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Study of Varying Welding Parameters on the Corrosion Behaviour of 316 Austenitic Stainless Steel in Acidic Medium

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ABSTRACT :*This research work set out to study the effects of Tungsten Inert Gas (TIG) welding parameters on the corrosion behaviour of 316 Austenitic Stainless Steel (ASS) immersed in 0.5M sulphuric acid (H2SO4) at ambient temperatures. The microstructure and corrosion behaviour of the welded material were investigated. Welding current of 600 Amperes, welding voltage of 29 volts, energy of 1.7 kJ/mol, weld speed of 10 mm/s and welding length of 60 cm with direct polarity (DC+) were the TIG welding parameters used for welding 316 austenitic stainless steel. Potentiodynamic polarization measurement method was used for investigating the corrosion behaviour of the austenitic stainless steel material. Microstructures of Base Metal (BM), Heat Affected Zone (HAZ) and Fusion Zone (FZ) before and after corrosion were determined by Optical Microscopy (OM). In weld metal (or FZ), chromium precipitation was observed. 316 ASS FZ exhibited the lowest corrosion resistance in 0.5M H2SO4, followed by HAZ, while BM displayed a relatively good resistance to corrosion in the acid (H2SO4). Pitting was observed in the microstructure of 316 ASS FZ after corrosion, which may have been initiated by the existence of large inclusions rich in S, Al and Si.*

KEYWORDS: *316 Austenitic stainless steel, Corrosion, TIG welding.*

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I. INTRODUCTION

Stainless steels are high alloy steels which possess high corrosion and oxidation resistance, making them widely used for resisting corrosion. These characteristics make stainless steel to have numerous applications in nuclear plants, petrochemical industries and food processing units, pulp and paper manufacturing plants. The alloys can be milled into sheets, bars, plates, wire and tubing to be used for cookware, cutlery, surgical instruments and building materials [1].

Austenitic stainless steel is the most popular stainless steel group and is used for numerous industrial and consumer applications, such as in chemical plants, power plants, food processing and dairy equipment [2].Austenitic stainless steels in general contain 16% to 26% chromium, up to 8% to 10% nickel and have very low carbon content. Some of these steels are alloyed with little amount of molybdenum, columbium and titanium [3].Corrosion can be defined as the chemical reaction between materials, glasses, ions, polymeric solids and even composites with environments that embrace liquid metals, gases, non-aqueous electrolytes and non-aqueous solutions [1]. It is the deterioration of a material by a chemical attack or reaction under the influence of the surrounding environment. Corrosion is a continuous process which could be difficult to control and terminate [4].Welding is a joining process which involves bringing together of two or more separate parts into permanent or temporary union in order to act as one member [5]. In other words, welding is a process of joining two or more pieces of the same or dissimilar metals to achieve complete coalescence.

Arc welding finds application in various indispensable construction of steel frames for buildings, shipping constructions, galvanized steels for car bodies, motor manufacture, and power plants industries [6]. The most common types of arc welding are: shielded metal arc welding, gas metal arc welding, gas tungsten arc welding, submerged arc welding, flux-cored arc welding and plasma arc welding.

Gas tungsten arc welding is also known as tungsten inert gas (TIG) welding. It uses tungsten electrodes as one pole of the arc in order to create the required heat. The gas is argon, helium, or a mixture of those two. Filler wires provide the molten material if it is necessary. This process is good for thin materials and the filler wires are similar in composition to whatever is being welded.

The four most important welding parameters are: welding current, welding voltage, welding speed and electrode diameter [7].Preparation of surfaces for welding is important, as the nature and properties of surface oxide films and absorbed gases the welding process employs significantly affect the temperatures developed and their distribution in the weld zone. Other factors are shielding gases, fluxes, moisture content of the coating on electrodes, welding speed, welding position, cooling rate, preheating and post welding techniques [8, 9]

II. MATERIALS AND METHODS

Materials

Austenitic stainless steel of grade 316 was used in this research work. Other materials/consumables are: distilled water, silicon carbide papers of grit sizes 180, 320, 600, 800 and 1200, diamond paste of 1µm and 3µm, acetone, etchant (oxalic acid) and 0.5M Sulphuric acid (H_2SO_4).

The equipment used for this research work are TIG welding machine, grinding machine, polishing machine, optical microscope, autolab potentiostat, grinder, fixtures and jigs.

The research work material (316 austenitic stainless steel plate) was gotten from the steel market in Ojota, Lagos, Nigeria. The chemical analysis by Atomic EmissionSpectroscopy (AES) was carried out to check and establish the chemical composition of the stainless steel material..

Welding Procedure

In this research, Tungsten Inert Gas (TIG) welding technique was employed. The TIG welding process of 316 austenitic stainless steel plate was done at the Industrial Training Fund (ITF), Ojota, Lagos, Nigeria. A 30mm x 20mm x 3mm of the ASS plate was cut to produce a plain face sample for butt welding. Prior to welding, the cut out plates were cleaned of dirt and oil in order to have a good weld quality.Adequate shielding was done by centering the filler metal in the gas and weld pool, argon was used as the shielding gas. Fixtures and jigs were used to keep the work in place

Table 1: Chemical Composition of 316 Austenitic Stainless Steel

Element	C	Si	Mn	P	S	Cr	Mo	Ni	Cu	Al	Fe
Weight %	0.0348	0.505	1.32	0.0489	0.0338	20.99	0.451	5.11	0.464	0.00011	Bal

Table 2: Welding Parameters for 316 Austenitic Stainless Steel [10]

Run	Polarity	Current (Amps)	Voltage (Volts)	Weld speed (mm/s)	Energy (kJ/mol)	Weld length (cm)
316	DC+	600	29	10	1.7	60

Microstructural Characterization

The welded samples of 316 austenitic stainless steel were cut to the three different zones viz base metal (BM), heat affected zone (HAZ) and weld metal/fusion zone (FZ). Thereafter, the samples were polished on the grinding machine at an inclined angle using silicon carbide papers and etchant before examination under optical microscope. The samples were ground with 180, 320, 600, 800 and 1200 grit sizes silicon carbide papers, and polished using 3µm and 1 µm diamond pastes to obtain a mirror-like surface. The samples were rinsed in distilled water and degreased with acetone. The 316 steel samples were etched with 10g oxalic acid in 100ml of distilled water to reveal the details of their microstructures.The samples for characterization of 316 stainless steel plate were gotten from the three different zones and a sample from each of these zones were characterized using an optical microscope to describe the features of the composition of the steels before and after corrosion to compare and contrast the effects of welding aswell as the effects of the corrosion media on their mechanical prope

Electrochemical Measurement

An Autolab potentiostat equipped with Nova 2.0 software is used for monitoring the corrosion potentials of the samples as well as potentiodynamic polarization measurements.The experimental set-up for the electrochemical measurements consists of a three-electrode cell with the sample as a working electrode, silver/silver chloride electrode (Ag/AgCl) as a reference electrode and a platinum rod as the counter electrode. The working electrode is placed in a cell consisting of 0.5M H_2SO_4 solution. The anodic and cathodic polarization curves are obtained for each sample, and the corrosion potentials and corrosion current densities are determinedby the Tafel extrapolation and linear polarization methods.

III. RESULTS AND DISCUSSION

Plate 1: Optical Micrograph of 316 ASS Base Metal (BM) (x100)

Plate 2: Optical Micrograph of 316 ASS Heat Affected Zone (HAZ) (x100)

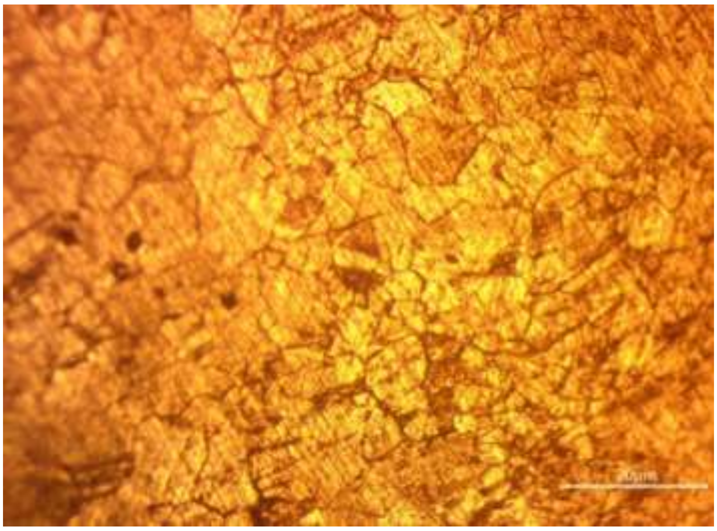

Plate 3: Optical Micrograph of 316 ASS Fusion Zone (FZ) (x100)

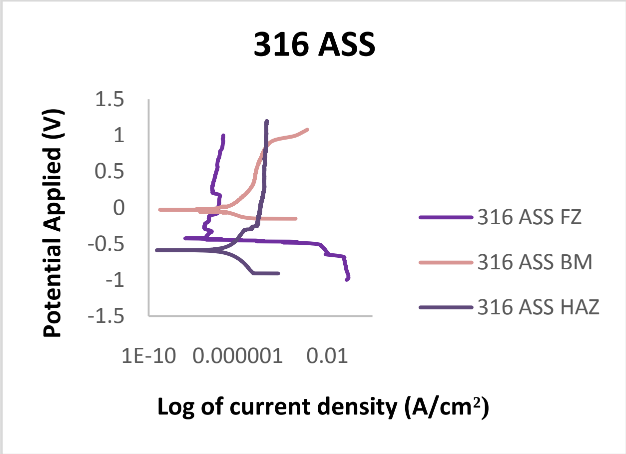

Figure 1: Potentiodynamic Polarization Curves of 316 ASS BM, HAZ and FZ in 0.5M H_2SO_4

Table 3: Electrochemical Parameters of different zones of Welded Austenitic Stainless Steels

Material	E_{corr} (V)	I_{corr} (A/cm^2)	Corrosion Rate (mm/yr)
316 ASS BM	-0.028105	1.606 E-06	0.018647
316 ASS HAZ	-0.565624	7.5664 E-05	0.87798
316 ASS FZ	-0.48024	0.00021059	2.447

Plate 4: Optical Micrograph of 316 ASS Base Metal after corrosion (x100)

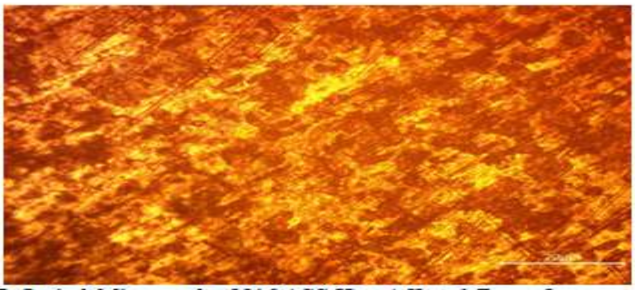

Plate 5: Optical Micrograph of 316 ASS Heat Affected Zone after corrosion **(**x100)
Plate 6: Optical Micrograph of 316 ASS Fusion Zone after corrosion (x100)

Microstructural Analysis of 316 Austenitic Stainless Steel

Plates 1, 2 and 3show the optical micrographs of 316 ASS FZ, BM & HAZ respectively before corrosion. The microstructure of 316 ASS BM shows a homogeneous structure having austenite phase. The microstructure of 316 ASS HAZ shows a coarser grain structure but with no inclusion. The microstructure of 316 ASS FZ shows a fine grain structure with inclusions.In the fusion zone, a small amount of chromium precipitation is formed. According to welding of the material external surface, center of weld metal is exposed to more heat [11].

Corrosion Rate Analysis of 316 Austenitic Stainless Steel

From Table 3, 316 ASS BM has a corrosion rate of 0.018647 mm/yr, 316 ASS HAZ has a corrosion rate of 0.87798 mm/yr and 316 ASS FZ has a corrosion rate of 2.447 mm/yr. This shows that 316 ASS BM is more corrosion resistant compared to 316 ASS HAZ and 316 ASS FZ. Also, 316 ASS HAZ has a higher corrosion resistance than 316 ASS FZ.

Microstructural Analysis of 316 Austenitic Stainless Steel after Corrosion

Plates 4, 5 and 6show the optical micrographs of 316 ASS BM, HAZ and FZ respectively after corrosion.From the microstructures obtained, formation of pits was observed in 316 ASS FZ. These pits may have been initiated by the existence of large inclusions rich in S, Al and Si which are observed in the FZ [12]. Also, galvanic corrosion may occur as a result of chromium depletion in the FZ, thereby increasing corrosion rate.

IV. CONCLUSION

The effect of TIG welding parameters; welding current, welding voltage, energy, welding speed, welding length and polarity on 316 austenitic stainless steels have been investigated. It was concluded that 316 austenitic stainless steel base metal has the lowest corrosion rate followed by heat affected zone and fusion had the highestcorrosion rate. There is an agreement with the microstructure after exposure to corrosion.

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