Experimental Determination Of Weld Pool Dimensions In TIG And A-TIG Welded Mild Steel Plates

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Abstract—**TIG welding is widely used in modern manufacturing industries. In almost all kinds of metals, TIG welding produces high quality welds, but shallow penetration in single pass is a major limitation. The purpose of present work is to investigate the effect of oxide flux agents on gas tungsten arc weld pool. Experimental study was carried out on steel plates of different thickness with different welding currents. Activated Tungsten Inert Gas (A-TIG) welding can increase the weld depth to bead width ratio, and reduce the deformation of welded plate. In this paper, the effect of different fluxes on the weld pool geometry is analysed by conducting suitable the experiments and results were compared with results available in literature.**

Keywords- A-TIG, oxide flux, penetration, weld pool geometry

I. INTRODUCTION

Activated tungsten inert gas (A-TIG) welding, was first proposed by Paton Electric Welding Institute in the 1960s [1,2]. This technique makes it possible to facilitate the conventional TIG practices for joining parts with thickness above 6 mm by single-pass welds, with no edge preparation, instead of multi-pass procedures [3, 4]. According to the work done by Heiple and Roper [5], and Y.L. Xu [6] the direction of fluid flow in the molten pool can affect weld geometry, and Marangoni convection is the most important factor that controls the heat transfer in weld pool. The weld pool shape depends on the direction of flow of molten metal in weld pool, which is governed by surface tension, electro-magnetic force, buoyancy force and plasma drag force.

The temperature coefficient of surface tension is a main factor that determines the direction of fluid flow in the molten pool as surface tension of molten metal is temperature dependent. In the case of pure metal, the surface tension coefficient is negative, i.e. surface tension of metal decreases when the temperature is increased. The surface active elements can change the surface tension coefficient to a positive value. And in such cases, surface tension of the molten metal increases as the temperature increases. The temperature at the centre of weld pool is higher than that of the surrounding region due to the variations in thermal conductivity. This temperature variation causes a shear force on the weld pool surface, which results in a flow in the weld pool known as Marangoni effect. The change in weld penetration during A-TIG weld has been explained with Marangoni flow by Rogers [7].

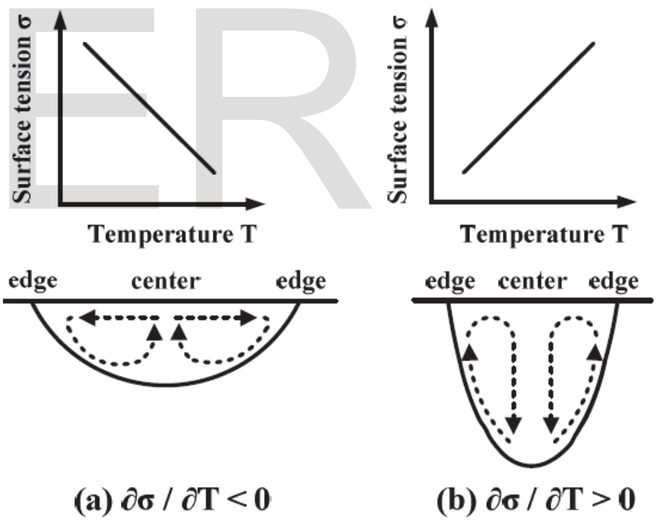


Fig 1. Schematic diagram of fluid flow pattern in the molten pool [8].

If the temperature dependent surface tension coefficient is negative, the cooler peripheral regions of the pool will have a higher surface tension than the centre of the weld pool and the flow will be outwards creating a wide shallow weld pool as in fig1(a). In materials with a positive surface tension temperature coefficient, liquid metal flow is reversed to the center of weld pool surface and the liquid metal flows to the root. This creates a narrower deeper weld pool for exactly the same welding conditions as shown in fig1 (b).

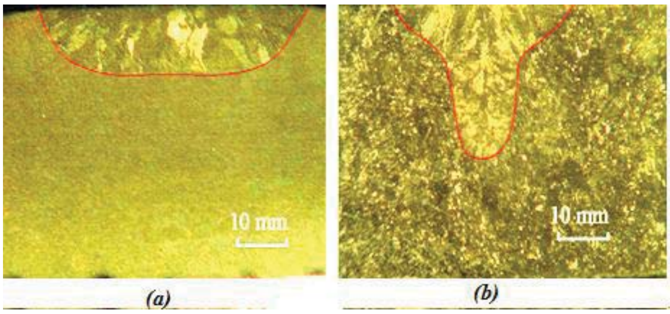


Fig 2. Weld shape in (a) TIG and (b) A-TIG welding [2].

Only a few data are available in the literature about the actual mechanism of fluid flow during A-TIG welding. Fig 2 shows the variation in TIG and ATIG weld pool geometry as reported [2].

II. EXPERIMENTAL DETERMINATION OF WELD POOL DIMNENSIONS

The commonly used fluxes for A-TIG welding are SiO_2, Al_2O_3, Cr_2O_3, CaO, TiO_2 etc. In the present work calcium oxide and silicon dioxide were used to study the effect of activating flux on weld morphology in low carbon steel welds.

A. Experimental procedure

Mild steel plates of 150mm length and 50mm width of 6mm and 10mm thickness were used for the study; these plates were polished with silicon carbide paper to remove surface contamination, and then cleaned with acetone. The fluxes were prepared by mixing the calcium oxide or silicon dioxide with acetone. This mixture was brushed manually on the top surface along the weld line of the specimen before welding. The coating density of flux was maintained approximately about 5–6mg/cm^2.

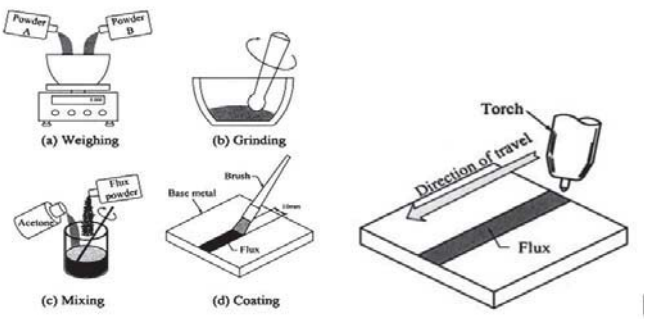


Fig 3. Schematic diagram of A-TIG welding [8].

Fig 3 shows schematic diagram of activated ATIG welding process. The TIG and ATIG welding process was performed on the test specimen using TIG welding machine (WARPP–TIME, WSM- 160). Table-1 lists the welding conditions used in this study.

Table 1 Welding parameters for A-TIG welding experiments.

specifications	values
Diameter of electrode	0.8mm
Tip angle of electrode	60◦
Electrode gap	2mm
Shielding gas	argon
Gas flow rate	12 L/min
Welding current	100A, 120A

Each specimen is applied with a 100A and 120A welding arc for 20 sec. By keeping all other parameters constant, three sets of trials were conducted on each set of plates using TIG welding machine. Fig 4 and fig 5 shows the TIG and ATIG welded specimenes.

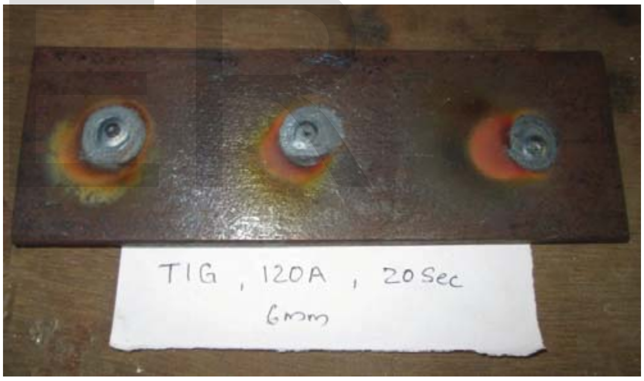


Fig 4. TIG Spot welded specimen.

Fig 5. ATIG Spot welded specimen.

B. Polishing process

After welding each specimen were cut across the weld line to get a cross section of weld pool and were filed using flat file to get a flat surface. After cutting process polishing operations were done on each specimen using sand paper of four different grit sizes 220, 300, 500 and 600. The specimens were rubbed on the sand paper in the presence of water. The specimens were rubbed with 220 grit size sand paper until a smooth finish was obtained on the surface where weld pool size had to be determined. Similar procedures were carried out for the same specimen on other grit size sand papers. The specimen was then cleaned with water and polished on velvet cloth polishing machine. The specimens were dipped in water and alumina powder and were polished on velvet cloth mounted on a rotating platform which rotates at high speed. After polishing on velvet cloth polishing machine, a glass like surface is produced on the welded specimen.

C. Etching process

Here in present analysis etching solution is a mixture of 20% nitric acid and 80% water. The mixture is heated to 70˚C and maintained at the same temperature for 30 minutes, using a water bath.

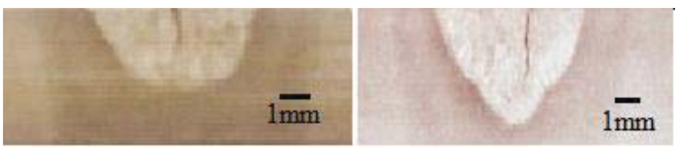
After etching the weld pool and the heat affected zone can be clearly be differentiated. The image is the taken on a digital camera. A steel rule is also kept inside the frame to measure the dimensions of weld pool in the image so captured

III. RESULTS AND DISCUSSION

To study the shape of weld pool geometry to find the weld penetration with TIG and A-TIG welding, both type of welding has been carried out on different thick plates using different welding currents. The effect of activating flux on weld morphology of TIG and A-TIG welded plate as well as the effect of different activating flux on weld pool shape are also studied.

A. Effect of Activating Flux on Weld Morphology

The significant effect of flux on penetration of TIG weld is clear from Fig.6; it shows comparison of TIG and A-TIG weld pool dimensions. TIG welds without flux exhibited comparatively wide and shallow weld pool. From figure 6 it is clear that active TIG weld provides a high weld depth to width ratio. The satisfactory improvement in penetration of A-TIG welds can be explained by studies of H.G.Fan [9] and Ding Fan [10].



(a) (b)

Fig 6. Variation of depth in TIG and A-TIG weld
a) 120A TIG b) 120A A-TIG (CaO)

According to them the activated flux exists on the surface of the TIG molten pool, accompanied by higher temperature in the pool centre under the arc, and lower temperatures at the pool edge, causes a flow reversal inside the weld pool. During TIG welding without flux, the temperature coefficient of surface tension on the molten pool generally exhibited a negative value. That is $\partial\gamma/\partial T < 0$, for a lower surface active element content in the weld. In this case, the surface tension is larger in the relatively cooler part of the pool edge than that in the pool centre under the arc, and hence, the fluid flows from the pool centre to the edge. The heat flux is easily transferred to the edge and forms a wide and shallow weld shape. During A-TIG welding, increased surface active element content in the weld surface tends to change the temperature coefficient of the surface tension from negative to positive i.e. $\partial\gamma/\partial T > 0$. Hence, the velocity of molten metal and temperature is increase towards the centre of pool and tends to produce a narrow and deep weld in A-TIG. The resulting variation on weld pool dimensions is clearly shown in experimental results.

B. Effect of different Activating flux as on weld pool dimensions

Experiments were conducted with 100A and 120A currents and by using different fluxes. Table 2 shows the variations of depth and width of weld pool for 6mm plate with different type of flux.

Table 2 Variation of weld pool width and depth of 6mm plate

6 mm plate		
	WELD ZONE	
	width	depth
TIG weld 100A	8.5	2
A-TIG (CaO) 100A	6	2.5
A-TIG (SiO2) 100A	9.5	3
TIG weld 120A	10	3.5
A-TIG (CaO) 120A	8	5
A-TIG (SiO2) 120A	10.5	3.5

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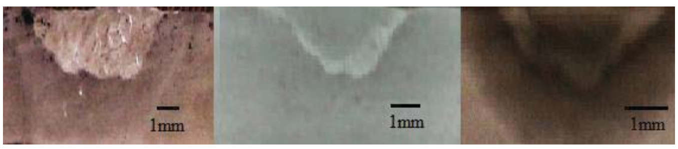
Fig 7 shows the variation of weld pool dimensions for different type of fluxes. From fig 7 it is clear that weld with CaO flux shows the maximum penetration for 100A currents.



(a) (b) (c)

Fig 7 variation of depth in TIG and ATIG weld
a) 100A A-TIG (SiO2) b) 100A TIG c) 100A A-TIG (CaO)

The figures 6-7 show the graphical comparison of weld pool dimensions for different currents, fluxes and plate thickness.

The figures 6 and 7 show that weld pool depth increases in A-TIG welds for 6mm and 10mm plates. Welded plates with CaO Flux have shown closer results for weld depth and width with that of the available journals. A-TIG welded plates with

CaO flux have shown increased depth and decreased width of weld pool geometry.

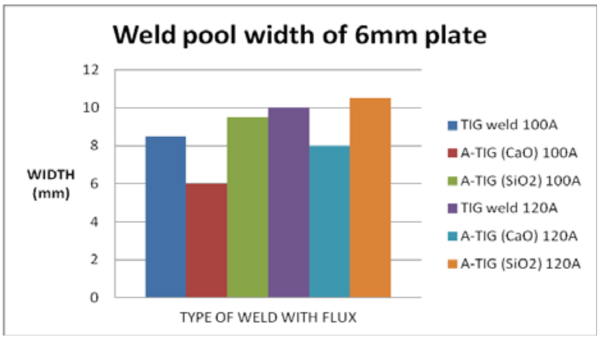


Fig 8. weld pool width of 6mm plate

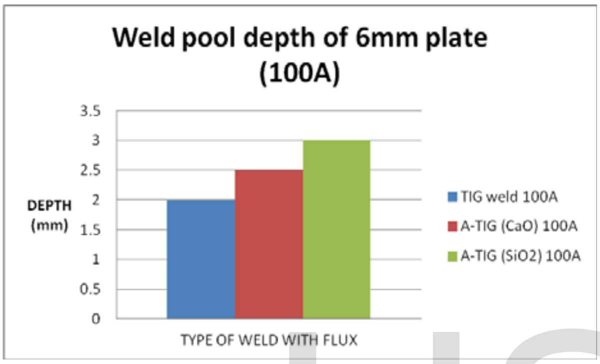


Fig 9. weld pool depth of 6mm plate (100A)

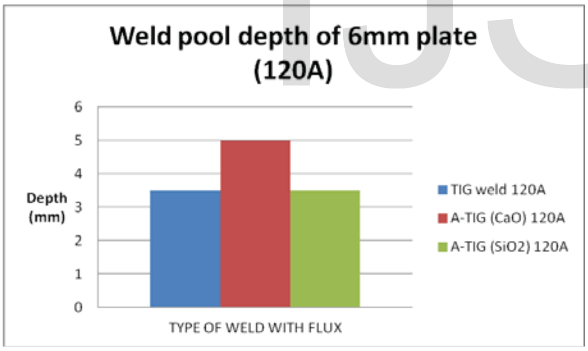


Fig 10. weld pool depth of 6mm plate (120A)

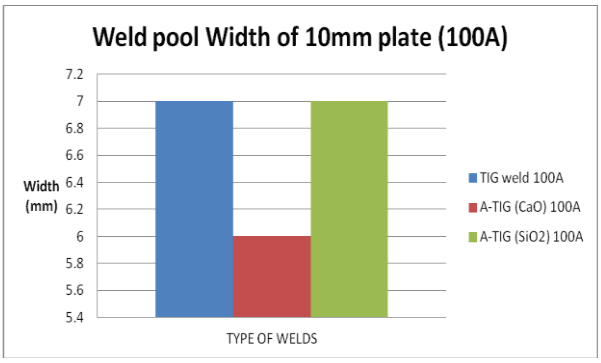


Fig 11. Weld pool width of 10mm plate (100A)

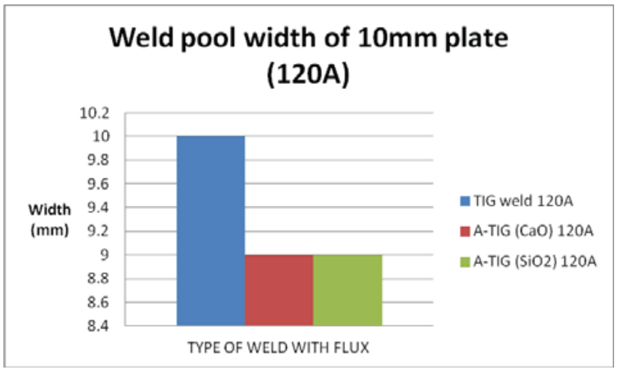


Fig 12. Weld pool width of 10mm plate (120A)

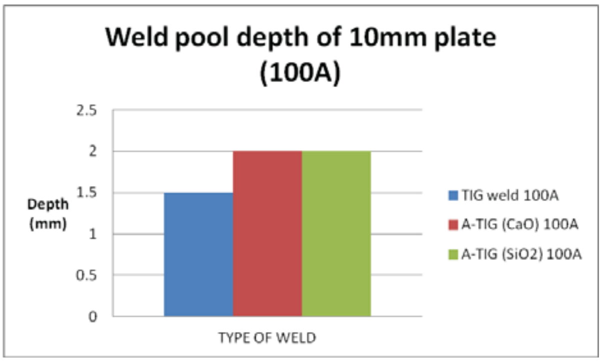


Fig 13. Weld pool depth of 10mm plate (100A)

The experimental results for 6mm plate shows that the application of calcium oxide flux has increased the depth and decreased width of the weld pool for both 100A and 120A current welding. Where in silicon dioxide flux application increases both depth and width of weld pool (fig.8-10). For 10mm plates calcium oxide application shows increase in depth and decrease in width of weld pool in both 100A and 120A. The depths of weld pool increased with the applications of silicon dioxide at 100A currents but weld pool width remaining same (fig 11-14).

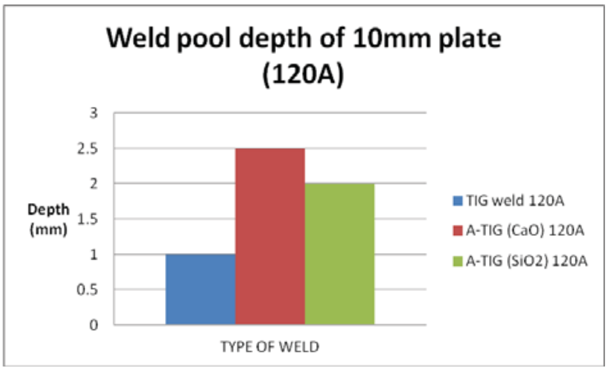


Fig 14. Weld pool depth of 10mm plate (120A)

IV. Conclusion

The effect of activating fluxes on weld pool geometry has been studied. The primary results and conclusions can be summarized as follows:

1. A-TIG welding, results in relatively narrow and deep weld morphology compared with the conventional TIG welding, i.e.

surface tension temperature coefficient is an important factor in determining weld pool shape.

2. A-TIG welding results in an increase in weld depth and a decrease in bead width. The oxide flux can facilitate increased penetration and significantly reduce the deformation of the weldment. But the conventional TIG process without flux led to a deterioration in the penetration.

3. The effect of CaO flux is prominent in both currents but the effect of SiO_2 is significant only for 120A currents.

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