EFFECT OF WELDING PARAMETERS ON BEAD GEOMETRY IN A-TIG WELDING PROCESS ON AZ-91 Mg ALLOY

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Abstract: In present work, an effort has been made to investigate the effect of welding parameters on bead geometry performance of AZ-91 magnesium alloy using A-TIG welding process. Mathematical models have been developed by using 2-level half factorial technique to predict the bead geometry within the range of control parameters or operating variables for activated tungsten inert gas welding process. The models developed can be employed easily in automatic or robotic welding, in the form of program, for obtaining the desired high quality welds. Welding current, active flux, welding speed and gas flow rate are taken as welding variables by keeping all the other variables constant to evaluate the bead geometry. It has been found that penetration increases significantly with $CdCl_2$ as compared to TiO_2 flux and welding current also have positive effect on penetration but penetration decreases with increase in welding speed and have negligible effect by shielding gas flow rate. The models have been developed from the observed values, with the help of design matrix. The adequacies of models have been tested by use of analysis of variance technique and significance of coefficients was tested by students 't'-test'. The combined and main effect of different parameters involved has been presented in graphical form.

***IndexTerms* - Mg AZ 91, Bead geometry, half factorial technique, Activated TIG Welding.**

I. INTRODUCTION

Magnesium is the lightest of all metals used as the basis for constructional alloys. This property which entices automobile manufacturers to replace denser materials, not only steels, cast irons and copper base alloys but even aluminum alloys by magnesium based alloys. The requirement to reduce the weight of car components as a result in part of the introduction of legislation limiting emission has triggered renewed interest in magnesium. The growth rate over the next 10 years has been forecast to be 7% per annum [1]. Among metals in use, magnesium is the lightest, with a specific gravity lower than quarter of iron and about the same as two third of aluminum.

In addition to its light weight properties, magnesium features outstanding strength and rigidity per weight in comparison to iron and aluminum, thereby contributing to creating strong and light products. Furthermore, it is an environmentally-friendly metal because of the high energy efficiency and recyclable properties, and is also abundant in nature .AZ-91 alloy is a magnesium alloy to which some 9% of aluminum and 1% of zinc are added in order to improve its corrosion resistance [2].

In the present work, an attempt is made to weld the thicker materials using TIG welding, TIG is also known as gas tungsten arc welding (GTAW), which uses a non-consumable electrodes with inert gas shielded weld pool made by arc on the work pieces to be joined. TIG welding is very widely used because it produces a superior quality and defect free joints and during welding. As discussed above, weld pool is completely shielded by an inert gas. So it has wide range of applications in industrial uses because it gives the best quality welds amongst the arc welding processes. It is used in aerospace, shipbuilding, nuclear plants etc.

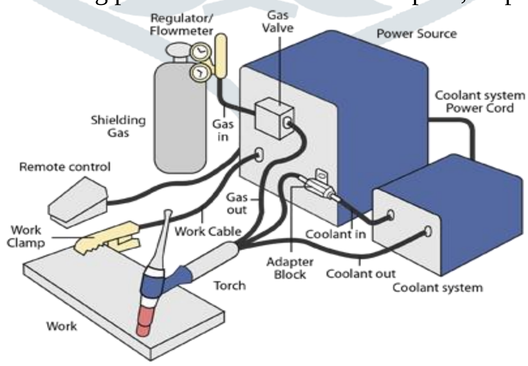


Fig.1.1: Schematic of TIG welding [4]

The limitation of TIG welding process is its low productivity due to less deposition rate and less penetration in thicker materials. This limitation of TIG welding process can be overcomes by using a variant of TIG welding process, i.e. Activated TIG welding process. In this process a very fine layer of active flux is laid on the surface of work piece prior to welding. A layer of active flux may be coated on the surface with the help of brush. Activated flux which gets vaporized during welding will constrict the arc by capturing electrons in the outer regions of the arc. Electron attachment can take place in the cooler peripheral regions where the electrons have low energy in a weak electric field. Towards the center of the arc where there is a strong electric field, high temperatures and very high energy electrons and ionization will dominate. Thus restricting current flow to the central region of the arc will increase the current density in the plasma and at the anode resulting in a narrower arc and a deeper weld pool. This process found very large changes in penetration and improves the strength of joint also. With the use of these active fluxes, chemical composition of base metal remains unaffected but the joint strength and properties get improved [3].

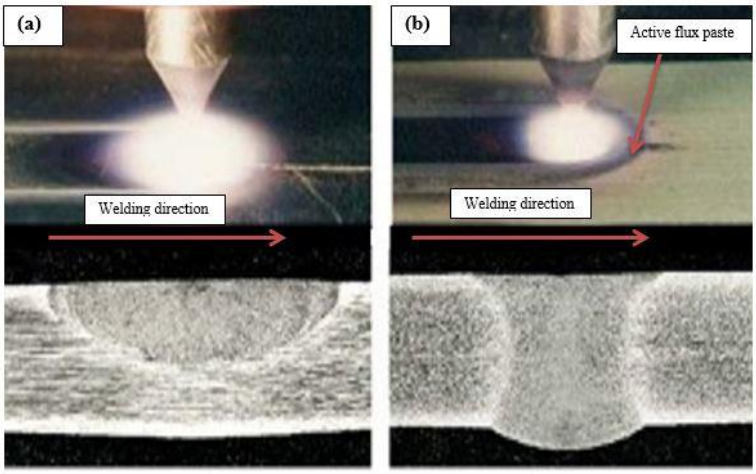


Fig. 1.2: (a) Conventional TIG welding and its bead geometry, (b) activated TIG welding and its bead geometry [5]

II. MATERIAL& METHOD

Among metals in use, magnesium is the lightest, with a specific gravity lower than quarter of iron and about two third of aluminum. In addition to its light weight properties, magnesium features outstanding strength and rigidity per weight in comparison to iron and aluminum, thereby contributing to creating strong and light products. Furthermore, it is an environmentally-friendly metal because of the high energy efficiency and recyclable properties, and is also abundant in nature [2]. In its pure form magnesium is very soft and it does not have good weldability. But in its alloy forms it exhibit satisfactory mechanical and metallurgical properties. For example AZ-31 B, AZ-61 A, AZ-63 A, AZ-80 A, AZ-81 A, AZ-91 and AZ-92 A are some alloys of magnesium.

AZ-91 alloy is a magnesium alloy to which some 9% of aluminum and 1% of zinc are added in order to improve its corrosion resistance. It also contains small amounts of aluminum, manganese, zinc, zirconium, etc., have strength equaling that of mild steels. They can be rolled into plate, shapes, and strip. Magnesium can be cast, forged, fabricated, and machined [3]. The chemical properties of AZ-91 alloy are represented in Table 2.1.

Table-2.1: Chemical composition of Mg alloy (AZ-91)

Mg alloy	**Composition (wt. %)**							
	Mg	**Al**	**Zn**	**Si**	**Mn**	**Cu**	**Fe**	**Be**
AZ-91	90.8	8.25	0.63	0.035	0.22	0.003	0.014	0.002

Magnesium (AZ-91) is a very soft metal Due to specific physical properties of magnesium; its welding requires low and well controlled power input. Moreover, very high affinity of magnesium alloys to oxygen requires shielding gases which protect the liquid weld from an environment. To magnify complexity, also solid state reaction with oxygen, which forms a thermodynamically stable natural active layer on magnesium surface, is an inherent deficiency of joining. [2]

Bead on plate technique was applied as per design on to three sets of plates. To meet the objectives set forth as mentioned previously, the experiment was planned in two phases. In the first phase, trails runs were made to set a perfect combination of welding current (I), active flux (F), welding speed (S) and shielding gas flow rate (G) with both active fluxes so as to avoid various welding defects like cracking, burn through etc.

In the second phase, weld beads were laid on all plates using pre-set parametric values those were set in the previous phase. Then specimens for testing were taken from these three sets of welded plates for real time assessment of the bead characteristics of magnesium alloy AZ-91.

Eight base plates marked as 1 to 8 was taken for laying weld beads using 2 levels half factorial design with four parameters as given in Table 2.2.

Table-2.2: Welding parameters used and their limits

Sr. No.	**Parameter**	**Unit**	**Symbol**	**Designation**	**Limits**	
					Low (-1)	**High (+1)**
1.	Welding Current	A	I	X_1	100	120
2.	Active Flux	-----	F	X_2	TiO_2	$CdCl_2$
3.	Welding speed	mm/sec	S	X_3	4	7
4.	Gas flow rate	l/min	G	X_4	10	15

Fig. 2.1: Magnesium alloy AZ-91 plates taken for the experimentation

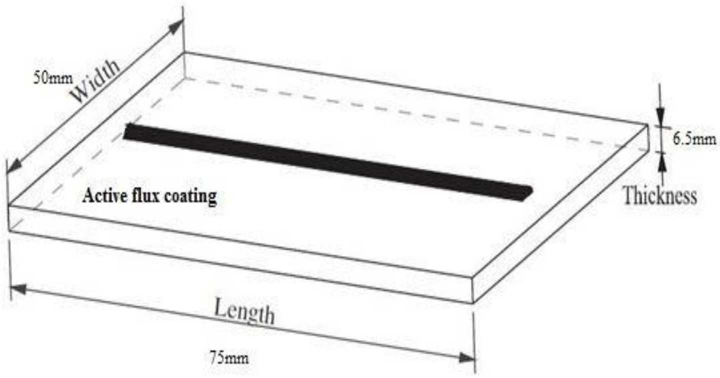


Fig.2.2: Procedure used for laying bead on plate using active fluxes

In view of the experimental study, for bead geometry examination of these deposits, one specimen each was sampled out from each weld plate. One sectioned side was grinded and polished before placing it against the bead geometry testing machine.

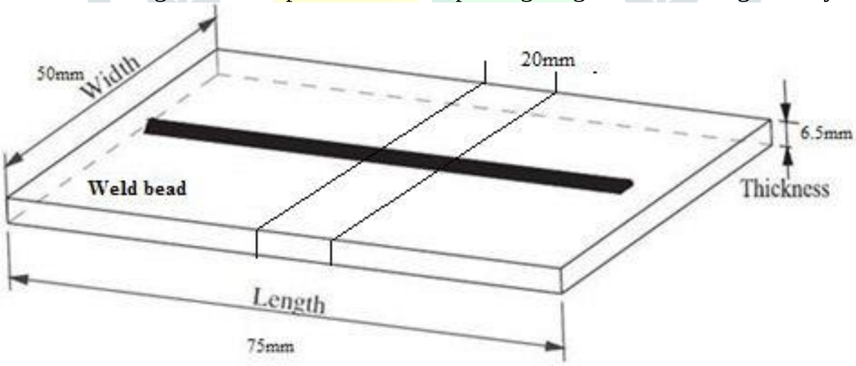


Fig. 2.3: Pattern used to take specimens from welded plates

To reveal bead geometry of these different polished plates, etching was used. Method used for conducting these operations is briefly discussed in next paragraph.

Fig. 2.6: Specimens used to test bead geometry

Polishing was started with emery papers of grade P-100 to P-3000 to have a good look at the weld bead. After polishing was over the test pieces were etched with compound made by using combination of 25 ml H_2O, 75 ml ethylene glycol and 1 ml HNO_3.

III. RESULTS AND DISCUSSION

As described in the mathematical model the four weld beads were laid using one type of active flux. Two types of active fluxes ($CdCl_2$& TiO_2) were used in the experimentation and their images are represented in the Table 6.1 to Table 6.3. A comparison of width (w) and penetration (p) of the weld beads laid by using the active fluxes (CdCl2 & TiO2) and without flux individually using same parametric combinations was evaluated.

Table-3.1: Images of bead geometry profile with CdCl2 active flux

Parameter / Active Flux	I=120;S=7;G=15	I=100;S=7;G=10	I=120;S=4;G=10	I=100;S=4;G=15
$CdCl_2$				

Table-3.2: Images of bead geometry profile with TiO2 active flux

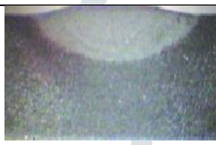
Parameter / Active Flux	I=100;S=4;G=10	I=120;S=4;G=15	I=100;S=7;G=15	I=120;S=7;G=10
TiO_2				

Table-3.3: Images of bead geometry profile with conventional TIG welding

Parameter / Active Flux	I=120;S=7;G=15	I=100;S=7;G=10	I=120;S=4;G=10	I=100;S=4;G=15
Without flux				

Measurements were taken with the help of a measuring scale for penetration and width of bead geometry from magnified bead profiles. Observed values have been presented in Table 3.4.

Table-3.4: Observed values for weld bead geometry response

S.No	P_1	P_2	P_{avg}	P_3	W_1	W_2	W_{avg}	W_3
1	4.20	3.90	4.05	3.69	12.75	13.00	12.87	10.54
2	4.52	4.32	4.42	3.85	14.50	14.15	14.32	11.64
3	6.24	6.04	6.14	5.75	11.79	12.10	11.94	13.48
4	6.15	6.45	6.30	6.11	10.90	10.98	10.94	12.36
5	3.41	3.21	3.31	4.02	13.97	14.29	14.13	11.68
6	4.14	4.02	4.08	4.31	12.83	12.69	12.76	10.45
7	5.76	5.86	5.81	6.01	10.02	9.96	9.99	13.41
8	5.95	6.15	6.05	6.39	11.01	10.46	10.73	14.44

The main effect plots means are shown in Figure 3.1. This plot shows the variation of penetration with change in four parameters; welding current, active flux, welding speed, gas flow rate. In the plot, the x-axis indicates the value of each process parameter (at two level of welding), y-axis the response value (penetration).

Horizontal line indicates the mean value of the response or penetration. The main effects plots are used to determine the optimal design conditions to obtain the optimal penetration. Main effects plots for penetration here are plotted between

- Penetration Vs. Welding current
- Penetration Vs. Active flux
- Penetration Vs. Welding speed
- Penetration Vs. Gas flow rate

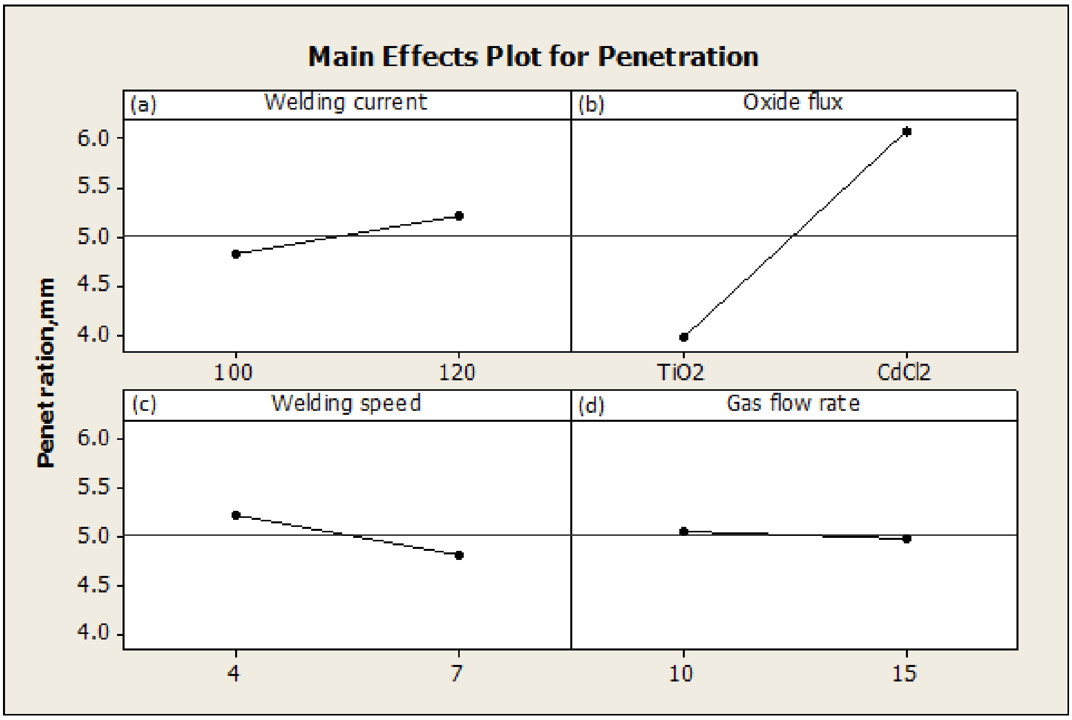


Fig. 3.1: Main effect plot for penetration

The effect of each parameter on the penetration is plotted on the graph in form of lines. From the Figure 3.1 main effects plot it can be clearly seen that the penetration is affected most by the variation in active flux. Penetration varies with variation in welding current, increase with low to high level and penetration decreases with increase in value of welding speed. Main effect plot of shielding gas flow rate and penetration indicate that penetration decreases slightly when the gas flow rate goes to high level.

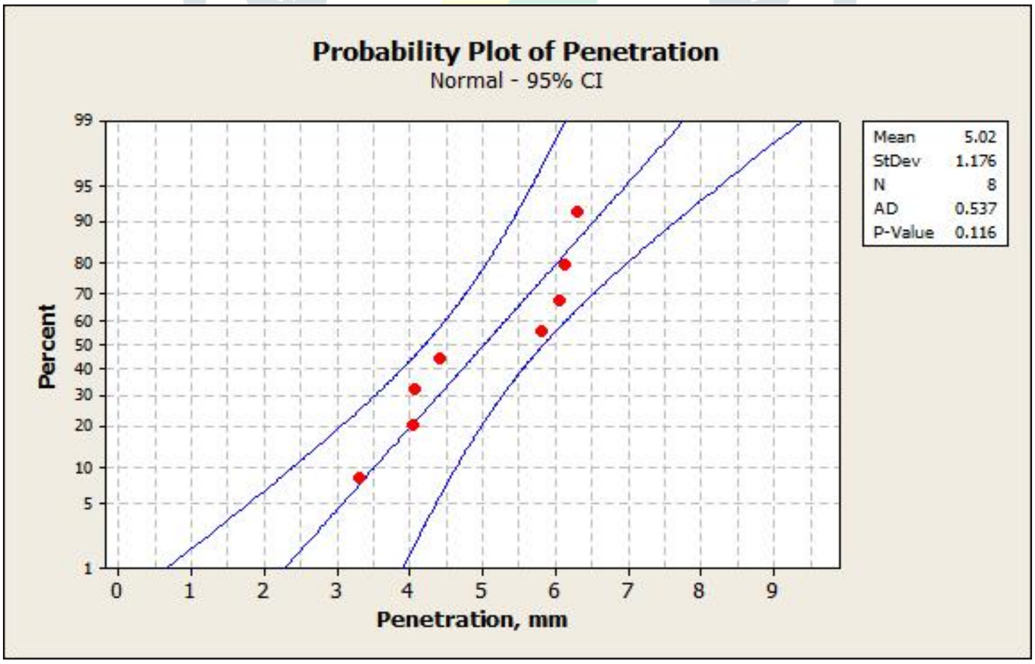


Fig. 3.2: Probability plot of penetration (mm)

The probability plot of penetration shows that the data is approximately adjacent to straight line having a good correlation between experimental results and predicted values. There is minimal variation between the observed values.

A normal distribution with a mean 5.02 and deviation of 1.176 appears to fit the data fairly well having characteristics as following:

- The plotted points form a reasonably straight line.

- The plotted points follow the fitted distribution line fairly closely.
- The p- value for Anderson- Darling test is above 0.10.
- Because the distribution fits the data, we can use the fitted line to estimate percentiles for the population.

IV. CONCLUSION

Research work depicts the influence of welding parameters on weld bead geometry. This work has been performed using Activated TIG welding process. All the experiments have been evaluated using half factorial design (DoE) methods. The performance metrics considered during the evaluation were: Welding current, active flux, welding speed and Gas flow rate. To perform welding, active fluxes (Cadmium chloride and Titanium dioxide) have been chosen. The conclusion drawn after observing the whole experimentation results as per design of experiment models are as follows:

1. Two level half factorial designs is found to be effective tool for quantifying the main and interaction effect of variable on bead geometry. Model is problem specific; however technique can be applied effectively. Proposed model is adequate to predict bead geometry with confidence level of 95%.
2. Penetration increases drastically with active flux $CdCl_2$, significantly increases with welding current and decreases with welding speed and negligibly affected by shielding gas.
3. Weld bead width decreases significantly with $CdCl_2$ as compared to TiO_2 active flux, decreases with increase in welding speed but increases with increase in shielding gas flow rate and negligibly affected by welding current.
4. As compared to the A-TIG welding of magnesium alloy using $CdCl_2$ active flux with conventional TIG, the weld penetration (P) and penetration to width ratio (P/W) with $CdCl_2$ flux are both two times greater than that of without flux under optimal parameters.
5. The results of experiments also demonstrate that the penetration decreases when using active flux TiO_2 and increases as the active flux is replaced with $CdCl_2$.
6. Arc contraction increases the weld penetration and decreases the weld bead width when using $CdCl_2$ as active flux. The spread of arc is more when using TiO_2 as an active flux which decreases weld penetration and increases the weld bead width.
7. It is economic to use $CdCl_2$ flux with parametric values: welding current 120 A, welding speed 4 mm/sec and shielding gas flow rate 10 l/min.

REFERENCES

[1] Magnesium alloy - Wikipedia, the free encyclopedia. 2014. Magnesium alloy - Wikipedia, the free encyclopedia. [ONLINE] Available at: http://en.wikipedia.org/wiki/Magnesium_alloy. [Accessed 21 May 2014].

[2] Global sei. 2011. Welding of magnesium based alloys. [ONLINE] Available at: http://global-sei.com/news/press/10/10_02.html. [Accessed 11 May 14].

[3] keytometals. 2013. Welding of magnesium based alloys. [ONLINE] Available at: http://www.keytometals.com/Article35.htm. [Accessed 01 July 14].

[4] Welding, (2014), welder_cable_drawing1 [ONLINE]. Available at: http://www.weldingcable.biz/images/welder_cable_drawing1.png [Accessed 01 June 14].

[5] Activating Flux - Improving the Performance of the TIG Process (February 2000). 2014. Activating Flux - Improving the Performance of the TIG Process (February 2000). [ONLINE] Available at: http://www.twi-global.com/technical-knowledge/published-papers/activating-flux-improving-the-performance-of-the-tig-process-february-2000/. [Accessed 27 June 2014].