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Technical Paper

Effect of oxide-based fluxes on mechanical and metallurgical properties of Dissimilar Activating Flux Assisted-Tungsten Inert Gas Welds

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ABSTRACT

Present investigation is to study the "Effect of Activating Fluxes on Mechanical and Metallurgical Properties of Dissimilar Activated Flux-Tungsten Inert Gas Welds". Effect of current, welding speed, joint gap and electrode diameter on weld bead dimensions on 6 mm thick dissimilar weld between carbon steel to stainless steel, was studied under Activated Flux-Tungsten Inert Gas Welding process. During this investigation three different types of oxide powders were used-TiO_2, ZnO and MnO_2. After welding samples were subject to mechanical testing, in addition to characterization via micro hardness and microstructures of Normal Tungsten Inert Gas Welds and Activated Flux-Tungsten Inert Gas Welds. Activating fluxes TiO_2 and ZnO are effective fluxes for Activated Flux-Tungsten Inert Gas Welding of dissimilar weld between CS to SS. Highest depth/width (D/W) ratio reported under TiO_2 and ZnO fluxes compare to Normal-Tungsten Inert Gas Welds. Lowest angular distortion was observed under TiO_2 flux compare to Normal-Tungsten Inert Gas Welds. Mechanical properties, Joint Efficiency of Activated Flux-Tungsten Inert Gas Welds are higher than normal-Normal Tungsten Inert Gas Welds. Tensile Test specimens of both the processes failed from the parent metal (carbon steel side). Carbon migration from CS to SS, had occurred which led to failure of weld joints from CS side.

1. Introduction

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding which uses an arc between a non consumable tungsten electrode and the workpieces to be welded under a shielding gas is an extremely important arc welding process. It has become a popular choice of welding process when a high level of weld quality or considerable precision welding operation is required. However the potential problems of TIG welding process lie in the limited thickness of material which can be welded in a single pass, poor tolerance to some material composition and the low productivity. If the welding current is increased in an attempt to increase the penetration, the weld becomes excessively wide with proportionally little gain in the penetration [1,5].

Improvements in the penetration have long been sought in many arc-welding processes. One of the most notable techniques is the use of activating flux in TIG welding process. Activated tungsten inert gas (A-TIG) welding process that increases the penetration was first proposed by Paton Electric Welding Institute in the 1960s [2,3]. Activating flux is a mixture of inorganic material suspended in a volatile medium. A thin layer of flux is applied on the surface of the joint to be welded by brush before welding [4,5]. The United States Navy Joining Center has been successfully used in everyday production to reduce the cost and improve the quality of Navy ships and aircraft, using A-TIG technique that was developed by Edison Welding Institute. A-TIG technique makes it possible to intensify the conventional TIG practices for joining the thickness of 8–10 mm by single pass full penetration welds, with no edge preparation, instead of multipass procedures. In fact, the penetration capability is up to 300% compared with the conventional TIG welding process, and the heat-to-heat variations in base metal compositions can be avoided when using the activating flux [5].

Dissimilar metal welding is frequently used to join stainless steels to other metal alloys. This approach is most often used where a transition in mechanical properties and/or performance in service are required. For example, austenitic stainless steel piping is often used to contain high-temperature steam in power generation plants. Below a certain temperature and pressure, however, low-carbon and low-alloy steels perform adequately, and a transition from stainless steel to other steels is often used for economic purposes. Most stainless steels can be successfully

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Table 1
Chemical compositions of SA516 Gr70 carbon steel and stainless steel (SS 304) materials.

Materials	Alloying elements										
	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	V	Al
CS	0.186	0.32	1.11	0.014	0.009	0.033	0.026	0.03	0.019	0.001	0.02
SS	0.064	0.250	1.020	0.025	0.006	–	8.20	18.45	0.021	–	–

welded to low-carbon and low-alloy steels. Consideration must be given to the effects of dilution of the weld metal with the two base metals and the different coefficients of thermal expansion in stainless steel and low-carbon or low-alloy steels [6].

LI Qinq-ming et al. reported that when using SiO_2, arc voltage increased. As the current increases, more and more SiO_2 powder is evaporated, thus the arc voltage is similar to the no flux state. However when using TiO_2, the arc voltage has no obvious change [4].

S.W. Shyu et al. investigated that TIG welding arc with SiO_2 shows a constriction in plasma column diameter compared with the conventional TIG welding arc at the same current level. Constriction of the plasma column increases the current density in the arc root, and a more focused arc increase in A-TIG penetration can be achieved compared with the conventional TIG welds [5].

Research papers are available in the area of application of activating fluxes for various ferrous, non ferrous and dissimilar materials using various arc welding processes like TIG [3–7], Gas Metal Arc Welding (GMAW) [10], Plasma Arc Welding (PAW) [11], Laser Beam Welding (LBW) [12] and Electron Beam Welding (EBW) [13] processes. There is only one investigation available, which highlights the application of the fluxes on Depth of Penetration (DOP), weld width, depth (D)/width (W) ratio in GTAW processes for dissimilar welding of carbon steel to stainless steel [6].

Cheng Hsien Kuo et al. reported that, the TIG welding without flux which produced a smooth and clean surface as compared to with flux. CaO, Fe_2O_3 and Cr_2O_3 fluxes produced excessive slag and less slag obtained under SiO_2. TIG welds without flux exhibited a wide and shallow morphology as compared with fluxes such as Fe_2O_3, Cr_2O_3 and SiO_2 which gave narrow and deep morphology. The CaO flux powder had no significant effect on penetration of TIG welds [6].

H.Y. Huang et al. reported that TIG flux welding can increase the arc voltage, the amount of heat input per unit length in a weld is also increased, and therefore the retained δ ferrite content in austenitic stainless steel welds will be increased. As a result, the hot cracking susceptibility in as welded structures is reduced. TIG flux welding can increase the weld depth/width ratio and reduce the HAZ range, which are characteristics of a high degree of energy concentration during the TIG flux welding process; the angular distortion of austenitic stainless steel weldments can therefore be reduced [7].

Kuang-Hung Tseng reported that for conventional TIG welds, the depth of finger-like penetration increases with the weld current because of the induced strong arc pressure. The arc pressure also raises the penetration capability of activated TIG welds. Full penetration and the maximal weld depth-to-width ratio result in the lowest angular distortion of the activated TIG weldment. This is because the arc heated the weld metal more evenly throughout the thickness of the weldment [14].

Double-sided arcing uses two torches on the opposite sides of the workpiece to force the welding current to flow through the thickness. If a keyhole is established through the thickness, part of the welding current will flow through the keyhole and maintain the electric arc inside the keyhole. It was reported that the through thickness direction of the welding current and the establishment of a keyhole both helped enhance the concentration of the arc and the density of the arc energy [16].

The keyhole DSAW process has proven capable of achieving deep, narrow joint penetration on square-groove, thick stainless steel plates up to 1/2-in. in a single pass. Keyhole DSAW reduces heat input into the work piece by at least 70% in comparison with regular keyhole PAW, which achieves the deepest and narrowest penetration at the least heat input of all existing arc welding processes as reported by authors. In other words, keyhole DSAW requires only 30% of the heat input needed by keyhole PAW. Welds produced by keyhole DSAW are less than 1 mm wider than those produced by the laser process. Keyhole DSAW tends to increase the amount of the desirable equiaxed grains in the solidified welds [16].

From the present experiment, the effect of three different oxide powders (TiO_2, ZnO and MnO_2) on dissimilar joints between carbon steel (CS) and stainless steel (SS) was studied, to determine relationship between weld bead penetrations and weld bead width.

2. Experimental procedure

The chemical compositions and mechanical properties of CS and SS are given in Tables 1 and 2 respectively.

Present investigation is to study the effect of activating fluxes on dissimilar joint of CS to SS. Initial trials were conducted to study the effect of activated fluxes (oxide powders) under 100% Argon gas shielding on weld bead dimensions (includes depth of penetration, bead width, depth to width ratio) at 200 amps. Plate thickness of 6 mm were cut into strip forms (100 mm × 50 mm), which were roughly polished (top of the plate as well as butting surfaces) with 120, 320 grit (silicon carbide) flexible abrasive papers to remove surface impurities, and then cleaned with acetone just before welding. Activating fluxes were prepared using the three different types oxide fluxes (TiO_2, ZnO and MnO_2) by mixing them with acetone, and a layer less than 0.2 mm thick was applied on the surface of the joint by mean of brush (15 mm width) just before TIG welding. Following experiment was conducted to study effect of activated fluxes on weld bead dimensions (depth of penetration, bead width, depth to width ratio).

An autogenous TIG welding was conducted on dissimilar metals to produce bead on plate welds. Welding variables are as follow [3,5, 6, and 7].

Electrode diameter:	3.0 mm with 2% thoriated tungsten electrode
Electrode tip angle:	60°
Welding current:	200 amps
Travel speed:	55 mm/min
Arc gap:	2 mm
Shielding gas:	Pure Argon (99.999)
Gas flow rate:	12 lit/min
Joint design:	Open Square Butt
Root gap:	1.5 mm
Material:	CS to SS (6 mm)
Filler metal:	No Filler metal was used; Autogenous welds

Table 2
Mechanical properties of SA516 Gr70 carbon steel and stainless steel (SS 304) materials.

Materials	Mechanical properties		
	YS	UTS	% EL
CS	382 Mpa	550 Mpa	24%
SS	290 Mpa	624 Mpa	56%