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Experimental Investigation on the Effect of Fluxes on the Bead Geometry Parameter of GTA Aluminium Welds

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Abstract: In this research the effects of various activated fluxes on weld characteristics in tungsten inert gas (TIG) process has been investigated. Activated metal oxides Silicon dioxide (SiO2),Titanium dioxide (TiO2) and the combination of these two were used for comparative studies on bead geometry such as depth of penetration, weld width and aspect (D/W) ratio, microstructure and microhardness on 5 mm thick 6063 aluminium alloy with conventional TIG welding. Paste form of activated flux which is made up with the mixing of acetone and binder (sodium silicate), applied on the surface of the workpiece by using brush. The result showed that all activated fluxes have satisfactory increased depth of penetration and aspect (D/W) ratio.
Keywords: A-TIG, Flux, Weld bead geometry, Aluminium Alloy

I. INTRODUCTION

AA 6063 is an aluminium alloy with magnesium and silicon as the alloying elements. The standard controlling its composition is maintained by The Aluminium Association. It has generally good mechanical properties and is heat treatable and weldable. Activated flux with GTA welding has been successfully used to improve productivity of the process. The process is also known as flux assisted GTAW or A-TIG welding process. Use of fluxes in GTA welding was first proposed by Pelton Electric Welding Institute of National Academy of Sciences, Ukraine in the mid-1960s.In this process a thin layer of flux is deposited on the surface that is to be welded, followed by the TIG welding process. Fluxes used in this process are generally oxides, chlorides and fluorides. Fluxes are deposited on the surface after mixing it with suitable solvent like acetone or ethanol in proper proportion with the help of brush or by spraying. Different tests have been performed to find out the bead profile and mechanical properties of the specimens. Present study is focused to find bead profile, microstructure, and microhardness of the material.

II. EXPERIMENTAL PROCEDURE

A. *Selection of Material*

AA 6063 is an aluminium alloy, with magnesium and silicon as the alloying elements. The standard controlling its composition is maintained by The Aluminum Association. AA6063 was taken for A-TIG welding in the form of rectangular plate and had the following dimensions:Length = 150mm, Width = 100mm, Thickness = 5mm. Composition of AA 6063 is shown in table 1.

TABLE I
Chemical composition of AA 6063

Component	Fe	Cu	Si	Mn	Mg	Zn	Ti	Cr	Al
Wt. %	0.35	0.1	0.4	0.1	0.6	0.1	0.1	0.1	98.15

B. *Selection of Fluxes*

Activating fluxes are basically used to improve the performance of the TIG Welding process. Because it is portable and easy to handle that’s why TIG welding is most popular welding process to weld materials and also used for maintenance. But there is some limitations of TIG welding process. To overcome these limitations, metal oxides are use to improve the welding and mechanical properties of the joints. These metal oxides are called activated flux. In the present study, SiO_2, TiO_2 and combination of these two oxides powder named AF1422 are used as activated flux.

TABLE II
Solution of activating flux paste

Components	Quantities	Unit
Activating Flux	1.15-1.25	Gms
Solvent (Acetone)	5-10	ml
Binder (Sodium Silicate)	2-4	Drops

C. TIG Welding Process

Based on trials and literature surveys, welding parameters have been selected for the present study. The parameters for A-TIG welding is given in Table:

TABLE III

Welding current(A)	Arc voltage(V)	Travel speed (mm/min)	Arc gap(mm)	Diameter of electrode(mm)	Gas flow rate(L/min)
130	55	150	2	2.4	13
140	55	150	2	2.4	13
150	55	150	2	2.4	13

First of all welding is performed on the workpiece without any flux on different current (130A, 140A and 150A). Now using SiO_2 flux welding is done on the workpiece on different current values. In the same way welding is done by using TiO_2 flux and AF1422 flux.

D. Preparation of Specimen for Testing

Specimen for testing is taken out from the middle of the workpiece with the help of power hacksaw. These specimens should be polished for accurate testing data. The polishing process has been conducted by the means of different grits emery papers namely from 220 grit paper and up to 3000 grit papers. For fine surface finishing alumina paste was applied. After surface finishing, etching has to be performed to revile bead geometry.

E. Testing and Analysis

Different tests have been performed to find out the bead profile and mechanical properties of the specimens. Present study is focused to find bead profile, microstructure, and microhardness of the material.

1) *Stereomicroscope Analysis :* The stereo or stereoscopic or dissecting microscope is an optical microscope variant designed for low magnification observation of a sample, typically using light reflected from the surface of an object rather than transmitted through. The test is performed to calculate the dimension of the weld bead such as weld width, depth of penetration and heat affected zone (HAZ).
2) *Microstructure Analysis* **:** Microstructure is the small scale structure of a material, defined as the structure of a prepared surface of material as revealed by a microscope above 25× magnification. The microstructure of a material such as metals, polymers, ceramics or composites can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behavior or wear resistance. These properties in turn govern the application of these materials in industrial practice.

3) *Microhardness Test* **:** Indentation hardness measures the resistance of a sample to material deformation due to a constant compression load from a sharp object; they are primarily used in engineering and metallurgy fields. The tests work on the basic premise of measuring the critical dimensions of an indentation left by a specifically dimensioned and loaded indenter. For microhardness testing, the specimens have been prepared using standard procedure like grinding, polishing using successively fine grades of emery up to 3000 grit size. This was helpful in removing coarse and fine oxide layer as well as scratches on the surface that are to be metallographic-ally analyzed. Microhardness tester is used to measure microhardness of the specimens at a load of 1000 gms, for the dwell time of 20 seconds. The microhardness values for specimens have taken from the center of the weld bead.

III. RESULTS AND DISCUSSION

Based on the experiments performed, the results have to be evaluated and the effects of various fluxes on the weld bead geometry, microstructure, and microhardness have to be found out. Here is the analysis of the experimental results to find out the effect of the fluxes used.

A. Effect of Various Fluxes on Weld Bead Geometry

Activating fluxes are used for higher depth of penetration, less weld width, and less heat affected zone (HAZ). In the present study, three fluxes SiO_2, TiO_2 and combination of SiO2 and TiO2 (AF1422) are used to check the effect on the bead geometry of aluminium 6063. The effects of these fluxes are compared with as welded bead on workpiece with different current values. The comparative results showed noticeable effects. These noticeable effects are discussed below:

1) *Bead Geometry without Flux:* The experiments have been performed on aluminium 6063 with the help of tungsten inert gas (TIG) welding process. In the present study, firstly TIG welding has been performed on the workpiece without using any activating flux on different current values and final specimen for testing is cut out from the workpiece. Conventional TIG welding produces wide arc width, low depth of penetration more weld bead width and more heat affected zone (HAZ). The result obtained from the testing of the specimen prepared by the TIG welding with 2.4 mm electrode diameter on different current values is as follows:

TABLE IV

Effect of different current on bead geometry of base metal

Current (amp)	Bead Width (mm)	Penetration (mm)	Reinforcement (mm)	A P (mm^2)	A R (mm^2)
140	8.71	1.93	0.93	23.62	6.69
150	10.18	2.36	1.29	10.38	9.12
160	11.83	2.86	1.30	19.88	10.24

2) *Effect of Fluxes on Depth of Penetration:* Keeping welding speed, gas flow rate and all parameters same, all activated fluxes are resulted in the increase of depth of penetration on different current values. By considering activated flux only, TiO_2 resulted lowest depth of penetration, but it is more than conventional TIG welding. SiO_2 resulted in increase of depth of penetration. During welding, activated flux SiO_2 is more unstable and get vaporized easily at low temperature which discharges electrons more efficiently. This cause high energy concentration at the arc column which is directly proportional to the content of molten metal, high depth of penetration, low bead width and low heat affected zone (HAZ) as seen from Figure. Combined activated flux AF1422 (SiO2+TiO_2) showed that the higher penetration than TiO2 flux and less penetration than SiO_2 flux as seen in table:

TABLE V

Flux	Penetration(mm) (130amp)	Penetration(mm) (140amp)	Penetration(mm) (150amp)
Base	1.93	1.04	2.86
SiO_2	2.86	3.11	4.61
TiO_2	2.39	1.43	2.64
SiO2+ TiO_2	2.75	2.29	3.86

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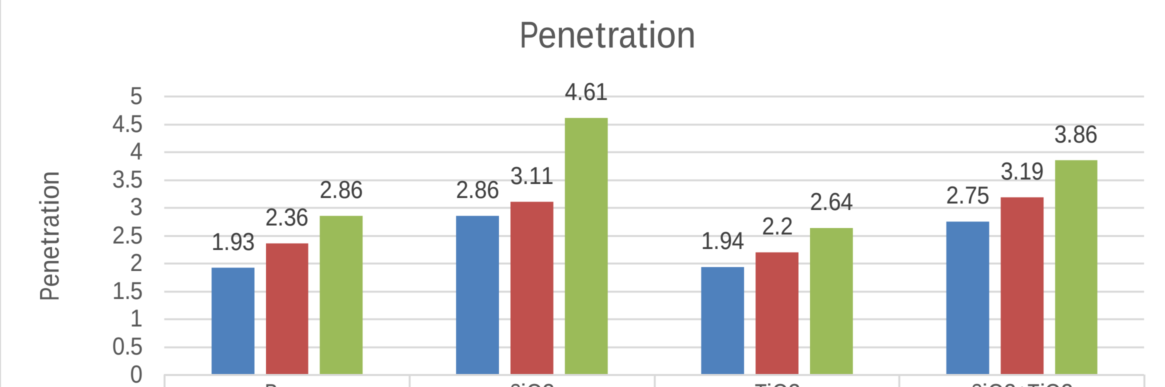


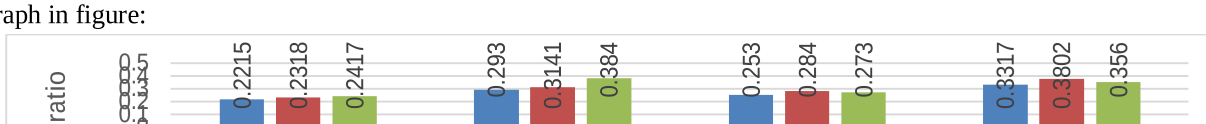
	Base	SiO2	TiO2	SiO2+TiO2
130 amp	1.93	2.86	1.94	2.75
140 amp	2.36	3.11	2.2	3.19
150 amp	2.86	4.61	2.64	3.86

3) *Effect of Fluxes on Weld Width:* Use of activated flux, concentrate the welding arc which produce high energy at the center of the arc column. This concentrated arc also affects the width of the weld. All bead analysis resulted TiO_2 flux have lowest weld width and TiO_2 has diverged arc as compare to convention TIG welding and other flux also. Activated flux SiO_2 has highest weld width which is less than conventional TIG welding. Combined flux (SiO2 and TiO_2) have higher bead width than TiO2 and lower bead width than SiO_2. Bead width using different fluxes on different current values is shown below:

TABLE VI

Flux	Bead width (130 amp) (mm)	Bead width(140amp) (mm)	Bead width(150 amp) (mm)
SiO_2	9.75	9.90	12
TiO_2	7.65	7.72	9.64
SiO2+ TiO_2	8.29	8.39	10.82

4) *Effect of Fluxes on Aspect Ratio:* In convention TIG welding surface tension at the center of the weld pool is lower than that at the edge. This results in less depth and more width of the weld pool. But when fluxes of unstable oxides like SiO_2, TiO_2 and combination of SiO_2 and TiO_2 are added, the reversal of Marangoni effect occurs and due to arc constriction, more increase in depth of penetration and less decrease in weld width are obtained. These variations of aspect ratio are represented with the help of graph in figure:



	Base	SiO2	TiO2	SiO2+TiO2
130 amp	0.2215	0.293	0.253	0.3317
140 amp	0.2318	0.3141	0.284	0.3802
150 amp	0.2417	0.384	0.273	0.356

B. Effect of Fluxes on Microstructure

The microstructure at various spots of the weldment is observed through optical microscopy LEICA DMI 5000 M microscope. Before analysis of microstructure of the weld bead, specimen should be prepared by grinding and polishing process. For fine surface polishing alumina paste (Al_2O_3) was used. After polishing has been done, etchant should apply on specimen to reveal the microstructure. Microstructures have been obtained at weld bead, HAZ and interface of the weld bead and HAZ.

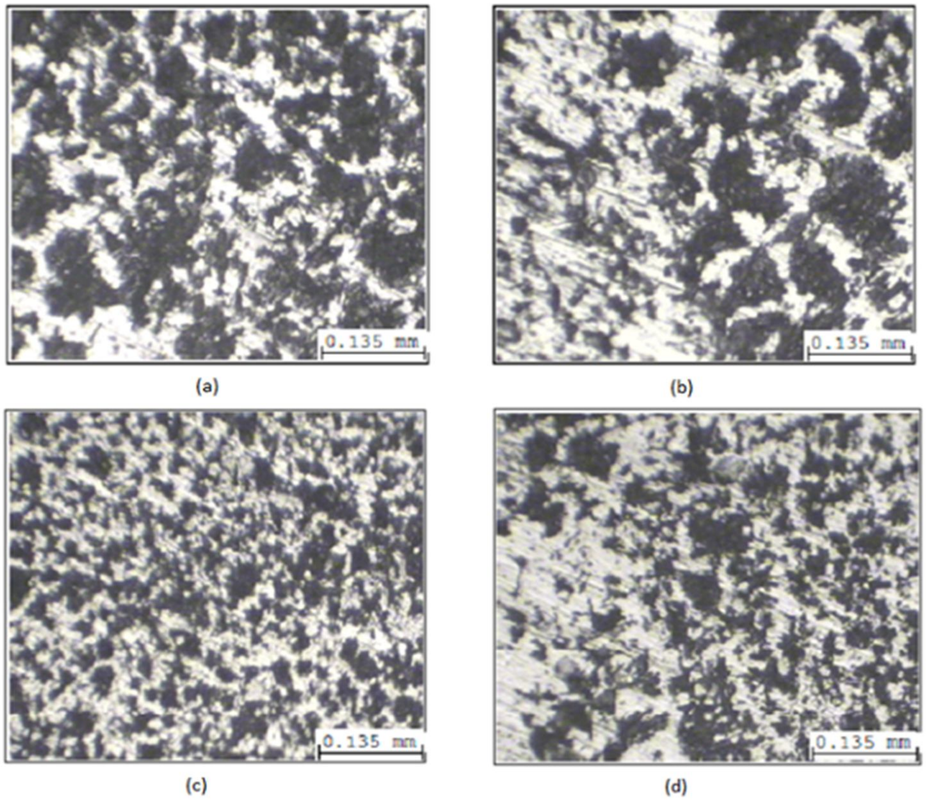


Figure 1 Microstructure of weld bead by A-TIG welding at 100x magnification on 130 amp current (a) weld bead of base metal (b) interface between weld bead and HAZ of base metal (c) weld bead of SiO_2 coated metal (d)) interface between weld bead and HAZ of SiO_2 coated metal

C. Effect of Fluxes on Microhardness

The specimens were prepared for the measurement of Vickers microhardness number. To prepare specimen, surface finishing and polishing is to be required for dust and scratch free surface by the means of different abrasive papers and at last alumina paste (Al_2O_3) is used for fine surface finish. Measurements were carried out across the weld section at 1000gms force with dwell time 20 sec.

TABLE VII

Effect on microhardness of different fluxes at different current values

Current (amp)	Base	SiO_2	TiO_2	SiO_2+ TiO_2
130	32.725	26.63	48.67	28.44
140	27.05	19.21	35.85	29.52
150	32.51	27.33	37.01	32.90

III. CONCLUSION

Based on the present study, some conclusions could be drawn. These conclusions specify the advantage of the activated TIG welding. And also specify that what changes are made in activated TIG welding at same parameters which are also used in conventional TIG welding process.

A. For present work selected welding current is directly current is directly proportional to bead width, penetration and reinforcement.

B. As welding current increases, area of penetration decreases but area of reinforcement increases.

C. Penetration is maximum in case of SiO_2 flux followed by AF1422 (SiO_2 + TiO_2) flux and TiO_2 flux.

D. Aspect ratio for weld bead is maximum for SiO_2 flux at 150 amp.

E. From microstructural examination coarse grain structure is obtained in case of SiO_2 flux and fine grain structure is seen in case of TiO_2 flux.

F. Microhardness is maximum in case of TiO_2 flux coating and minimum in case of SiO_2 flux coating.

It can be concluded that activated TIG welding improve the overall quality of AA6063 weld bead. Depth of penetration, aspect ratio, microstructure and microhardness all are improved by using metal oxides in conventional TIG welding. It does not affect the cost of welding because fluxes are not much costly.

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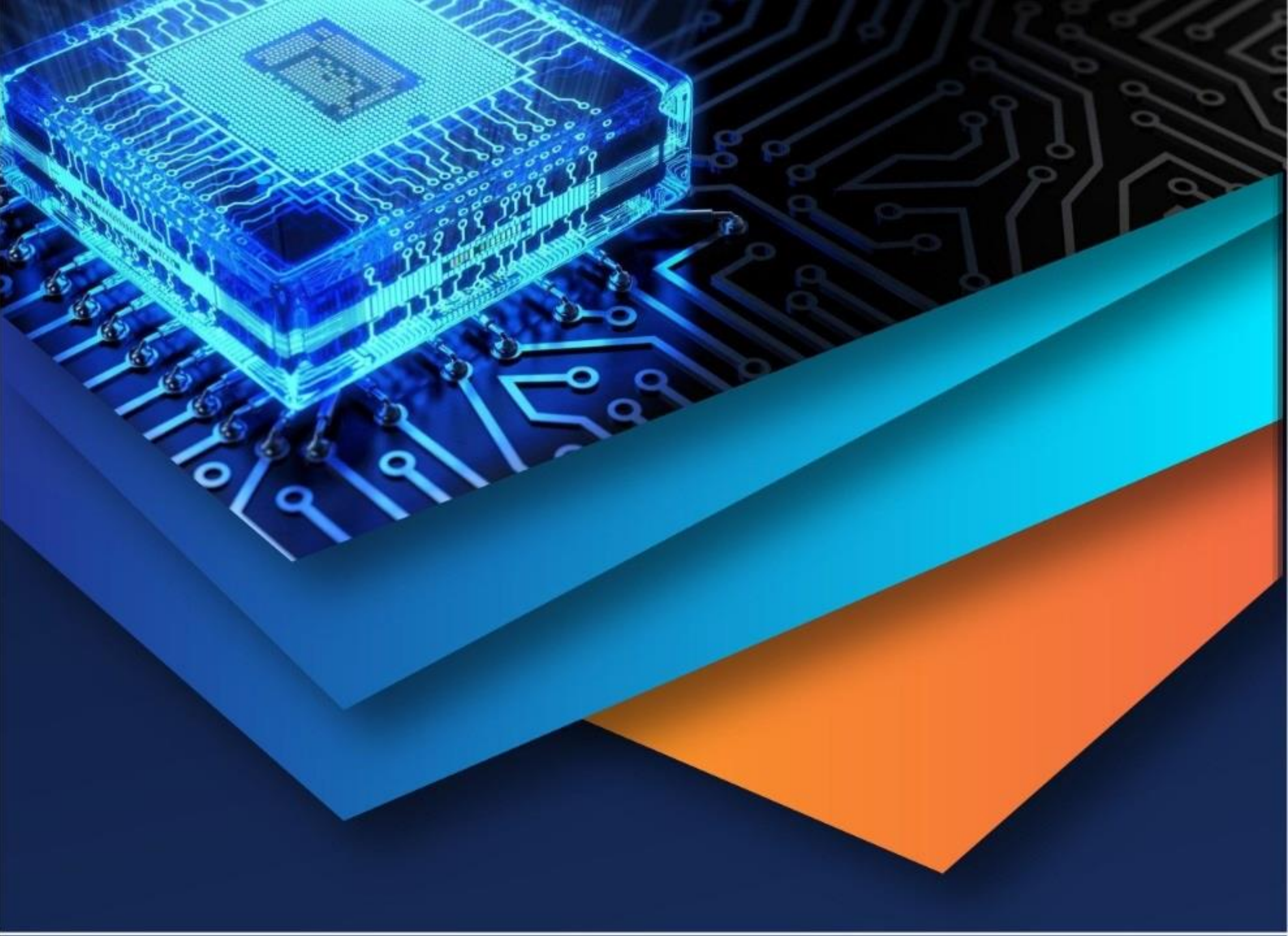

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