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Analyzing a Tig-welded butt joint's Mechanical properties using silicon oxide-activated flux

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ABSTRACT

The objective of the current research was to examine the impact of certain oxide fluxes on the visual characteristics of the surface. In order to acquire mechanical qualities. This study investigates the behavior of the butt joint formed by Tungsten Inert Gas (TIG) welding technique on stainless steel (SS-316L) plates with a thickness of 4mm. Silicon serves as a flux material, while acetone acts as a solvent, both of which are used to cleanse the metal surface of plates before welding steels. This process involves the application of a thin coating of activating flux to facilitate the formation of a bead in the joint during plate welding. Austenitic stainless steels find extensive use in many applications such as aviation engine components, heat exchangers, and furnace parts, among others. The mechanical characteristics of the material will be assessed by the use of Rockwell hardness testing, impact strength testing, and tensile testing procedures. The experimental parameters for performing weld joint experiments include the selection of essential processing restrictions, such as the welding current (ranging from 50 to 100A) and the velocity flow of argon gas.

I. INTRODUCTION

This study examined the dissimilar metal weld (DMW) junction between AISI 316L stainless steel and Alloy 800, which was created using A-TIG welding. A comprehensive examination of the microstructure was conducted by investigating the development of the fusion zone microstructure and analyzing several sub-zones inside the weldment. The junction between AISI 316L stainless steel and Alloy 800, which was welded using the A-TIG welding process, exhibited complete penetration over the whole thickness of 8 mm plates, without any occurrence of solidification fractures or flaws. The weldment produced using the A-TIG welding technique exhibited an ultimate tensile strength of 514 MPa, while achieving a joint efficiency of 91% when compared to the base metal of Alloy 800. The mechanical characteristics of the fusion zone were negatively affected by the presence of local microstructural heterogeneity (1).This study primarily focuses on examining the microstructure and behavior of butt joints in stainless steel (SS-316L) plates with a thickness of 8 mm, using the A-TIG welding procedure. Alumina serves as a flux material, while acetone functions as a solvent, both of which are used to cleanse the metal surface of the plates before commencing the welding process. The present study experiment incorporates certain important processing restrictions, namely the welding current ranging from 50 to 100A, as well as the velocity of the argon gas flow, which are carefully chosen for the purpose of performing the weld joint experiment (2).The welding process is evaluated by conducting tests on samples, taking into consideration several characteristics such as electrode filler rod, welding current, and gas flow rate. The determination of the ultimate tensile strength of the samples was conducted using a Universal Testing Machine (UTM). The use of a welding current of 60 Amps, an electrode filler rod with a diameter of 2 mm, and a gas flow rate of 6 L/min resulted in the attainment of the highest tensile strength recorded at 424.31 Mpa. Conversely, the use of a welding current of 40 Amps, an electrode with a diameter of 1.5 mm, and a gas flow rate of 5 L/min yielded the lowest tensile strength seen at 356.10 Mpa(3). The objective of the study was to reduce the occurrence of defects in the weld junction of stainless steel SS304 sheets in order to enhance the strength and longevity of the hoarding structure. The use of optimal welding conditions resulted in a notable enhancement in the tensile strength of the joint, with an increase from 515 MPa to 556 MPa. This corresponds to a substantial improvement of 10.56% in the joint's overall strength. The hardness exhibited a notable improvement from an initial value of 92 HV to a final value of 100 HV, achieved by the use of optimal welding conditions. This enhancement in hardness corresponds to a percentage increase of 7.36%, as reported in reference (4). The present study presents an investigation on the Tungsten Inert Gas (TIG) welding procedure used to stainless steel 316 materials with thicknesses of 20 mm and 40 mm. The mechanical tensile characteristics, bend tests, and impact tests were conducted to characterize the 20 mm and 40 mm samples. Additional hardness assessments and microstructural analyses are conducted. The examination of microstructures indicates that the welding operation was executed well and did not result in any notable flaws. The establishment of welding techniques for thick SS materials is necessary to meet the needs of VV components in the manufacturing and development of future fusion reactor components (5). This review paper provides a summary of the literature study and analysis conducted to evaluate the application of A-TIG and its comparative efficacy with M-TIG in welding martensitic and austenitic grade steels. The use of dissimilar welded joints (DWJs) in Ultra Supercritical (USC) power plants is imperative for the purpose of cost optimization, component reduction, and prevention of early failure (6). The analyzed research papers are the subject of investigation.The optimal conditions for achieving the lowest surface roughness included using a parametric combination of an arc current of 125 A, a voltage of 18 V, and a shielding gas flow rate of 12 L/min. The primary determinant of surface roughness is arc current, with voltage and gas flow rate being secondary factors of influence. The optimal ultimate tensile strength (UTS) was achieved by the implementation of a parametric combination including an arc current of 100 A, a voltage of 18 V, and a shielding gas flow rate of 6 L/min. The primary determinant of UTS (ultimate tensile strength) is the current, which is closely followed by the gas flow rate and voltage (7). The two prevailing processes that have been extensively studied in relation to the significant enhancement of penetration depth in A-TIG welding are the Arc constriction and the reversal of the Marangoni convection. The vapor emitted by the flux during the welding process exhibits electronegative properties, resulting in the narrowing of the ion path of the arc plasma towards the central region of the arc. The application of flux on the surface results in a reduction of the surface tension of the weld pool. Additionally, it causes a reversal of the surface tension gradient from negative to positive. This reversal is responsible for the movement of fluid from the border of the fusion zone towards the center of the weld pool (8). This study focuses on the evaluation of the long-term creep rupture characteristics of the base metal of 316L(N) SS, the weld joint of 316L(N) SS, and the weld metal of 316(N) SS. The investigation was conducted at temperatures of 873 K and 923 K, in accordance with the high temperature codes specified by ASME and RCC-MR. The creep strength reduction factors for the weld joints exhibit greater values compared to the RCC-MR values. This suggests that the actual creep strength of the weld joints surpasses the designated values, indicating a minimal disparity between the strengths of the base metal and weld metal (9). Numerous endeavors have been undertaken to enhance the efficiency of the GTA welding procedure. The use of activated flux in gas tungsten arc (GTA) welding has shown to be effective in enhancing process efficiency. The procedure is sometimes referred to as flux aided gas tungsten arc welding (F-GTAW) and activated tungsten inert gas (A-TIG) welding process. The first proposition of using fluxes in GTA welding was put out by the Paton Electric Welding Institute of the National Academy of Sciences.

2. EXPERIMENTAL PROCEDURE

2.1 Material

Materials are used for carrying out Tig welding was stainless steel grade 316L (AISI 316L) plate of thickness 4mm. It is used as base metal. Table 1,2 shows the chemical composition of the AISI 316L physical properties, and chemical properties respectively. Energy dispersive X-Ray analysis (EDX) was used to determine chemical composition of material used. AISI 316L was selected over other materials because of very low percentage of carbon content (<0.03% by mass).

Table 1- Physical Properties of AISI 316L

Material	Melting point (^{0}C)	Specific heat capacity (J/kg.K)	Thermal conductivity (W/m.K)	Thermal expansion (K^{-1})
AISI 316L	1375	490	15	16

Table 2- Chemical Properties of AISI 316L

Element	AISI 316L
C	0.024
N	0.059
Si	0.03
P	16.6
Cr	0.98
Mn	0.08
Co	0.02

2.2 Cutting and shape of workpiece

The base material, stainless steel (AISI 316L) was procured from local market. It was in the form of large plate of thickness 3 mm. It was cut according to prescribed dimensions 60 mm (length) x 60 mm (width) x 3 mm (thickness) by press machine, Is shownFig.1

Fig. 1. Cutting of workpiece

2.3 TIG Welding setup

In current research the equipment, DC argon arc welding machine (model WSM-160) is utilized for TIG welding of stainless steel, depicted in TIG welding machine is equipped with a standard 2 percent thoriated electrode with a diameter of 2.4 mm. The TIG welding machine's polarity was direct current DC with a negative potential electrode. Whole welding setup include argon cylinder, primary power supply cable, grounding cable, welding torch, Tig welding machine and work piece.

Fig. 2. Welding setup

2.4 Filler Material

SS 316L filler wire was used during welding process, shown in Diameter of filler wire is selected 0.08 mm. Chemical composition of 316L filler wires is given in table 3.

Table 3-Chemical composition of filler material

Elements	**316L (Wt %)**
C	0.026
Si	0.37
Mn	0.16
Cr	16.55
Cu	0.16
Ni	10.0
P	0.029

2.5 Mechanism of TIG

TIG welding with activated flux has resulted in a dramatic enhancement in the depth of penetration as compared to the conventional TIG process with the same input parameters. Various forces in arc zone like gravity force, drag force due to arc, electromagnetic force due to current flow, etc. should be similar for same process parameters in both the cases. The mechanism of increased penetration depth with flux in the weld pool is discussed in the following section. The use of flux in TIG welding to improve the properties of titanium alloys in argon-arc welding was first reported by An improvement in the weld penetration of titanium alloys using an oxygen free activated flux was also reported in same work. After this, a number of researchers have been published on the understanding of the mechanism of higher penetration with constricted weld width during the welding of titanium and steels with different fluxes However, they did not observe any constriction in arc using flux during A-TIG welding of water cooled copper. It was also seen that the non-arc processes such as electron beam welding and laser welding produced variable penetration.

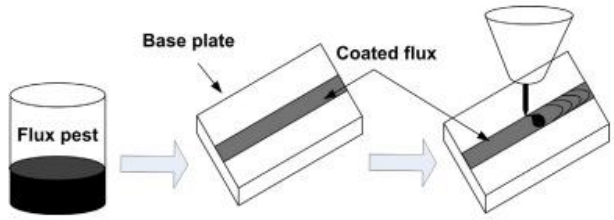

Fig. 3. Schematic of processing of TIG

2.6 TIG welding process

Experiments are carried out in a specified experimental order in this study. Before welding, all of the plates were washed with acetone to remove contamination. Welding procedure was carried out in flat position, presented in Fig. 2. Square buttjoints between AISI 316L with dimensions of 60 mm 60 mm x 3 mm are joined by TIG welding using SS 316L filler wire. Various input parameters are used to create square butt-welded joints. For this research, the Taguchi L9 experimental design was used to prepare a total of 9 specimens, shown in Fig. 3. All nine samples were subjected to a surface roughness evaluation test following the welding procedure. After this by cutting/machining the welded joints, specimens for tensile tests and hardness tests have been prepared.

Fig. 4. Welding Process

3. WELDING RELATED PROCESS PARAMETERS

3.1 Welding Current

Gas tungsten arc welding uses a constant current power source, meaning that the current (and thus the heat flux) remains relatively constant, even if the arc distance and voltage change. This is important because most applications of GTAW are manual or semiautomatic, requiring that an operator hold the torch. Maintaining a suitably steady arc distance is difficult if a constant voltage power source is used instead since it can cause dramatic heat variations and make welding more difficult.

Table 4-Process parameters of welding current

Welding position	PLANE
Welding voltage	12V
Welding current	23-25A
Average speed	10.0 cm/min
Filler material	0.08mm

3.2 Welding Speed

Welding speed is the average linear travel speed of the welding torch over the base plate/pipe to be welded during welding. Welding speed influence the total heat input per unit length of the weld and hence has an effective impact on weld fusion zone geometry also. The fusion of the substrate, and hence an obvious decrease in the weld pool cross-sectional area should take place, which finely affect the weld pool geometry. Different investigators reported the effect of welding speed on the weld pool geometry differently. The average speed will be shown in the table 4.

3.3 Arc Length

The tungsten electrode. Arc length in the TIG welding process affects the amount of heat generated and supplied to the work piece for fusion. An arc in TIG welding is created between the electrode and workpiece by the ionization of the gases present. An increase in the arc length will result in

(a) Increase in the voltage if current maintained at a constant value;

(b) Increase in the anode root (heat distribution) area;

(c) Increases in aerodynamic drag force;

(d) reduce the arc efficiency for runs carried out at constant current.

3.4 Shielding Gas Composition

In A-TIG welding process, shielding gases protect the weld zone and electrode from oxidation and also help to control the temperature of the electrode by cooling effect. Pure argon is commonly used shielding gas in A-TIG welding process. Different gases have different ionization potential (IP) and as per their IP, heat flux also affected during A-TIG welding process. Consequently, it also affects the fusion zone area.

3.5 Fluxes

In A-TIG welding process, concept of use of flux was first introduced by Paton welding institute way back in the 1960s. A simple process of applying a thin layer of flux over the surface of the component to be welded before welding showed a spectacular increment in penetration. These fluxes are generally oxides and halides. The two most renowned and accepted effects of these fluxes are arc constriction and reversal of Marangoni convection; because of which about 100–200% increase in penetrationachieved during TIGwelding. These fluxes later also known as activating or activated flux. These fluxes break down into their constituents and evaporate during welding and make a cover of fumes (electron negative in nature) around the arc. These fumes extract electrons from the outer part of the arc column which in turn left narrow path to flow the charged ions between the electrode and the workpiece. Hence increase the energy density per unit area of TIG welding process.

3.5.1 Silicon dioxide

Silicon dioxide, also known as silica, is an oxide of silicon with the chemical formula SiO_2, most commonly found in nature as quartz. In many parts of the world, silica is the major constituent of sand. Silica is one of the most complex and most abundant families of materials, existing as a compound of several minerals and as a synthetic product. Notable examples include fused quartz, fumed silica, silica gel, opal and aerogels. It is used in structural materials, microelectronics as an electrical insulator, and as components in the food and pharmaceutical industries.

3.5.2 Uses of silicon dioxide in metals

- Silicon dioxide is used in the construction industry to produce concrete.
- In its crystalline form it is used in hydraulic fracturing.
- Used as a sedative.
- Used in the production of glass.
- Used in the production of elemental silicon.
- Used as an anti-caking agent in powdered foods like spices.

It contains the different sizes and different shapes. And we have to use the spherical shape and size 350 Nm.

And then the nano powder is mixed with the acetone and to apply a thin layer before welding process.

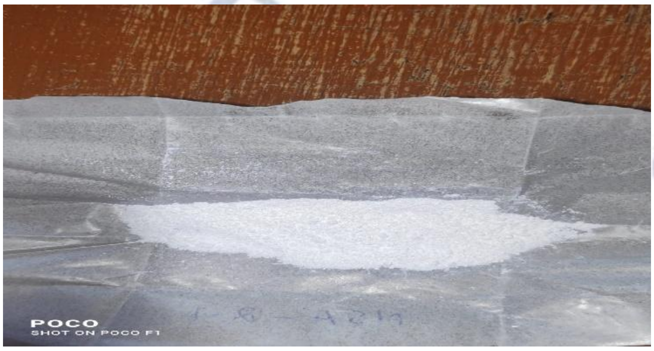

Fig. 5. Silicon dioxide

4. TESTING PROCESS

4.1 Micro Hardness test

Hardness measurements were performed with micro-Vickers, Wolpert 401/402MVD-CHINA, shown in Fig. 6. Test was performed with a load of 200-gf and dwell time of 15 s. Prior to measuring with micro hardness, the samples were hot mounted using a mounting press. The mounting material was Bakelite powder. The mounted samples were then ground gradually from 180, 500, 1200 and 2400 grit then mirror polished. Three indents on each portion (fusion zone, heat affected zone and base metal) were taken and Vickers hardness numbers were recorded.

Table 5- Hardness values

S. No	Sample	HV
1	Base	166.0
2	Weld piece	168.0

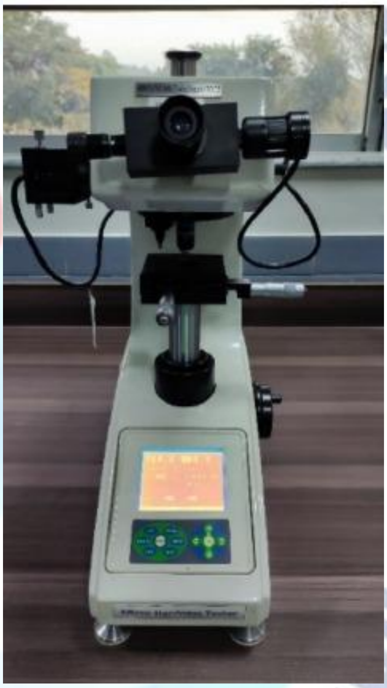

Fig. 6. Vickers hardness tester

4.2 Tensile Test

Standard tensile test samples were retrieved from welded specimens in such a way that weld bead being in the center of each sample. Dimensions of standard tensile test sample is shown in Fig. 7. Cutting was done with Laser cutting machine, Bodor/F3015T3-CHINA, shown in. Samples were cut at three positions through weld bead from each specimen. Test was performed using universal testing machine, QCHAIDA/ HD-B607-S, shown in Fig. 8. Test was performed with a load cell of 50 KN and strain rate of 0.001 mm/s.

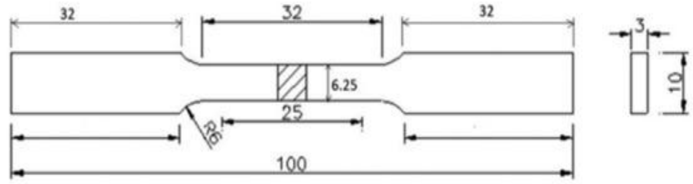

Fig. 7. Dimensions of the tensile test samples

These tensile testers are suitable for applications such as material elongation testing, connector withdrawals testing, spring testing, and more.

Fig. 8. Universal testing machine

Fig. 9. Variety of samples before testing

Fig. 10. Broken metals after test

Table 6 Tensile test results

S. NO	Sample	UTS(MPa)	Yield strength	Elongation
1	Base metal	688.842	509.40	50.28
2	S1	664.36	437.14	42.48
3	S2	652.82	431.55	44.44
4	S3	663.38	480.48	48.40

4.3Impact Test

Fig. 11. Impact testing machine

Table 7 Impact test results

Locations	Impact values
Base metal	10.0
Weld metal -1	22.0
Weld metal - 2	36.0
Weld metal - 3	22.0

5. CONCLUSION

The present investigation may be succinctly stated and ultimately concluded in the following manner: Superior butt welded connections with increased tensile strength and impact resistance, surpassing that of the base metal, may be achieved by the use of A-TIG welding technique, wherein SS316L is employed as the filler metal. The hardness seen in the welded area is comparatively lower than the hardness observed in the heat affected zone (HAZ) and the base metal. The optimal level of hardness was achieved by the use of a parametric combination consisting of an arc current of 125 A, a voltage of 20 V, and a shielding gas flow rate of 9 L/min. The primary determinant of hardness is arc current, with gas flow rate and voltage being secondary factors of influence. The optimal ultimate tensile strength (UTS) was achieved by the implementation of a parametric combination including an arc current of 100 A, a voltage of 18 V, and a shielding gas flow rate of 6 L/min. The primary determinant of UTS is the present condition, with gas flow rate and voltage being secondary factors of influence. The optimal performance efficiency (PE) was achieved by the use of a parametric combination consisting of an arc current of 100 A, a voltage of 16 V, and a shielding gas flow rate of 9 L/min. The primary determinant of the performance of PE is the prevailing current, with voltage and gas flow rate being secondary factors of influence.The depth of penetration of an A-TIG weld is seen to rise as the flux coating density increases. However, this increase reaches a maximum at an optimal value of flux coating density. Beyond this optimal value, the penetration depth remains relatively constant within a large range. Any additional increase in coating density beyond this range leads to a decrease in the penetration depth.

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