An Experimental Study of Effect of Welding Parameters on T- Weld Joint in TIG Welding of SS 316L and Development of its Microstructure and Mechanical properties

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***Abstract*- The microstructure and tensile strength of T weld joint of stainless steel 316 material in TIG (tungsten inert gas) equipment was analysed by varying shielding gas (argon gas and Carbon dioxide) and voltage. Vastly different microstructures are formed in 316L stainless steel joints welded with Argon and Carbon dioxide and by varying voltage, respectively. Different microstructures, yield strength, tensile strength and weld bead hardness are tested in my project. Effect of varying voltage and shielding gas on stainless steel 316 material T-weld joint are analysed.**

Keywords- TIG Welding, Argon, CO2, Operating Variables, Microstructures

I. INTRODUCTION

In the TIG (tungsten inert gas) welding process, an essentially non-consumable tungsten electrode is used to provide an electric arc for welding. A sheath of inert gas surrounds the electrode, the arc, and the area to be welded [1, 2, 6, 11]. This gas shielding process prevents any oxidization of the weld and allows for the production of neat, clean welds. TIG welding differs from MIG (metal inert gas) welding in that the electrode is not consumed in the weld. In the MIG welding process the electrode is continuously melted and is added into the weld. In TIG welding, no metal is added unless a separate filler rod is used. TIG welding can be performed with a large variety of metals. The two most commonly TIG welded metals in the PRL are steel and aluminium. Steel is relatively easy to TIG weld and it is possible to produce very tight, neat welds. Aluminium takes a little more skill, and one should have at least a little bit of experience in welding steel before making the transition to aluminium [4, 5, 8]. However, the basic technique is essentially the same and most people can make the jump to aluminium fairly easily. TIG welding is an extremely powerful tool. With a little practice, it is possible to make beautiful welds much more quickly and easily than with oxy-acetylene welding. It is also the only option currently available in the shop for welding aluminium. Put in a little time and you will be rewarded in spade. The shielding gas used in TIG welding can be argon, helium or a mixture of the two. Although the shop keeps a tank of the each next to the welding machine, the helium is almost never used except for special applications. Argon is usually a better choice because it is heavier than air and therefore tends to provide a better blanket over the weld [3, 9]. The flow from the argon tank is controlled by the regulator/flow meter which is screwed onto the top of the tank. The double seating main valve controls whether the argon will flow at all and the smaller valve at the bottom of the flow meter allows one to adjust the flow rate. Select a flow rate from this document's Appendix or from the guidelines posted on the TIG machine.

II. OPERATION

Following operating parameters were used during the operation

A. Operating Variables

Following are the operating variable in TIG

- Welding Current
- Arc Voltage
- Travel Speed
- Size of Electrode
- Electrode stick-out
- Heat input rate

B. Welding current

It controls the melting rate of the electrode and thereby the weld deposition rate. It also controls the depth of penetration. Too high a current causes excessive weld reinforcement which is wasteful, and burn through in the case of thinner plates or in badly fitted joints, which are not proper backing. Excessive current also produces too narrow bead and under cut, excessively low current gives an unstable arc and over lapping. TIG control panel is usually provided with an ammeter to monitor and control the welding current.

C. Arc voltage

Arc voltage means the electrical potential difference between the electrode wire tip and the surface of molten weld pool. It is indicated by the voltmeter provided on the control panel. It hardly affects the electrode melting rate, but it determines the profile and surface appearance of the weld bead. As the arc voltage increases, the bead becomes wider and flatter, and the penetration decreases.

The bead width increases with an increase in arc voltage because an increase in arc voltage provides a longer arc which owing to its divergence is spread over a larger surface area thereby spreading the deposited metal over a wider area. The penetration as well dilution have been found to increase abruptly with the increase of arc voltage, but their rate of increase are found to be reduced significantly with further increase of arc voltage.

D. Travel speed

For a given combination of welding current and voltage, increase in welding speed result in lesser penetration, lesser weld reinforcement and lower heat input rate.

Excessively high travel speed decreases fusion between the weld deposit and the parent metal. Increases tendencies for under cut, arc blow, porosity and irregular bead shape. As the speed decreased, penetration and reinforcement increased. But too slow a speed result in poor penetration. Excessively high welding speed decreases the welding action and increases the probability of under cutting, causes blow weld porosity and uneven bead shapes. Excessively low speed also produces a convex hat shape beads that are subjects to cracking, cause excessively melt through, and produces a large weld puddle that flows around the arc resulting in rough bead, spatter and slag inclusions.

E. Size of electrode

At a given welding current, larger electrode results in wider, less penetration bead. Hence in joints with poor fit-up, a large electrode is preferred to a smaller one for bridging the root gap. For a given electrode size, a high current density results in a strong, penetration arc, while a lower current density gives a soft arc which is less penetrating.

F. Electrode stick-out

It is also termed as electrode extension. It refers to the length of the electrode, between end of contact tube and the arc, which is subjected to resistance heating at the high current densities used in the process. The longer the stick-out, greater will be amount of heating and higher the deposition. However, with the long stick-out, the increase in deposition rate is accompanied by a decrease rat in penetration. Hence longer stick-out is avoided when deep penetration is desired.

G. Heat input rate

Also termed arc energy, it is calculated by using formula as given below

HIR = (VxAx60)/(Sx1000)

Where HIR=Heat Input Rate (KJ/mm)

V= Arc Voltage

A = Welding Current (amp.)

S = Arc travel speed in mm/min.

For a given joint thickness, higher the heat input rate the lower is the cooling rate of the weld metal and (HAZ) heat affected zone of the parent metal, and vice versa. Heat input rate has an important bearing on the weld metal micro structure and the final structure of HAZ, and thereby on their toughness. The process usually is not suitable for use on metal less than 3/16 inch thick, because burn through is likely.

III. EXPERIMENTATION

A. Welding Equipments

For this purpose submerged arc welding equipment which is available to us is as follows:

- Fully automatic
- Circuit Voltage range 25-55 V
- Maximum Current 800 A
- Argon and Carbon Dioxide Gases are used as shielding gas.
- Electrode wire is of Stainless Steel single wire of diameter 3.16 mm.
- Stainless Steel 316L material is used for experimentation work.

B. Steps followed during the process

Tube of type AISI 316 with 100-mm length, 50mm diameter, 3mm thickness has been opted with welding voltage of 24, 40 and 55 Volts, and electrode type AWS E 316L. Electrode diameter was taken as nominal 2 mm with positive electrode Polarity and flat position. Pipe joint with 90degree angle and Root gap of 2 mm was kept. The two pieces to be welded were rigidly fixed with bolts at the edges in a fixture before welding process to reduce the wrapping of the welded joint after welding.

Then Tungsten Inert Gas Welding by varying voltage and shielding gas (Argon & CO2) was done. Checking was also done for Microstructure on SEM Microscope, yield strength, tensile strength and hardness of weld bead. Experimental results are shown in diagrams and tables.

C. Gas Cutting

The oxy fuel process is the most widely applied industrial thermal cutting process because it can cut thicknesses from 0.5mm to 250mm.

D. Grinding and U-groove making

The U-groove is made with the help of cylindrical grinder in which one piece is grooved. Grinding is used to remove light rust and dirt also.

E. Rooting

The separation of the members to be welded together at the root to avoid the leakage of fused metal.

F. Welding with the help of TIG machine

After the rooting process for each specimen is over welding with the help of TIG machine at different parameters is made. After this welding by TIG process, the samples for testing the Yield Stress,

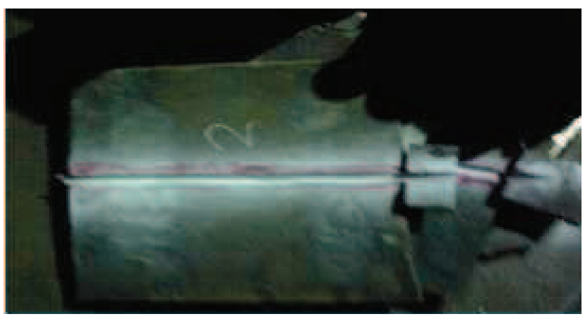

Figure 1. Welding with TIG Machine

Ultimate Tensile test are made, microstructure test are conducted of which the results are attached with.

IV.TEST REPORTS

Following are the test reports for the experimentation

A. Materials

AISI-316L austenitic stainless steel samples consisting of metal pipes of size 100x50x3 mm were welded using three two inert gases by varying voltage: Argon gas and CO2 gas . Austenitic AISI 316L stainless steel has an fcc structure. It has good weld ability due to its low carbon content, what makes it more difficult for chrome carbides to form on grain boundaries when welding. This steel is used extensively in the chemical and petro chemical industry. AusteniticAISI-308L stainless steel is widely used, especially in manufacturing equipment for corrosive food products. It gives excellent results when applied as welding rods in welding.

Table I
Chemical composition of the used plate and electrode E316L

Material	Tube (wt%)	Electrode (wt%)
C	0.075	0.02
Cr	17.4	18.5
Ni	11.0	12.0
Si	05.0	0.7
P	0.04	-
S	0.009	-
Mo	2.3	2.6
Mn	1.6	0.8
Fe	Bal	Bal

B. Microstructure Test

All samples, after each TIG welding with Argon gas and Co2 gas as shielding gas with varying voltages were ground and polished using standard metallographic techniques and were subsequently etched in a marble etchant, which has chemical compositions as follows; 10 g. CuSO4, 50 ml HCl and 50 ml H2O. The microstructures of reheat-treated samples were viewed using scanning electron microscope (SEM) in the secondary electron mode. The size and area fraction of gamma prime particles were determined by the image analysis software.

C. Hardness Test

Vickers micro-hardness Tester is a key piece of equipment that is indispensable to metallographic research, product quality control, and the development of product certification materials. Vickers micro hardness test procedure as per ASTM E-384, EN ISO 6507, and ASTM E-92 standard specifies making indentation with a range of loads using a diamond indenter which is then measured and converted to a hardness value This machine used to make at least ten hardness indentations on the studied weld deposit specimens in the as weld and after heat treatment conditions. The Also, the test was carried out for the weld joint at the base metal; heat affected and welds metal zones. The applied load is 300 mg and the indentation time is 30 according to ASTM E92-72. The arithmetic mean, the maximum and minimum values of the hardness number of each specimen are determined.

D. Micro structures

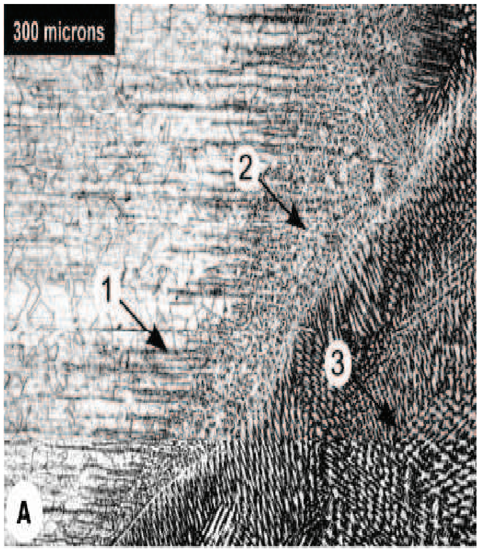

Figure 2 Micrographs of the AISI-316L steel welds with CO2 gas as shielding gas at 40 volts.

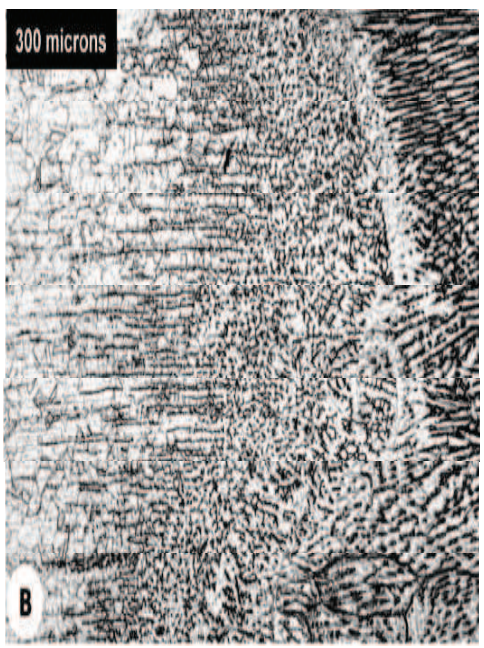

Figure 3 Micrographs of the AISI-316L steel welds with Argon gas as shielding gas at 40 volts.

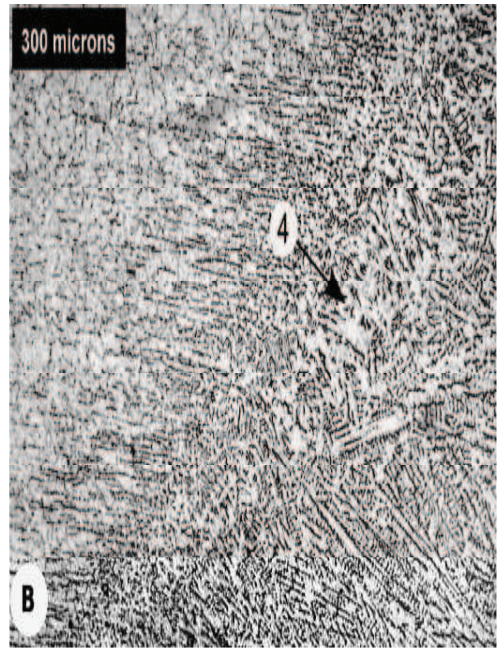

Figure 4 Micrographs of the AISI-316L steel welds with Argon gas as shielding gas with 55 volts voltage in room conditions

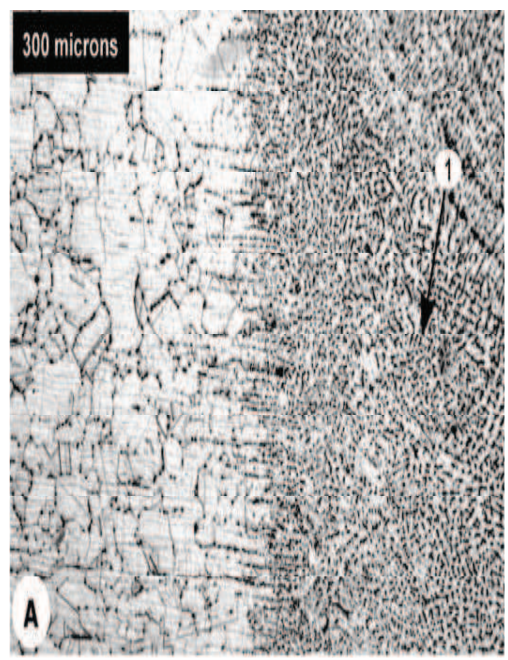

Figure 5 Micrographs of the AISI-316L steel welds with CO2 gas as shielding gas with 55 volts.

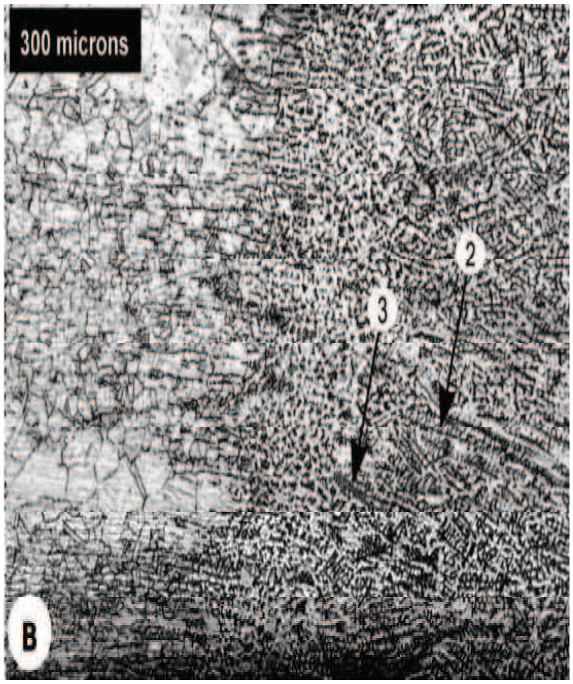

Figure 6 Micrographs of the AISI-316L steel welds with Argon gas as shielding gas with 25 volts voltage in room conditions

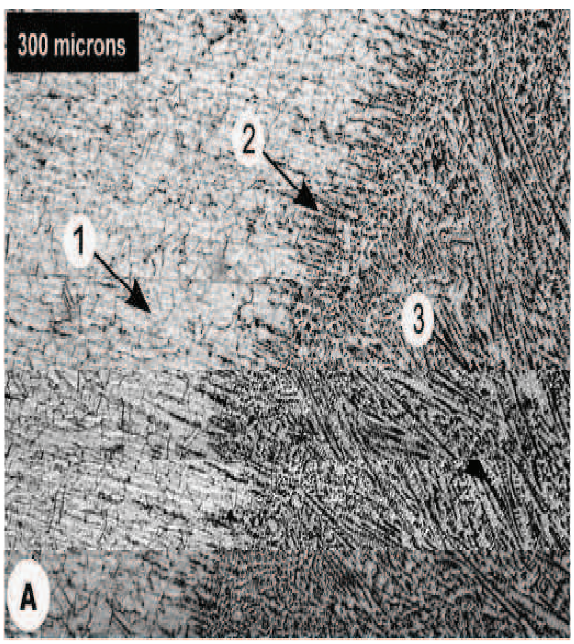

Figure 7 Micrographs of the AISI-316L steel welds with CO2 gas as shielding gas with 55 volts.

E. Metallographic Structure

Figure 2 & 3 shows the microstructure of the zone of transition from the bed to the base metal when using Co2 gas as shielding gas in room conditions at 55 volts(Figure 2) and when the inert gas Argon was used with 55 volts(Figure 3). An equiaxed austenitic structure typical of stainless steel can be observed on the left-hand side of each image. It is smaller than that of the base material, due to the changes that appear at the HAZ (heat affected zone). At the near fusion boundary, the structure presents smaller equiaxial grains of austenite (Figure 4) with ferrite stringers. The morphology of the weld bed shows duplex structure of austenite plus skeletal ferrite (Figure 5), although near the base metal the ferrite becomes interdendritic(Figure 6). The use of the Argon gas as shielding gas increased notably the size of the transition zone between the bed and the base metal. This is why figure 6 presents a wider area of both interdendritic ferrite and ferrite stringers. Also, finely distributed chrome carbide precipitates were detected when the weld was performed with CO2 gas, but not when the inert gas Argon was used. Figure 4 & 6corresponds to the welds carried out with AISI 308L using the usual TIG procedure with CO2 gas as shielding gas (A) and the Argon as shielding gas (B). A completely austenitic structure can be observed in the base material for the HAZ, with a notable reduction in grain size for the samples that were welded using the Argon gas as shielding gas. At the bed, the use of the Argon gas shielding gas induced a change from interdendritic (1 in Figure 5) to skeletal ferrite (2 in Figure 6), with zones of lathy ferrite (3 in Figure 6), signal of a faster cooling due to the continuous argon supply. The micrographs (Figure 7) of the AISI 316L steel welded with Argon gas as shielding gas and CO2 gas shielding gas shows the same structures than the other two: a reduction of austenitic grain size at the HAZ, ferrite stringers (1 in Figure 7) at the near fusion boundary and a zone of interdendritic ferrite (2 in Figure 7) at the beginning of the bed. Because of the great differences in composition between Argon and CO2, the weld bed, which presents a full austenitic columnar solidification (3 in Figure 7), is separated from the partially melted zone by a clearly marked line.

F. Mechanical Characteristics

As can be seen in tables I and III, the micro structural changes that appear due to the presence of a weld bed - when the inert gas Argon is not used- increase the elastic limit of the material but reduce its tensile strength and its strain. Table III shows the tensile characteristics of the various joints according to the standardized tests specified in UNE–EN 895 and hardness in the bed, interface and heat affected zone (HAZ), as per Standard UNE 6507-01. As can be seen in tables I and III, the micro structural changes that appear due to the presence of a weld bed -when the inert gas Argon is not used- increase the elastic limit of the material but reduce its tensile strength

Table II
316L STEEL TIG WELD IN AMBIENT CONDITIONS WITH ARGON

Material	AISI 316L	AISI 316L	AISI 316L
Voltage in Volts	25	40	55
Yield strength MPa	318.5	325.0	345.5
Tensile strength MPa	410	450	495
Hardness (HV) base material	339	339	339
Hardness (HV) base material	328	335	348

Table III shows the tensile characteristics of the various joints according to the standardized tests specified in UNE–EN 895 and hardness in the bed, interface and heat affected zone (HAZ), as per Standard UNE 6507-01. As can be seen in tables I and III, the micro structural changes that appear due to the presence of a weld bed -when the inert gas Argon is not used- increase the elastic limit of the material but reduce its tensile strength and its strain.

Table III
316L STEEL TIG WELD IN AMBIENT CONDITIONS WITH CO2

Material	AISI 316L	AISI 316L	AISI 316L
Voltage in Volts	25	40	55
Yield strength MPa	315.5	322.5	330.0
Tensile strength MPa	402.5	425.0	468.5
Hardness (HV) base material	339	339	339
Hardness (HV) base material	298.5	318.5	330

At the same time, hardness at the weld increases notably if compared to the original alloy if the filler metals are the stainless steels but experiment no substantial changes if CO2 is used. These facts imply a slight deterioration of the mechanical characteristics of the welded structure due to fact that the weld is a linear zone of higher fragility. The use of an inert gas Argon and stainless steel pipes increases even more the yield strength despite the filler metal and reduces the tensile strength. On the other side, a much less increment in hardness is noted when welding with inert gas Argon, in fact the reduction in hardness ranges from a 28 % with 308L as using Argon as shielding gas at 55 volts to more than 50 % with Co2 gas as shielding gas at 55 volts. Although the decrease in tensile strength is not desirable, the lower hardness values obtained with the use of the inert Argon lead to assuring a non fragile behaviour of the joint, which can be useful. In this case, the yield strength reaches its higher value, but the tensile strength and hardness are also improved, obtaining values, for some parameters, almost identical to that of the base metal: values of harness around 154 HV were measured at the weld bed and the interface and a tensile strength only a 0.04 % lesser than the corresponding to the base metal. Although, due to limitations in size and economic requirements, its use is only advisable for demanding applications, hard-to-weld metals.

V. CONCLUSIONS

The use of an inert gas Argon as shielding gas resulted in a wider interface between the weld bed and the base metal, increasing both the presence of ferrite stringers and vermicular ferrite. Its use caused, in every case, a decrease of hardness and an increase of tensile strength and yield strength. On the other hand, the tensile strength was reduced, except when Argon gas is used as shielding gas at 55 volts. The weld carried out with Argon gas as shielding gas, presented the best characteristics. It combined high elongation and the best mechanical properties of all, very similar to that of the original 316L, which assures the best behaviour of the joint by maintaining the continuity of the mechanical characteristics in a welded structure.

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