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Determining the Optimal Amount of Oxide Flux in A-TIG Welding of HSLA-100 Steel

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1- Introduction

The increasing demand for materials with optimum performance for use in construction and military applications has led to the development of high strength low alloy steels [1]. High strength and low-temperature toughness of low-alloy steel HSLA-100 have made this type of steel an ideal candidate for the replacement of HY-100 steel in marine and construction applications. Moreover, due to the lower carbon content of the HSLA-100, this steel has a better weldability than HY-100 steel, which results in lower cost of construction due to elimination of preheating process [2, 3].

Tungsten inert gas (TIG) welding is most commonly used method for welding of thin sections of ferrous and nonferrous alloys. High quality welds with proper mechanical properties are the main advantages of TIG welding. This process extensively used for sheet and tube welding in the nuclear industry, aerospace, power generation and shipbuilding industries. Low welding speed and weld penetration are the main limitations of TIG welding. Therefore, full penetration welding is restricted to joints thickening up to 3 mm [3-7].

Active flux TIG (A-TIG) is a novel modification of the TIG process that increases the penetration of TIG welds resulting in enhancement of productivity. This process was developed for the welding of titanium in the Paton institute of electric welding in the 1960s [8-9]. In this process, a suspension of the activating flux in acetone or ethanol is applied on the joint surface before welding. Therefore, due to acetone evaporation, a thin layer of flux left on the surface of the weld joint, and then autogenous TIG welding carried out [3 & 9-12].

2- Experimental procedure

In this investigation, the used samples were HSLA-100 steel plates of 100 × 100 × 5.4 mm^3. The chemical compositions and mechanical properties of the samples are shown in Tables 1 and 2, respectively. To remove all impurities, prior to welding the surface of each specimen ground off with abrasive paper subsequently degreased with acetone.

Table. 1 Chimical compostions (wt% balance Fe) of HSLA-100 Steel plates

C	Si	Mn	P	S	Cr	Mo	Ni	Cu	Nb	Ti	V	N
0.061	0.27	0.82	0.005	0.008	0.71	0.71	3.35	1.7	0.044	0.015	0.014	0.013

In present study, TiO_2 and SiO_2 compounds were used as the activated flux. The active flux consisted of the powders that mixed with solvent (8 g powder was mixed into 200 ml acetone) to produce a paint-like consistency.

Table. 2 Mechanical properties of HSLA-100 steel plates

Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)
707	859	22

To achieve accurate results, the flux coating should be applied uniformly on the surface of the specimens. So, fluxes applied by controlled spray method. In order to evaluate the effect of flux content on the surface layer depth and depth to width ratio (D/W), different flux densities were used.

Table.3 shows the welding conditions used in present study.

Table. 3 Welding conditions of experiments

Electrode				Shielding gas		Welding parameters		
Type	Diameter (mm)	Tip angle	Polarity	Type	Flow rate (l/min)	Current (A)	Travel speed (mm/s)	Arc length (mm)
W-2%ThO_2	3.2	60°	DCEN	Argon	10	150	2	3

3-Result and discussion

1. Effect of surface fluxes density on weld geometry

As shown in Fig.1, The D/W ratio for both fluxes initially increased sharply with increasing the surface flux density and subsequently became approximately constant. In common TIG welding, that surface flux density is zero, weld D/W ratio is about 0.36. Conversely, in activated TIG welding of HSLA-100 steel with SiO_2 and TiO_2 fluxes, maximum D/W ratio were 1.14 and 0.51 respectively.

Thus, by using SiO_2 flux with a surface flux density of 36.9 mg/cm2, the D/W ratio increased up to 200%. In other words, using SiO_2 as a flux not only increased the D/W ratio in comparison with conventional TIG but also, improved the productivity. Fig.2 shows the variation of penetration depth with surface flux density in A-TIG welding of HSLA-100 steel plates. As can be seen, maximum penetration of 6.2 mm for A-TIG obtained, where the SiO_2 surface flux density ranged between 5-10 mg/cm^2.

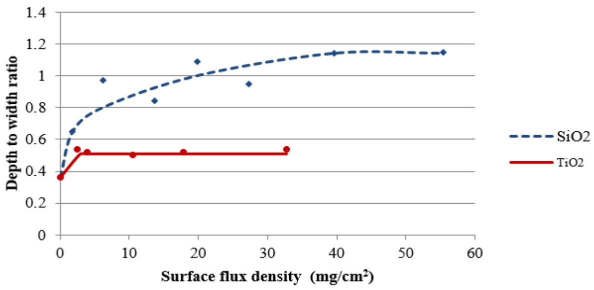

Fig.1. Effect of surface flux density on depth to width ratio

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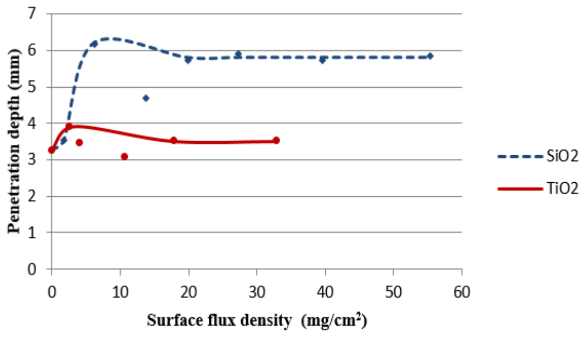

Fig.2. Variation of penetration depth with surface flux density in A-TIG welding of HSLA-100 steel plates

Based on the previous studies, the oxygen content in the weld, due to decomposition of oxide fluxes, changed the weld penetration. The weld penetration in TIG welding is determined by the liquid pool convection mode. With increasing oxide fluxes, dissolved oxygen in the weld metal increased. As a result, with increment of temperature and oxygen content, the temperature coefficient of the surface tension (i.e., Marangoni convection) increased, and then in a certain amount of oxygen, changed from negative to positive (i.e., reverse Marangoni convection). In this situation, a relatively deep and narrow weld produced [15].

2. Effect of surface flux density on arc voltage

In order to evaluate the effect of SiO2 and TiO2 oxide fluxes on the arc voltage, TIG welding of HSLA-100 steel plates was performed, while different types of surface oxide fluxes applied with variable densities. The other parameters of welding (e.g., welding current, travel speed, arc length and gas flow rate) were kept constant. Fig. 3 shows the variation of arc voltage with surface flux density in A-TIG welding for SiO_2 and TiO_2 oxide fluxes. As shown in Fig.3, it can be found out that with increasing SiO_2 surface flux density, the arc voltage increased sharply, and then reduced. Comparing to the conventional TIG welding, where the arc voltage is equal to 12.9 V, with increasing the SiO_2 flux density the arc voltage reached to 17 V, while it decreased to 12 V with increment of TiO_2 flux density. Side views of arc in TIG and A-TIG welding with different SiO_2 surface flux illustrated in Fig. 4 (a-e). As can be seen in Fig. 4 (b-d), by using SiO_2 flux, obvious arc deflection toward rear of arc moving direction was observed while this phenomenon did not occur while TiO_2 flux was used (Fig. 4e). SiO_2 is a non-metallic oxide with higher electrical resistivity than TiO_2 that is a metal oxide. Therefore, a conductive channel formed between tungsten electrode tip and the workpiece, when the flux became either liquid or vaporized. SiO_2 flux evaporation behind the welding arc stretched the welding arc back toward the molten pool caused the enhancement of the effective length of the arc and the arc voltage. As can be seen in Fig. 4.c and d, by increasing SiO_2 flux, the arc stretching towards the rear of the electrode become higher. Increasing of surface flux density prevented the arc to establish, and higher energy is required to overcome the flux barrier leading to the arc length increase. TiO_2 flux has a better conductivity and smaller electrical resistance than SiO_2, therefore the conductive channel established easily between tungsten electrode tip and the workpiece.

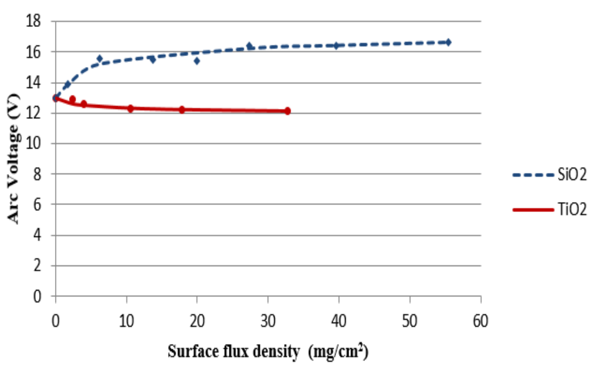

Fig.3. variation of arc voltage with surface flux density in A-TIG welding for SiO_2 and TiO_2oxide fluxes.

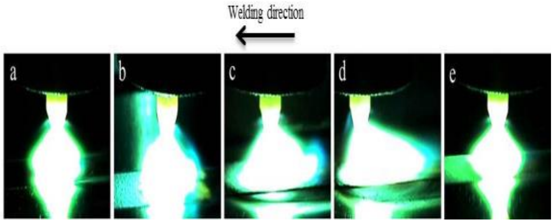

Fig.4.Side views of arc in TIG and A-TIG welding; (a) conventional TIG, SiO_2 with surface flux density of (b) 1.8, (c) 6.2, (d) 27.3 and TiO_2 2.5 mg/cm^2.

4- Conclusions

In present study an activated-flux assisted TIG welding of HSLA-100 steel was investigated. The D/W ratio for both fluxes initially increased sharply, with increasing of surface flux density, and subsequently became approximately constant. The maximum penetration of 6.2 mm for A-TIG obtained for SiO_2 flux in which the density ranged between 5.5-10 mg/cm^2.