A Detailed Study on Optimization on Gas Tungsten ARC Welding Process of Austenitic Stainless Steels (304 & 316L)

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***Abstract* - Stainless steel has huge applications in daily life. Here I take AISI 304 and AISI 316 L using the filler of 316 l. In the present study, investigation of tungsten inert gas (TIG) welding techniques for similar butt joint of 304 and 316L stainless steel sheets was carried out. The effects of voltage, traveling speed and yield strength, elongation, hardness, and weld width were investigated. Moreover, in order to examine the mechanical and metallurgical behavior of the weld, microstructure analysis was used. It was observed that strength and toughness of samples decreased by increasing voltage in TIG. There are zero cracks, porosity, blow holes, spatter found in welding process of plate using non consumable tungsten electrode with argon gas and also the microstructure study shows that the welding is self-cooled welding structure with fine austenitic structure and very little heat affected zone found in this process.**

***Index Terms* - Austenitic Stainless Steel, TIG Welding, Shielding gas, NDT, Characterization.**

I.INTRODUCTION

Austenitic stainless steels have been widely used in manufacturing pressure vessels, tanks, and heat exchangers, piping systems, valves, and pumps because of their excellent mechanical properties. However, welding often leads to low mechanical properties owing to the metallurgical changes such as micro-segregation, precipitation of secondary phases, presence of porosities, solidification cracking, grain growth in the heat affected zone (HAZ) and loss of materials by vaporization [1,2].

Generally speaking, welding is one of the most widely used processes to fabricate stainless steel structures. 304 is the most commonly used types of austenitic stainless steel and versatile, because it has good mechanical properties such as susceptibility formation and welding, so this type serves the industrial sector in a wide range [3].

304 stainless steel is a widely used material, as it has superior corrosion resistance. In this alloy, 18% chromium is added to improve corrosion resistance, whereas alloying nickel at 8% is used to stabilize the austenite matrix [4-7].

Alloy 316L stainless steel is a structural material that has been widely used in many industrial fields, such as the nuclear, cryogenic, and shipbuilding industries [8].

Gas Tungsten Arc Welding:

Gas tungsten arc welding (GTAW) is an arc welding process that uses an arc between a non-consumable tungsten electrode and the workpiece to establish a weld pool. The process is used with shielding gas and without the application of pressure and may be used with or without the addition of filler metal.1,2 Because of the high quality of welds that can be produced by gas tungsten arc welding, the process has become an indispensable tool for many manufacturers, including those in the aerospace, nuclear, marine, petrochemical and semiconductor industries. The possibility of using helium to shield a welding arc and weld pool was first investigated in the 1920s.3 However, there was no incentive for further development or use of this process until the beginning of World War II, when a great need emerged in the aircraft industry to replace riveting as the method for joining reactive materials, such as aluminum and magnesium. The welding industry responded by producing a stable, efficient heat source with which excellent welds could be made using a tungsten electrode and direct current arc power with the electrode negative. Helium was selected to provide the necessary shielding because it was the only inert gas readily available at the time.

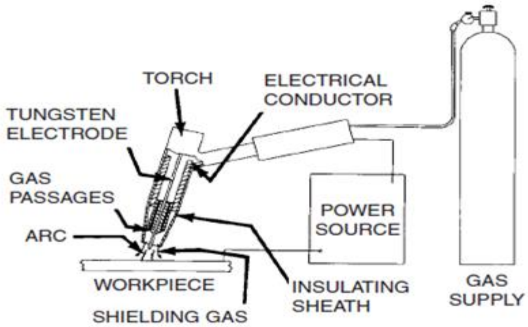

Fig 1.1 schematic diagram of TIG Process

The process has been called non consumable electrode welding and is very often referred to as TIG (tungsten inert gas) welding. However, because shielding gas mixtures that are not inert can be used for certain applications, the American Welding Society (AWS) adopted gas tungsten arc welding (GTAW) as the standard terminology for the process. Numerous improvements have been made to the process and equipment since the early days of the invention. Welding power sources were developed specifically for the process, some providing pulsed direct current and variable-polarity alternating current. Water-cooled and gas-cooled torches were developed.

II. LITERATURE REVIEW

Halil Ibrahim et al. [1] studied microstructure and mechanical properties of AISI 304 austenitic stainless steels, welded by TIG welding, using 308 grade filler metal. Microstructures of base metal, heat affected zone and weld metal were studied with microscopy. They reported, observing chromium carbide precipitation and dendrite structure in weld metal.

G. R. Mir shekari et al. [2] investigated on "Microstructure and corrosion behavior of multipass gas tungsten arc welded 304 stainless steels. The purpose of this study is to discuss the effect of single pass and multipass gas tungsten arc welding on microstructure, hardness, and corrosion behavior of 304 stainless steel. They concluded that the microstructure of fusion zones exhibited dendritic structure contained lathy and skeletal ferrite.

Subodh kumar et al. [3] Investigated the "Effect of heat input on the microstructure and mechanical properties of gas tungsten arc welded AISI 304 stainless steel joints. Three heat input combinations designated as low heat, medium heat and high heat were selected from the operating window of the GTAW process and weld joints made using these combinations were subjected to micro structural evaluations and tensile testing so as to analyze the effect of thermal arc energy on the microstructure and mechanical properties of these joints.

S.P.Gadewar et al. [4] investigated the effect of process parameters of TIG welding like weld current, gas flow rate, work piece thickness on the bead geometry of SS304. It was found that the process parameters considered affected the mechanical properties with great extent.

L .Suresh Kumar et al. [5] discussed the mechanical properties of austenitic stainless steel AISI 304 and 316 and found out the characteristics of welded metals using TIG & MIG welding process. Voltage was taken constant and various characteristics such as strength, hardness, ductility, grain structure, HAZ were observed in two processes, analyzed and finally concluded.

P .Atanda et al. [6] conducted sensitization study of normalized 316L stainless steel. The work was concerned with the study of the sensitization and desensitization of 316L steel at the normalizing temperatures of 750-950°C and soaking times of 05, 1, 2 and 8 hours.

A.M. Torbati et al. [7] has optimized a combination of current Intensity, welding speed, electrode angle and shielding gas parameters for better penetration and free from inner layer defects of duplex steel joints by Gas tungsten arc welding (GTAW).

Radha Raman Mishra et al. [8] investigated the tensile strength of MIG and TIG welded dissimilar joints of mild steel and stainless steel. TIG and MIG welding process were used for welding different grades of steel with mild steel.

Swapnil Ingle et.al [9] The objective is to study the variation of temperature in TIG welded plate of 5mm work piece thickness. Based on the experimental records of temperature at specific locations during the TIG welding process, Thermo - Mechanical simulation is developed. Comparison with the temperature measured by the thermocouples records shows that the results from the present simulation have good agreement with the test data.

Mr. R. Ramachandran [10]. Studied the austenitic stainless steel (316L) is welded by GTAW process and its mechanical property were studied and the process welding parameters like CURRENT, VOLTAGE AND GAS FLOW RATE of TIG for getting maximum weldments, best mechanical properties and min HAZ. The analysis of the test results is conducted and the combination of welding parameter ranges that gives best result is found. This combination can be considered as good working ranges for TIG welding of SS316L material and conduct the study of temperature distribution and total heat flux of welding area using ANSYS.

Y. F. Hsiao et.al [11] studied the optimal parameters process of plasma arc welding (PAW) by the Taguchi method with Grey relational analysis was studied. SUS316 stainless steel plate of thickness 4mm and the test piece of 250mm x 220mm without groove was used for welding. Torch stand-off, welding current, welding speed, and plasma gas flow rate (Argon) were chosen as input variables and Welding groove root penetration, Welding groove width, Front-side undercut were measured as output parameters.

Ramazan yilmaz et.al [12] studied the mechanical properties of 304L and 316L austenitic stainless-steel weldments, such as tensile properties, hardness and impact properties were determined. The results show that the yield and tensile strength, hardness, and impact energy values of 304L and 316L stainless steels welded by GTAW process.

III. EXPERIMENTAL WORK

From the literature review, for welding of AISI 304 and AISI 316 L using AISI 304 Filler wire was studied, and survey explains that the process used for welding of stainless steel are SMAW, MIG, TIG, MICRO PLASMA, AND PLASMA WELDING are widely used for welding of AISI 304 and AISI 316 L by studying the various literature. It is observed that Tungsten inert gas welding is the most feasible process for welding AISI 304 and AISI 316 L most productively and economically.

Material Selection:

- AISI 304
- AISI 316 L

Elements	C	Mn	Si	Cr	Ni	P	S
Weight %	0.060	0.86	0.031	18.350	8.200	0.0310	0.010

Table 3.1 chemical composition of AISI 304

Elements	C	Mn	Si	P	S	Cr	Mo	Ni
Weight %	0.03	2	0.75	0.045	0.030	18.850	2-3	10.0

Table 3.2 Chemical composition of

AISI 316 L & AISI 316L Filler metal

For welding Stainless steel of AISI 304 and AISI 316 L plate using the filler wire of AISI 316L I do bead on plate welding using the different current ranges varying from 25 amps to 35 amps. From the bead on plate we choose the correct current range of 30 amps and we characterized it by bead width, penetration, melting rate of filler wire etc.

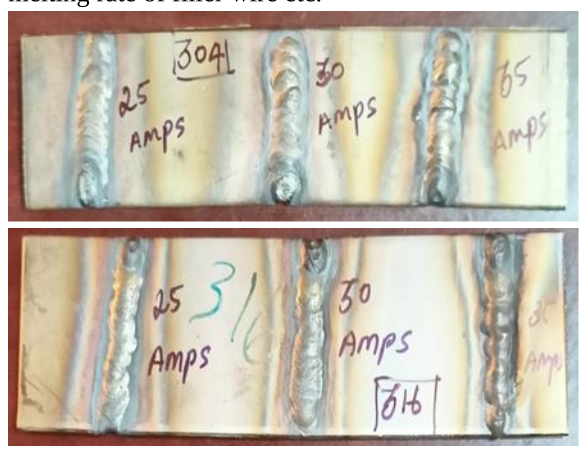

Fig 3.1 bead on plate on AISI 304 & AISI 316 L using AISI 316 L filler wire for Choosing the current range.

Welding Parameters:

Dimensions for Joining 2 Plates	50*25*2 mm (Similar)
Weld Type	BUTT JOINT
Groove Type	Single V Groove
Current Range	35 A
Voltage	60-70 Volts
Shielding Gas	Argon

Dimensions for Joining 2 Plates	50*25*2 mm (Similar)
Shielding Gas Flow Rate	21.5 Psi
Polarity	DCEN
Mode of Operation	Manual
Electrode	2%Thoriated tungsten Electrode
Electrode Dia	1mm
Torch Position	Vertical

Fig 3.3 Welding Parameters

Visual inspection:

Visual inspection (VT) visual inspection is a nondestructive testing (NDT) weld quality testing process where a weld is examined with the eye to determine surface discontinuities. It is the most common method of weld quality testing. The magnification range has 10X.

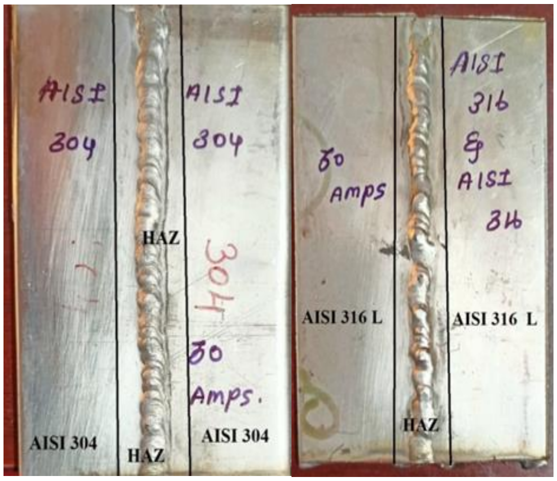

Fig 3.2 Visual inspection of Welded Plates of AISI 304 and AISI 316L

Almost all the inspection parameters was too good except these,

- Linear Misalignment - Due to application of heat.
- Lack of Side Fusion - Due to improper feeding of filler wire.
- Improper bead width

Liquid penetrant testing:

Liquid Penetrant processes are non-destructive testing methods for detecting discontinuities that are open to surface.

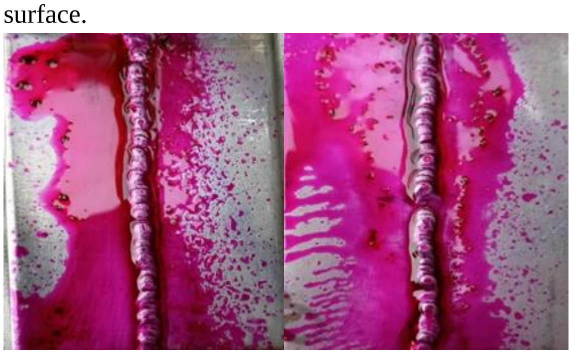

Fig 3.3 Liquid penetrant testing of Welded Plates of AISI 304 and AISI 316L

There is no any surface flaws and cracks in the surface of the specimen. Therefore, we can say that there is a good quality of weld and proper penetration of the weld are achieved.

Characterization:

AISI 304:

Fig 3.4 TIG welded AISI 304 Weld metal

Microstructure shows that Austenitic Structure in the welded zone.

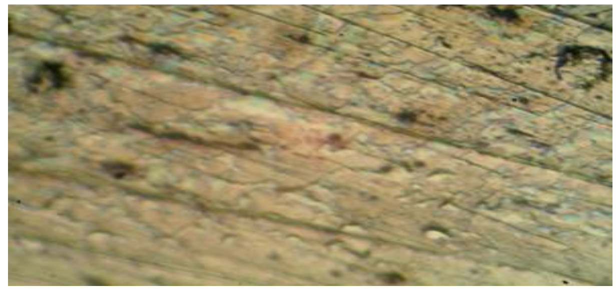

Fig 3.5 TIG welded AISI 304 HAZ

Microstructure shows that grain coarsening observed at some areas on the heat affected zone.

AISI 316 L:

Fig 3.6 TIG welded AISI 316 L Weld metal

Microstructure shows that Austenitic Structure in the welded zone.

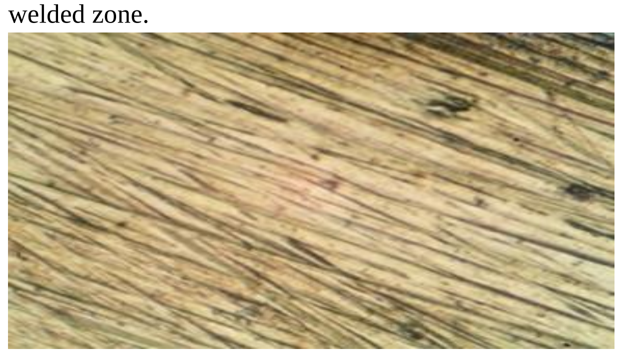

Fig 3.7 TIG welded AISI 316 L HAZ

Microstructure of AISI 316 L HAZ shows that coarse grains of austenite.

Vickers micro hardness testing:
The Vickers hardness may be determined from the following equation.
Vickers hardness = 2Psin (ϴ/2)/l² = 1.854P/L²
Where P = applied load, kg
L = average length of diagonals, mm
ϴ = angle between opposite face of diamond = 136°

The following hardness values have been achieved in the Vickers micro hardness testing method.

AISI 304	Base Metal	HAZ	Weld Metal	HAZ	Base Metal
1	330	265	358	251	328
2	312	279	343	266	338
3	317	281	359	272	278

Table 3.4 Vickers hardness values for load of 500 kgf for AISI 304

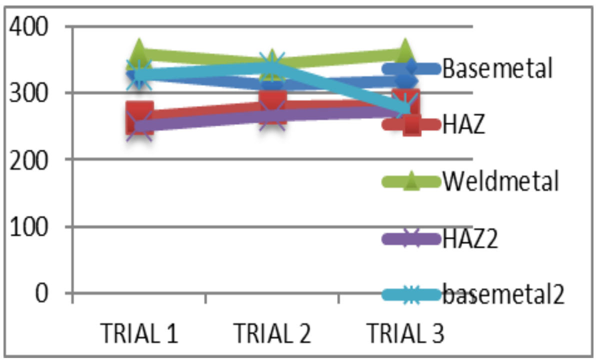

Chart 3.1 Micro hardness chart for AISI 304

AISI 316L	Base Metal	HAZ	Weld Metal	HAZ	Base Metal
1	318	272	346	263	332
2	326	267	357	281	341
3	321	265	351	269	339

Table 3.5 Vickers hardness values for load of 500 kgf for AISI 316 L

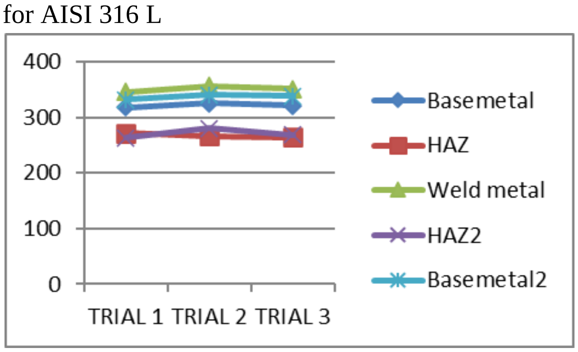

Chart 3.2 Micro hardness chart for AISI 304

Tensile test:
Tensile test specimens are prepared in a variety of ways depending on the test specifications. The most commonly used specifications are BS EN ISO 6892-1 and ASTM E8M.

Specimen	Ultimate tensile strength (Mpa)
AISI 304	529.18
AISI 316L	563.31

Table 3.6 Tensile test of AISI 304 & AISI 316L

IV. CONCLUSION

The AISI 304 and AISI 316L are welded using the filler wire of AISI 316L In Tungsten Inert gas welding by choosing the welding parameter of shielding gas, current range, type of electrode etc
From the test results its observed that from visual inspection there is angular distortion in the weldments and some mechanical damages occur.
From the penetrant testing there are no cracks or defects in the weld
In micro hardness testing the AISI 316L has high hardness value than the AISI 304.
The tensile test result also shows that AISI 316L has high tensile strength than the AISI 304. The AISI 304 has tensile strength of 529.18 Mpa and AISI 316 L has the tensile strength of 563.31 Mpa.

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