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EFFECT OF DIFFERENT FLUXES ON HARDNESS AND MICROSTRUCTURE OF SS 304 IN GTAW WELDING

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ABSTRACT

Gas tungsten arc welding (GTAW) is a popular technique for joining thin materials in the manufacturing industries. This type of welding achieves a high quality weld for stainless steels and non-ferrous alloys. TIG welding is fundamental in those industries where it is important to control the weld bead shape and its metallurgical characteristics. However, compared to the other arc welding process, the shallow penetration of the TIG welding restricts its ability to weld thick structures in a single pass, thus its productivity is relativity low. From the industrial point of view stainless steel 304 is a very commonly used material due to its property of resistant to corrosion and better creep rupture strength. The use of activating flux effects the different properties of the joint produced by the welding. In this work, Fe_2O_3, $MgCl_2$, MnO_2, and ZnOwere used as activating flux to investigate the effect of activated tungsten inert gas (activated TIG) process on microstructure and hardness of grade 304 stainless steels. Since the activated TIG welding showed non uniformly cooled unidirectional grains with size varying from fine to coarse in the weld zone in their microstructure characteristics. The results show that MnO_2 flux can only led to increase in the hardness (306Hv) in weld zone except the other flux used.

KEYWORDS: Activated Flux, Hardness, Microstructure, TIG Welding

INTRODUCTION

Welding is the process used to join two or more pieces of metal together by applying thermal energy or pressure. It is a precise, reliable, cost-effective method for joining materials. Thus welding is essential to produce most of usual objects from big structures such as bridges and ships, to vehicles, to microelectronic components [1]. Gas tungsten arc welding (GTAW) is a process that uses a non-consumable tungsten electrode to produce the weld. A constant-current welding power supply produces energy which is conducted across the arc through a column of highly ionized gas and metal vapors known as plasma [2]. The mixture of an organic solvent and an organic powder is known as activated flux. The TIG-flux technique intensifies the conventional TIG technique for welding to a thickness of 8–10 mm using a single-pass full penetration weld, without edge preparation instead of using multi pass welding procedures [3]. Furthermore, the sensitivity of weld shape to variations in the chemical composition of the base metals can be reduced when using the specific fluxes.

LITERATURE SURVEY

A lot of work has been done on gas tungsten arc welding process. From the literature survey, it is observed that the effects of different activated flux such as oxides, chlorides and fluorides has been studied by various researchers on angular distortion, weld penetration, weld depth to width ratio, ferrite contents, weld morphology and mechanical properties like hardness, tensile strength, ductility etc. Welding current, welding speed, gas flow rate, electrode angle and arc length are the key input parameters used by various researchers but mostly work has been done on activated flux [4]. Different researchers used the different type of materials like AISI 316L, G3131mild steel, 17Cr–10Ni–2Mo alloys, AZ61magnesium alloy, Ti-6Al-4V alloy and AZ31B magnesium alloy. Some scholars used the TiO_2, MoO_3, SiO_2, and $Al2O_3$ as an activated flux and some researchers found that FeO and FeS powders results in a substantial increase in both the joint penetration and weld aspect ratio thereby reducing angular distortion [5]. Five kinds of oxide fluxes, MnO_2, TiO_2, MoO_3, SiO_2, and Al_2O_3, were used to investigate the effect of activated tungsten inert gas (activated TIG) process on weld morphology, and hardness of SS 316L.

The experimental results indicated that the SiO_2 flux facilitated root pass joint penetration, but Al_2O_3 flux led to the deterioration in the weld depth and bead width compared with conventional TIG process. The addition of oxide flux does not significantly affect the hardness of Type 316L stainless steel activated TIG weld metal. [6]. Some researchers found the SiO_2 flux produced the better tensile strength and hardness as compare to the TiO_2 for 316L austenitic stainless steel. [7]. But still a little work is done on stainless steel 304 which is one of the most commonly used steel in manufacturing industries due to its better corrosion resistance, weldability properties and also called as “marine grade stainless steel”.

Only few researchers measured the properties like hardness, micro hardness and microstructure etc. Hardness is the most important properties used in high pressure vessels and chemical storage vessels in the fabrication industries. To increase the hardness as compare to conventional TIG welding process it is important to know which flux possesses better results. So in this experimental work, it is proposed to study the effects of surface activating fluxes ($Fe_2O_{3,}$ $MgCl_{2,}$ MnO_2, and ZnO) on hardness and microstructure by using gas tungsten arc welding (GTAW) process.

WORK-PIECE MATERIAL

Stainless steel 304 is most widely used material in fabrication industries. Stainless steel differs from the carbon steel by the amount of chromium present. Unprotected carbon steel rusts readily when exposed to air and in moisture. The mechanical properties and composition of Stainless steel 304 is shown in the table 1 and table 2 respectively.

Table 1: Mechanical Properties of Stainless Steel 304

Tensile Stress (MPa)	Yield Stress (MPa)	% Elongation	Poisson Ratio
599	285	30	0.24

Table 2: Composition of Stainless Steel 304

C	Cr	Si	P	Ni	Mn	S	Fe
0.06	18.45	0.58	0.029	8.83	1.83	0.05	Balance

Stainless steel 304 typical applications include architectural paneling, trim & railings, chemical containers, Heat Exchangers.

ACTIVATED FLUX USED

The activating flux is concerned with the liquid metal which interacting with fusion zone in arc welding process. In our welding experiment, a fine layer of activating flux like Iron Oxide ($Fe_2O_{3),}$ Magnesium Chloride ($MgCl_2$), Manganese Oxide (MnO_2), and ZnOwas applied on the surface of base metal and they show the effective results on hardness and microstructurein the welding process. The properties of different activated fluxes are shown in table 3.

Table 3: Properties of Different Activated Fluxes

Flux	$MgCl_2$	ZnO	MnO_2	Fe_2O_3
Melting point	714°C (decomposes)	1975 °C (decomposes)	535 °C (decomposes)	1566 °C (decomposes)
Density	$1570 kg/m^3$	$5600\ kg/m^3$	$5030\ kg/m^3$	$5239 kg/m^3$
Colour	Whitecrystalline solid	White	Blackish	Red/brownish
Water soluble	soluble	soluble	Insoluble	Insoluble

EXPERIMENTAL DETAIL

The base metal used in this study is austenitic stainless steel 304. The test specimens are cut from a long plate of SS 304 and measured dimensions of 100x100mm, having6 mm of thickness. Each specimen surface is rubbed with abrasive paper to remove the deposited scales on surface. Before performing the welding, cleaning is done with help of acetone. The surface activating fluxes used in this research Fe_2O_3, MnO_2, $MgCl_2$ and ZnO were in the powdered form. Prior to welding, the quantity of acetone 1.5 ml was mixed with 1500 milligram of flux powder. The paint (powder acetone mixture) is applied on the central line of each plate with the help of a paint brush in the form of a layer. The thickness of paint layer is so sufficient that a visual observation is made on to the surface of base metal. The thickness of flux layer remains constant 0.2 mm. The appearance of prepared specimen with active flux layer is shown by figure 1.

Figure 1: Schematic Representation of Activated Flux

Flux layer thickness = 0.2 mm

Coating density of activated flux =1.5 mg/ cm^2

WELDING MACHINE SET-UP

The TIG welding machine having model ‘TIG ESAB 400’ was used for the experimental work located at Steel Arcthitect Limited, Ambala Cantt. The direct current electrode negative (DCEN) mode is used with a mechanized operating system in which the torch travels at a constant speed. Single-pass, auto genous, bead-on-plate TIG welds are used along the center line of the test specimens. Auto genous welds are made as close to the centre of samples as possible. The electrode tip is a blunt point with a 45° angle. Argon of 99.99% purity is used as shielding gas. The tip angle of the electrode is grounded and the electrode gap is measured for each new weld prior to welding to ensure that the welding is performed under the same operating conditions. The gas flow rate of 10 lit/ min is constant during this research work. The bead on the plates is traced along the centre line of the specimen. The welding speed of torch is 2.3 mm/sec throughout the whole procedure. The constant welding current is used in this work of 150 Amp and the arc length used in it of 2 mm. The weld is allowed to cool before further work.

VICKERS HARDNESS TESTER&MICROSCOPE FOR MICROSTRCTURE

The Vickers Hardness test is a hardness measurement based on the net increase in depth of impression as a load is applied. The Hardness numbers have no units and are commonly given in the (25 Hv- 1300 Hv) scales. The higher the number in each of the scales means the harder the material. Hardness has been variously defined as resistance to local penetration, scratching, machining, wear or abrasion and the yielding. In the Vickers method of hardness testing, the depth of penetration of an indenter under certain arbitrary test conditions is determined shown in figure 2. The Vickers test has two distinct force ranges, micro (10g to 1000g) and macro (1kg to 100kg), to cover all the testing requirements.

Figure 2: Vickers Hardness Tester

The metallurgical microscope is used for the measurement of the microstructure of weld bead geometry for the specimen in this research work. The Axio observe MAT inverse microscope (Carl Zeis Micro imaging GMBH, Germany) is used for microstructure observation. The range of magnification power of this microscope varies from X50 to X1000. The metallurgical microscope is shown in figure 3.

Figure 3: Metallurgical Microscope

PREPARATION OF SPECIMEN FOR TESTING HARDNESS AND MICROSTRUCTURE

For hardness test, base metal is cut out from the specimens and filling is provided to the samples. After filling, the samples were carried out for finishing by the emery paper and buffing process. For hardness test of the weld bead specimen was cut out on the power hacksaw. The specimens were cut in such a way that the weld bead remains in the center and a good grip can be provided by the hand for the further operations. Then a filing operation is provided to all the faces of the weld bead sample. In this we use emery paper of grade 4. By finishing process, a very neat and clean surface is obtained in which hardness is to be determined.

For microstructure, after welding the surfaces of the weld pieces are finished by filling. Then a filling operation was provided to all the faces of the weld bead sample. After filling by the help of emery paper the finishing process has been carried out. In this we use emery paper of grade 2. By this process, a very neat and clean surface was obtained on which microstructure is to be seen. The polishing process was carried out by the help of grinding wheel with diamond grit on the face. After the buffing process, etching process was carried out. Etching is the process in which NITAL solution is sprayed on the test pieces. NITAL solution is prepared by mixing out the 2% nitric acid and the 98% methanol. By doing so weld bead and the heat affected zones are clearly visible due to which it becomes very easy to find out the microstructure of the weld.

Figure 4: Specimens for Microstructure Measurement

RESULTS AND ANALYSIS

The effect of different surface activated flux on micro hardness has been taken from the test report. The results show that the oxide and chloride flux does not produce a significant change in hardness of SS 304 except manganese oxide flux. The austenite has a cubic face-centered (FCC) crystal structure. The delta-ferrite has a body-centered cubic (BCC) crystal structure. The BCC structure has a higher mechanical strength than that of the FCC structure. When TIG welding with or without flux is used, the delta-ferrite content in the weld metals is increased and has a beneficial effect in increasing the hardness of stainless steel weld structure. Figure 5 shows the hardness profile of SS 304 TIG weldment produced with and without flux. The average value hardness of base metal is estimated as 269 Hv, whereas the average value of hardness for weld metal is found 272 Hv. The MnO_2 flux produced highest hardness at weld metal zone of 306 Hv whereas remaining flux like ZnO, Fe_2O_3 and $MgCl_2$ gives values 266 Hv, 212 Hv and 285 Hv respectively.

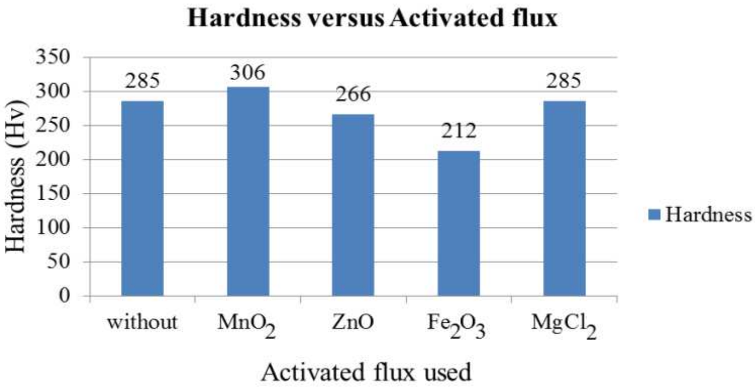

Figure 5: Effects of Activated Flux on Hardness

The microstructure of specimens with and without different kind of fluxes is shown in figure 6.

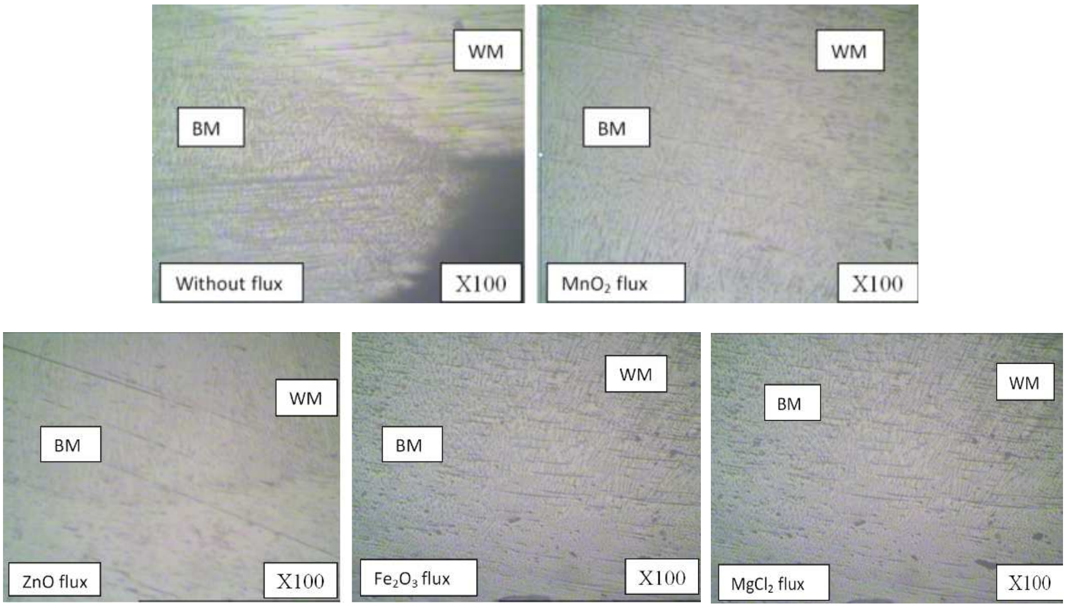

Figure 6: Microstructure of Specimens with Different Activated Flux

The effects of activated fluxes used on microstructure are considered on the basis of test report. The BM and WM in the figure indicate the base metal and weld metal zone. The results shows that microstructure of without flux is fully austenitic ferrite grain structure at the base metal and uniformly distributed unidirectional grain with orientation in the direction of heat dissipation. For MnO_2 flux, a non-uniformly cooled unidirectional grains with size varying from fine to coarse and no discontinuity observed between weld zone and base metal. The ZnO flux shows grain orientation in the direction of heat dissipation. The $MgCl_2$ flux gives elongated austenitic ferrite grain structure at the base metal and unidirectional self-cooled mixed grain structure of austenite and ferrite in the weld metal.

CONCLUSIONS

From the experimental work, the effects of Fe_2O_3, $MgCl_2$, MnO_2 and ZnOfluxes on microstructure of base metal and weld zone, and on the hardness, by using gas tungsten arc welding (GTAW) for stainless steel 304 (SS 304) was investigated. The welding is done autogenously bead on plates and all welding parameters remains constant. The primary conclusions are summarized as follows:

- The MnO_2 flux can only led to increase the hardness (306Hv) of welded zone for stainless steel 304 joints as compared to other oxide fluxes, which does not significantly affect on the hardness of the metal.
- In the experimental work, all the fluxes show fully austenitic ferrite grain structure at the base metal and non-uniformly cooled unidirectional grains with size varying from fine to coarse in the weld zone of the metal except $MgCl_2$, which shows unidirectional self- cooled mixed grain structure of austenite and ferrite in the weld zone.

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