HEURISTIC STUDY OF SINGLE COMPONENT AND BINARY FLUXES ON THE DEPTH OF PENETRATION IN A-TIG WELDING OF INCOLOY 800H AUSTENITIC STAINLESS STEEL

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Abstract— A-TIG welding differs from conventional TIG welding process by the way of employing a thin layer of flux in the area to be welded. The flux can be a single component salt or a mixture of multiple salts. Usually these salts are of oxides, chlorides or fluorides. Use of these fluxes improves depth of penetration by two to three times in relation to the depth of penetration that can be achieved by conventional TIG welding. Though several mechanisms have been proposed for the improvement in depth of penetration, arc constrictions and/or reversal of Marangoni forces are considered as major influencing factors. The present aims to study the effect of single component fluxes viz., SiO2, ZnO and a combination of SiO2 and ZnO on the weld bead geometry in TIG welding of Incoloy 800H austenitic stainless steel. To study the effect of combination of these salts as flux mixture on the bead geometry several ternary flux mixtures were designed and used in producing autogenous TIG melt runs.

***Index Terms* :TIG welding, Incoloy 800H austenitic, SiO_2, and TiO_2 fluxs, metallography**

1. INTRODUCTION

The TIG welding is one of the main arc welding processes, in which the necessary heat for welding is generated by maintaining an arc between a refractory tungsten electrode and the base metal to be welded. The electrode, the arc, and the area surrounding the molten metal are protected from atmospheric contamination by an envelope of inert gas during heating and subsequent cooling. TIG welding is one of the cleanest and the most decorative weld joint surface producing welding procedure. Its carrier started during the Second World War, when it became a real mass production procedure. But the relations of that time had been changing by the second third of the century due to the introduction of new and higher productivity welding procedures (for example MIG/MAG, laser and electron beam welding). Low productivity results from a combination of the low welding speed and the multipass welding procedure for thick section plates or heavy wall pipe materials. Additional costs are incurred through edge preparation and substantially longer welding time because several passes with filler metal are required to fill the groove joints Apart from this the quality of TIG welding did not change any. Improvements in productivity in TIG welding technology have long been sought in the welding community. This demand has led to a so-called flux assisted TIG (TIG-flux)or A-TIG(Activated TIG) welding, a modified TIG welding process that uses flux compounds, such as oxide, chloride, or fluoride to overcome the limitations by increasing joint penetration using a single-pass operation without any edge preparation.

Welding is the process of permanently joining two or more metal parts, by melting both materials. The molten materials quickly cool, and the two metals are permanently bonded. This is often done by melting the workpieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the workpieces to form a bond between them, without melting the workpieces. Arc welding processes, which are very popular in welding techniques, maintains an electric arc between an electrode and the base material to melt metals at the welding point, by utilising a welding power supply. They can use either direct (DC) or alternating (AC) current, and consumable or non-consumable electrodes. The welding region is sometimes protected by some type of inert or semi-inert gas, known as a shielding gas, and filler material is sometimes used as well.

Tungsten Inert Gas welding (TIG welding) or Gas–tungsten arc welding (GTAW) is a fusion welding process that melts and joins metals by heating them with an arc established between a non-consumable tungsten electrode and the metals. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. As no slag is produced, the chance of slag inclusions in the weld metal is eliminated and the finished weld requires virtually no cleaning. The tungsten electrode is usually in contact with a water-cooled copper tube, called the contact tube, which is connected to the welding cable from the terminal.

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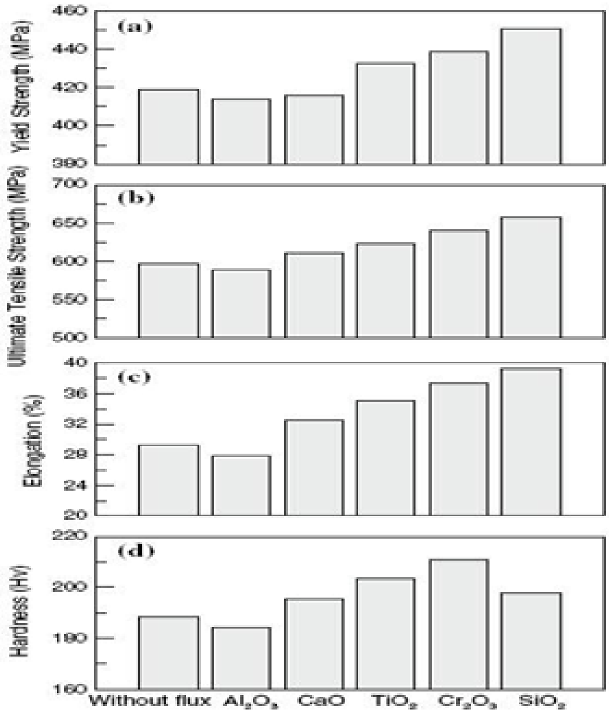
Alternating current, commonly used when welding aluminium and magnesium manually or semi-automatically, combines the two direct currents by making the electrode and base material alternate between positive and negative charge. This causes the electron flow to switch directions constantly, preventing the tungsten electrode from overheating while maintaining the heat in the base material. GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminium, magnesium, and copper alloys.

To study the effect of multi component fluxes, three oxide fluxes are selected. Studies on the effect of 32 oxide fluxes on A-TIG welding of stainless steel have shown that TiO_2 and SiO_2 are the best performing fluxes when considering depth of penetration.

Effect of oxide fluxes on mechanical properties



2. METHODOLOGY

Study of the Performance of Stainless Steel A-TIG Welds using five different oxide fluxes (Al_2O_3, Cr_2O_3, TiO_2, SiO_2 and CaO) shows that increases in weld depth and the decrease in bead width are significant with use of the TiO_2 and SiO_2. The greatest improvement function in the penetration is with the use of SiO_2. A-TIG weldment exhibits better mechanical properties (including strength, ductility, and hardness) than those of TIG welding without flux as shown in the Fig.

When TIG welding with TiO_2 and SiO_2 is used, the retained delta-ferrite content in weld metal is increased. A certain amount of retained delta-ferrite in austenitic stainless steel weld metals has a beneficial effect in reducing the hot cracking susceptibility. The result clearly indicates that the hot cracking susceptibility of stainless steel 304 as-welded can be reduced when certain flux was applied to TIG welding process.

Thus, with the use of SiO_2, and TiO_2 as single component activating fluxes in A-TIG welding, greatest improvement in depth of penetration, better mechanical properties and good microstructure were observed. Because of above reasons we selected these fluxes for our investigation on A-TIG welding along with Zno, CaO and Fe_3O_4.

The main objectives of the present work are listed below:

1. To successfully carry out the Tungsten Inert Gas welding process on the Incoloy 800H plates with the application of fluxes as well as flux combinations as well as without application of flux.
2. To compare the effect of each activating flux in varying the depth of penetration of weld
3. To study the metallurgical aspects of the weld samples using Optical microscopy.
4. To study the metallurgical aspects of the weldments using Scanning Electron Microscopy technique with EDS.

SELECTION OF MATERIAL AND ITS PROPERTIES

Material selected for present work is Incoloy 800H (UNS N08810, Fe-31Ni-20Cr). Incoloy is a family of austenitic nickel-chromium-based super alloys with a mean grain size greater than ~70 µm in diameter. Inventors of these alloys were Special Metals Corporation Group of Companies and they were introduced to market in 1950's. The mechanical properties of INCOLOY alloys 800H combined with their resistance to high-temperature corrosion make these alloys exceptionally useful for many applications involving long-term exposure to elevated temperatures and corrosive atmospheres. It is a solid–solution-strengthened alloy with additional strengthening by precipitation of titanium nitrides and carbides such as MC (rich in Ti) and $M_{23}C_6$ (rich in Cr). The 800 series of alloys were introduced to the market in the 1950s to fill the need for a heat- and corrosion-resistant alloy with relatively low nickel content since nickel was, at the time, designated a "strategic" metal. Over the past forty years it has been widely used for its strength at high temperatures and its ability to resist oxidation, carburization, and other types of high-temperature corrosion. Applications include furnace components and equipment, petrochemical furnace cracker tubes, pigtails and headers, and sheathing for electrical heating elements. In 1963, the alloy was approved by the ASME Boiler and Pressure Vessel Committee, and the design stresses were published in Code Case 1325.

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Process Parameters of Incoloy 800H

Weld current	100 A
Travel speed	0.83 mm/sec
Diameter of electrode	3.2 mm
Tip angle of electrode	45°
Shielding gas	argon
Gas flow rate	12.5 l/min

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Then the specimens were etched in a solution composed of15 ml HCl + 10 ml HAC + 10 ml HNO3 in order to use for metallographic analysis. Four such specimens were prepared from welded specimen using flux as well as without flux

Welding parameters

Welding speed	150 mm/min
Polarity	DCEN
Welding current	140 A
Shielding gas	99.9% Pure argon
Shielding gas flow rate	12 L/min
Electrode used	3.2mm diameter,2% thoriated tungsten
Arc length	2 mm
Electrode tip angle	55 degrees
Electrode tip	Taper

MACROSTRUCTURAL AND MICROSTRUCTURAL STUDIES

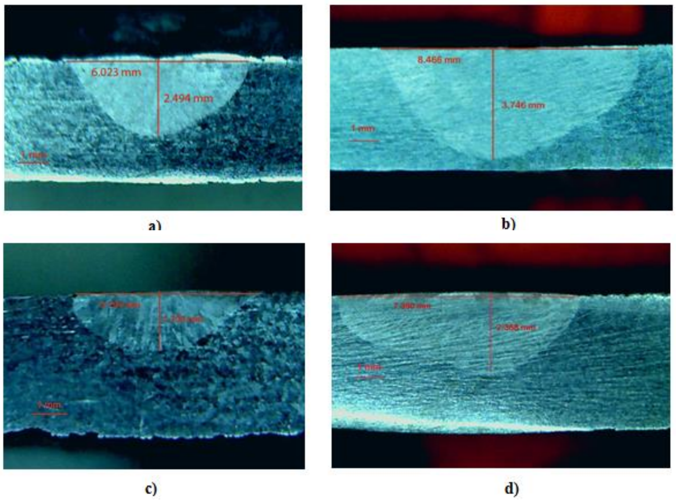
After welding, small specimens of adequate size were cut from the weld bead in the transverse direction for macroscopic and microscopic analysis. The samples were ground and polished according to the standard metallographic practice with emery papers, alumina polisher and diamond paste polisher in the order. Polished specimens were etched with reagent of following composition,

Etchant- 30 g$FeCl_3$ +10 ml HCl + 3 ml HnO_3 + 20ml H_2O for macro and micro analysis.

3. RESULTS AND DISCUSSIONS

METALLOGRAPHIC ANALYSIS

Study macrostructures of the welded specimen



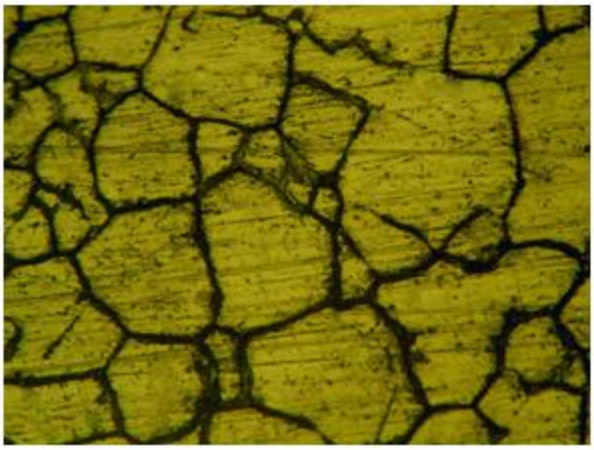
a)macrostructure of welded specimen without using flux
b) macrostructure of welded specimen using SiO_2 flux
c) macrostructure of welded specimen using ZnO flux
d) macrostructure of specimen using combination of SiO_2 and ZnO (50%-50%)

The depths of penetration obtained are tabulated as follows:

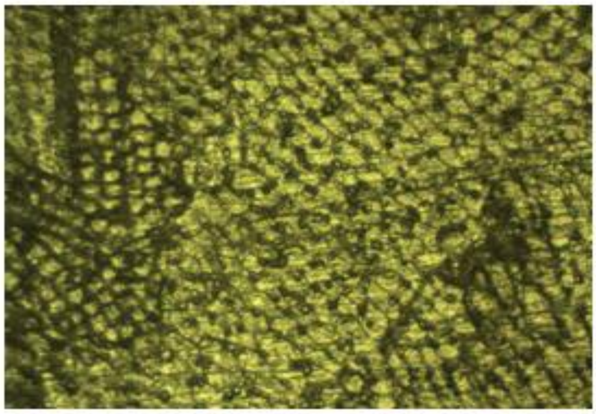
Specimen	Depth of penetration (mm)	Bead width (mm)
a) Without Flux	2.494	6.023
b) SiO_2	3.746	8.466
c) ZnO	1.706	5.194
d) SiO_2 + ZnO	2.368	7.390

It was observed that when SiO_2 activating flux was used for welding the specimen the depth of penetration was higher compared to the TIG welding without any flux. This can be related to the effect of this flux on the direction of fluid flow in the molten pool, as well as the constriction of arc during the welding process. It was also observed that use of ZnO as a flux during the welding process had a detrimental effect on the depth of penetration. It showed the lowest depth of penetration among the samples.The weld specimen welded using combination of SiO_2 and ZnO fluxes (50% each) showed a depth of penetration lower than that obtained using SiO_2 flux alone. This confirms the fact that ZnO flux has a negative effect on the depth of penetration.

Study of Microstructures



Microstructure of the base metal Incoloy 800H (magnification 200X



Microstructure of weld zone of the welded specimen without flux

The weld zone microstructure of specimen welded using combination of SiO_2 and ZnO fluxes, exhibited dendritic structures with fully developed side branches.It is known that dendritic structures are associated with a greater degree of segregation and are more prone to cracking.

So in case of TIG welding using SiO_2 higher penetration was obtained due to either reversed Marangoni convection mechanism or due to constriction of arc. In addition to it the exposure to high heat input during welding might have induced the formation of precipitation of chromium carbide,$Cr_{23}C_6$ along the grain boundary, which in turn caused chromium depletion zones in close vicinity to grain boundaries. The overall decrease in Cr content as shown by the EDS results for weld specimen using SiO_2 flux, proves the fact that sensitization has occurred in regions adjacent to the grain boundaries.

4. CONCLUSION

When SiO_2 activating flux was used for welding the specimen the depth of penetration was higher compared to the TIG welding without any flux The weld specimen welded using combination of SiO_2 and ZnO fluxes (50% each) showed a depth of penetration lower than that obtained using SiO_2 flux alone ZnO flux has a negative effect on the depth of penetration.

5. REFERENCE

[1] L.Y. Xu, P. Zhu, H.Y. Jing, K. Guo , S.X. Zhong, Y.D. Han (2013) Failure analysis of incoloy 800h at high temperatures ,Engineering Failure Analysis 31 375–386

[2] L. Tan, X. Ren, K. Sridharan, T.R. Allen (2008) Effect of shot-peening on the oxidation of alloy 800H exposed to supercriticalwater and cyclic oxidation,Corrosion Science 50 2040–2046

[3] Kuang-Hung Tseng, Chih-Yu Hsu (2010), Performance of activated TIG process in austenitic stainless steel welds, Journal of Materials Processing Technology 211 503–512

[4] Fujii, H., Sato, T., Lu, S.P., Nogi, K., 2008. Development of an advanced A-TIG (AA-TIG) welding method by control of Marangoni convection. Mater.Sci. Eng. A 495,296–303.

[5] Huang, H.Y., 2009. Effects of shielding gas composition and activating flux on GTAW weldments. Mater. Des. 30 (7), 2404–2409.

[6] Leconte, S., Paillard, P., Chapelle, P., Henrion, G., Saindrenan, J., 2006. Effect of oxide fluxes on activation mechanisms of tungsten inert gas process. Sci. Technol. Weld. Join. 11 (4), 389–397.

[7] Xu, Y.L., Dong, Z.B., Wei, Y.H., Yang, C.L., 2007. Marangoni convection and weld shapevariation in A-TIG welding process. Theor. Appl. Fract. Mec. 48, 178–186.

[8] H. Purmohamad, A . Kermanpur, M. Shamanian,2010, Numerical simulation and experimenta l investig ation of temperature distributionin the circumferentially butt GTAW of Incoloy 800H pipes,International Journal of Pressure Vessels and Piping 87 424 e 432