# STUDY ON ACTIVATING TIG WELDING FOR ALUMINIUM ALLOYS

**Fan Ding[1], Huang Yong[2]**
**State Key Lab of Gansu New Non-ferrous Metal Materials**
**Gansu University of Technology (China)**
**E-mail: [1] fand@gsut.edu.cn [2] hyorhot@163.com**

## ABSTRACT

Activating TIG welding for aluminium alloys have been made using $SiO_2$ and multi-component flux AF305 developed by our group respectively to study the effects of activating flux and flux coating method on weld penetration. It has been found that, the weld penetration with AF305 was much deeper than that of $SiO_2$ in both FBTIG welding and A-TIG welding. For both $SiO_2$ and AF305, the weld penetration increased with decreasing of the flux gap ($x$) and the weld penetrations of A-TIG welding were deeper than that of FBTIG welding. In A-TIG welding with AF305 flux, the weld penetration increased over 3 times compared with that of the conventional TIG welding.

***IIW Thesaurus keywords:*** *A TIG welding; Arc welding; Gas shielded arc welding; GTA welding; Aluminium alloys; Light metals; Active fluxes; Fluxes; Penetration; Practical investigations.*

## 1 INTRODUCTION

Aluminium alloys have more and more intensive applications in many areas, including chemical vessel, aircraft and aerospace industry, ship and automobile, electrical power etc., because of light weight, high intensity and corrosion proof. Because aluminium alloys have high thermal conductivity coefficient, high specific heat capacity and large welding deformation, the welding processes with high power density, TIG welding, electron beam welding, laser welding for example, are required, especially TIG welding with AC mode. But weld penetration is still poor even like this. It must apply extra processes to welding aluminium alloys, like preheat process, with appliance difficulty enlarging, welding cost increasing and welding efficiency decreasing.

Recently, a new type of welding process called A-TIG (Activating flux TIG) welding attracts high attention all over the world, which applies surface activating fluxes to improve weld penetration dramatically by arc root constricting or changing of fluid flow in welding pool. Many researchers [1-8] have applied A-TIG welding to stainless steel, titanium alloy, mild steel and so on, but little work has been devoted to this process for aluminium alloys. Recently, two French scholars S. Sire and S. Marya [9] proposed a welding process called FBTIG (Flux Bounded TIG) on the basis of welding characteristics of aluminium alloy, which applied a thin surface activating flux to the bounds of weld bead with a flux gap in the center and welding arc burning on the central uncovered metal. FBTIG welding with only $SiO_2$ flux could improve weld penetration in their work.

In this experiment, a series of activating TIG welding with AC mode for aluminium alloy have been made with $SiO_2$ and a multi-component flux AF305 developed by our group to study the effects of activating flux and flux coating method on the weld penetration in activating TIG welding for aluminium alloys.

## 2 EXPERIMENTAL

The experimental material was aluminium alloy 3003 with dimension of 200 mm × 80 mm × 8 mm. Chemical composition and physical properties of the base metal are listed in Table 1 and Table 2 respectively. Before

**Table 1 – Chemical composition of the base metal (wt %)**

| Cu | Mg | Mn | Fe | Si | Zn | Ti | Al |
|---|---|---|---|---|---|---|---|
| 0.20 | 0.05 | 1.0-1.6 | 0.7 | 0.60 | 0.10 | 0.15 | Bal. |

**Table 2 – Physical properties of the base metal**

| | |
|---|---|
| **Density $\rho$ ($g.cm^{-3}$)** | 2.73 |
| **Specific heat capacity (100 °C) $c_p$/ ($J.kg^{-1}.°C^{-1}$)** | 1009 |
| **Heat conductivity coefficient (25 °C) $K$/ ($W.m^{-1}.°C^{-1}$)** | 180.0 |
| **Thermal expansion coefficient $\beta$ /($\times 10^{-6}.°C^{-1}$)** | 23.2 |
| **Electrical resistivity $\Omega$/ ($\times 10^{-6}\Omega.cm$)** | 3.45 |
| **Melting point $T_m$/ (°C)** | 634-654 |

Doc. ICRA-2003-06

**Table 3 – Welding specification**

| | |
|---|---|
| **Welding current** <br> ***I*/A** | 160 |
| **Welding travel speed** <br> $\upsilon$ **/(mm.min$^{-1}$)** | 125 |
| **Flow rate of argon** <br> ***Q*/(L.min$^{-1}$)** | 15 |
| **Arc length** <br> ***L*/mm** | 3 |
| **Electrode diameter** <br> $\varphi$ **/mm** | 3.2 |

welding, the activating flux mixed proportionally was stirred to paste-alike with acetone, then brushed onto the surface of base metal just preventing visual observation of the base metal. During welding, a melt run weld on the surface of base metal was made with automatical TIG welding with AC mode, and the welding specifications are listed in Table 3. The welding torch was required to move accurately along the central line of the specimen. After welding, the specimens were cut, mechanically polished and etched to measure the weld penetration depth $D$ with flux and the weld penetration depth $D_0$ without flux.

$SiO_2$ and multi-component flux AF305 developed by our group were used as the experimental fluxes. $SiO_2$ was chosen as the experimental activating flux by many researchers and has been proved to improve weld penetration obviously in A-TIG welding for stainless steel, mild steel and so on. S. Sire and S. Marya also used $SiO_2$ as activating flux in FBTIG welding and obtained desired welding results. The multi-component flux AF305 was developed by our group with the "uniform experimental design method" to improve weld penetration dramatically in A-TIG welding for aluminium alloy, which consists of various metal oxides.

Three different flux coating methods, A, B and C, were used in this experiment, and the schematic diagram is shown in Figure 1. For the flux coating method A, flux was coated on one side of weld bead with a flux gap ($x$) between sideline of flux and central line of specimen. For the flux coating method B, flux was coated on two sides of weld bead with a flux gap ($x$) between two strips of flux. For the flux coating method C, flux was coated on the whole weld bead.

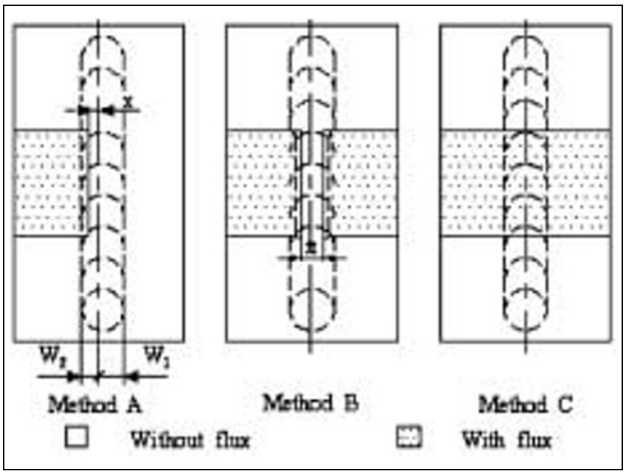


**Figure 1 – Schematic diagram of the three flux coating methods**

## 3 EXPERIMENTAL RESULTS

### 3.1 Results for the flux coating method A

Figure 2 shows the weld penetration depth ratio $D/D_0$ applying the flux coating method A with $SiO_2$ and AF305 fluxes respectively, and the flux gaps ($x$) chosen are 0 mm, 2 mm and 4 mm respectively. Figure 3 shows the corresponding weld deviation ratio $p$ which can be derived from the formula as below:

$$p = \frac{W_1 - W_2}{W_1 + W_2} \times 100\ \% \qquad (1)$$

where

$p$ is the weld deviation ratio of TIG welding with flux, $W_1$ (see Figure 1) is the distance between the sideline of weld towards the side without flux and the central line of specimen, $W_2$ is the distance between the sideline of weld towards the side with flux and the central line of specimen.

Because of different current channel resistance between the side without flux and that with flux, the arc will lean to the side with low current channel resistance and result

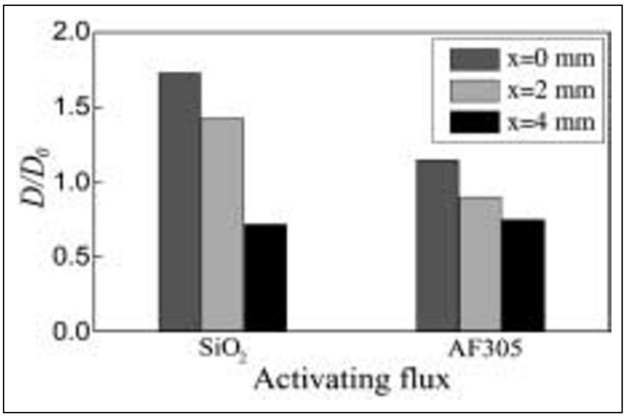


**Figure 2 – D/$D_0$ for the flux coating method A**

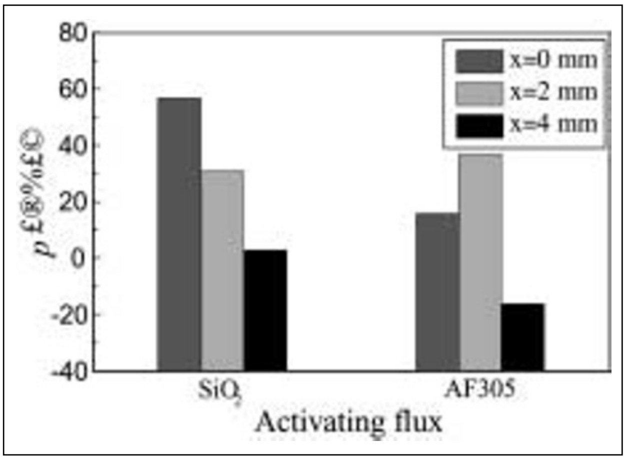


**Figure 3 – Weld deviation ratio for the flux coating method A**

in the weld deviation. So the weld deviation ratio *p* represents the current channel resistance resulting from the activating flux.

It could be found that, with $SiO_2$ flux, the weld penetration depth ratio $D/D_0$ and the weld deviation ratio *p* decreased with increasing of the flux gap (*x*). When the flux gap (*x*) was small, 0 mm for example, the weld penetration increased much and the weld moved to the side without flux. When the flux gap *x* was big, 4 mm for example, the weld penetration was lower compared with that of the conventional TIG welding and there was hardly any weld deviation. With AF305 flux, the weld penetration depth ratio $D/D_0$ was not uniform with increasing of the flux gap (*x*), while the weld deviation ratio (*p*) changed with a complicated tendency. When the flux gap is 4 mm, it is very surprising that the arc and the weld moved to the side with flux.

This indicated that the introduction of $SiO_2$ flux could increase the current channel resistance during activating TIG welding while the effect of AF305 flux on the current channel resistance was very complicated. In the whole, the effect of AF305 flux on the increase of current channel resistance was smaller than that of $SiO_2$ flux.

### 3.2 Results for the flux coating method B

TIG welding process with the flux coating method B is also called as FBTIG welding by French scholars S. Sire and S. Marya. Figure 4 shows the weld cross-sections with $SiO_2$ and AF305 flux, and the flux gaps (*x*) chosen are 4 mm and 8 mm respectively. Figure 5 shows the corresponding weld penetration depth ratio $D/D_0$. It could be found that, with both $SiO_2$ flux and AF305 flux, the weld penetration for flux gap of 4 mm were deeper than that for flux gap of 8 mm. With the same flux gap, the weld penetration with AF305 flux are much deeper than that with $SiO_2$ flux.

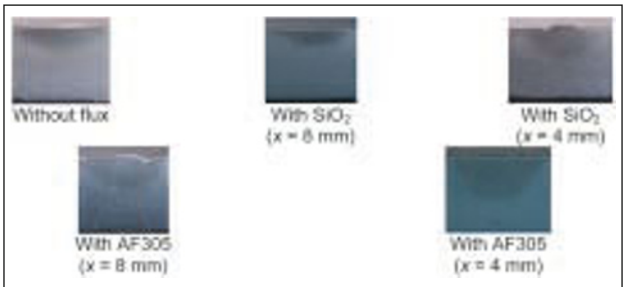


**Figure 4 – Weld cross-section for the flux coating method B**

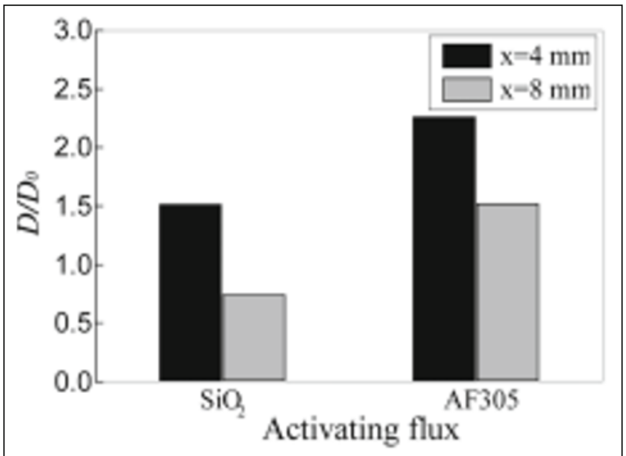


**Figure 5 – $D/D_0$ for the flux coating method B**

### 3.3 Results for the flux coating method C

TIG welding process with the flux coating method C is normally called as A-TIG welding. Figure 6 shows the weld cross-sections using the flux coating method C with $SiO_2$ and AF305 fluxes respectively. From this figure, it could be found that the weld penetration with AF305 flux was deeper obviously than that with $SiO_2$ flux. The weld penetration in A-TIG welding were deeper than that in FBTIG welding and that without flux. Especially with AF305 flux, the weld penetration increased up to 3.14 times compared with that of the conventional TIG welding.


**Figure 6 – Weld cross-sections for the flux coating method C**

## 4 DISCUSSION

Many studies on the mechanism improving weld penetration with surface activating fluxes in A-TIG welding with DC mode have been made. It is believed that there are two aspects leading flux to improve weld penetration, the first one is arc root constriction, and the second is change of surface tension gradient.

Due to a thin layer of refractory aluminium oxide on the surface of aluminium alloy, TIG welding process with AC mode is required to welding aluminium alloys normally. From the results above, it was found that the improvement of weld penetration was only observed when the flux gap was much smaller than the weld. This indicated that, because of the high specific heat capacity and heat conductivity of aluminium alloys, arc constriction could not improve weld penetration unless the scale of arc constriction was large enough to compensate for the heat loss for the introduction of flux.

Figure 7 shows the weld surface appearances for the flux coating method A, B and C respectively. For the flux coating method A, flux particles only existed on the side with flux for both $SiO_2$ and AF305, which indicated that there was not an inward fluid flow on the surface of welding pool. In FBTIG welding, the arc was limited by flux and the flux gap represented the scale of limitation. For $SiO_2$, because of higher melting and boiling temperature and higher electrical resistivity, when the flux gap was small enough, the arc was limited within the flux gap and the arc root constriction was the main reason

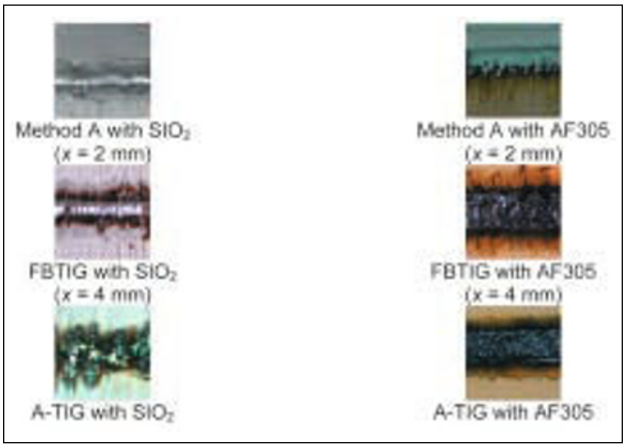


**Figure 7 – Weld surface appearances for the flux coating method A, B and C**

resulting in the increase of weld penetration. For AF305, because of lower melting and boiling temperature and lower electrical resistivity compared with $SiO_2$, the arc could not be limited within the flux gap. A possible inward fluid flow in the surface of welding pool brought the activating flux particles into the cental region. When there were many black particles on the surface, the surface would be divided into many micro-sections, only in which metal vaporation could take place. This could result in the decrease of arc spot area and increase of arc force. The inward fluid flow in the welding pool and the formation of arc spot in the micro-sections could improve the weld penetration simultaneously. In A-TIG welding, the similar mechanism as that in FBTIG welding results in the increase of weld penetration.

## 5 CONCLUSION

Through the experiments and discussions above, the conclusions can be obtained as follows:

(1) For the three types of flux coating methods A, B and C, the method C (namely A-TIG) is the most effective one to increase weld penetration.

(2) In A-TIG welding, the weld penetration with AF305 flux developed by our group increases over three times compared with that of the conventional TIG welding, it is much deeper than that with $SiO_2$ flux.

(3) In FBTIG welding, the weld penetration decreases with increasing of the flux gap ($x$). When the flux gap is the same, the weld penetration with AF305 flux is much deeper than that with $SiO_2$ flux.

(4) In activating TIG welding with AC mode, $SiO_2$ flux has a bigger effect on the increase of current channel resistance than that with multi-component flux AF305.

(5) When there exists black particles of activating fluxes on the whole weld surface, the weld penetration is deeper.

## REFERENCES

[1] Paskell T., Lundin C., Castner H.: GTAW Flux Increases Weld Joint Penetration, Welding Journal, 1997, 76 (4), 57-62.

[2] Howse D.S., Lucas W.: Investigation into arc constriction by active fluxes for tungsten inert gas welding, Science and Technology of Welding and Joining, 2000, 5 (3), 189-193.

[3] Tanaka M., Shimizu T., Terasaki H., Ushio M., Koshiishi F., Yang C.-L.: Effects of activating flux arc phenomena in gas tungsten arc welding, Science and Technology of welding and Joining, 2000, 5 (6), 397-402.

[4] Zhang Ruihua, Fan Ding: Weldability of Activating Flux in A-TIG Welding for Mild Steel, Transactions of The China Welding Institution, 2003, 24 (1), 85-87, 90. (In Chinese).

[5] Fan Ding, Gu Yufen, Zhang Ruihua: Experimental study of A-TIG procedure of carbon steel, Welding & Joining, 2002 (2), 16-19. (In Chinese).

[6] Zhang Ruihua, Fan Ding: Study of Weldability of Activating Flux for A-TIG Welding of Stainless Steel, Journal of Gansu University of Technology, 2002, 28 (2), 12-14. (In Chinese).

[7] Fan Ding, Nakata K., Tanaka M., Ushio M.: 2003 APIC: YAG Laser Welding of Stainless Steels with Surface Activating Flux, Asian Pacific International Congress, 1-6. Suntec Singapore International Convention and Exhibition Centre, Singapore: IIW.

[8] Zhang Ruihua, Fan Ding: Activated Electron Beam Welding, Journal of Gansu University of Technology, 2002, E-6 (1), 13-16.

[9] Sire S., Marya S., T. Ohji: New Perspectives in TIG Welding of Aliuminium through Flux Application FBTIG Process, Proc. of the 7th Int Symp., 2001, 113-118. Kobe Japan: JWS.