, the following can be concluded from the present study:

- Statistically designed experiments based on Taguchi methods were performed using L18 orthogonal arrays to analyze mechanical properties as response variable. Conceptual S/N ratio and ANOVA approaches for data analysis drew similar conclusions.
- The optimum level of process parameters for Tensile strength was obtained as A2B3C3D3.
- The optimum levels of process parameters for Yield strength was obtained as A2B3C2D3.
- The optimum level of process parameters for Hardness was obtained as A2B3C3D3.
- The optimum Tensile strength by taguchi method was obtained as 170.55 Mpas
- The optimum Yield strength by taguchi method was obtained as 155.08Mpas
- The optimum Hardness by taguchi method was obtained as 68

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Y.mahesh (M.tech), Department of Mechanical Engineering, PBR VITS, Kavali, India

K.v.n.v.n Rao (P.hd), Department of Mechanical Engineering, PBR VITS, Kavali, India