EXPERIMENTAL INVESTIGATION & ANALYSIS OF SS304L & SS410 WELD CHARACTERISTICS USING TIG WELDING

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Abstract: - TIG welding is highly regarded because of quality and applicability; the process is applied to several industries and aid in the creation and repair of many items. This form of welding is common in the aerospace, automotive, repair and art fields. To improve welding quality of SS 304 L & SS 410 using TIG welding system, by which welding speed can be control during welding process. Surface roughness and tensile strength of the weld joint has been investigated on the weld zone to evaluate the effect of welding parameters on welding quality. Micro-hardness value of the welded zone has been measured at the cross section to understand the change in mechanical property of the welded zone. At lower welding speeds, strength is more due to more intensity of current. With the increase in current, tensile strength of the weld joint increases. Comparison between methodical model and experimental results is in good agreement indicating that the developed models can predict the responses adequately within the limits of welding parameters.

Keywords: TIG Welding System, Surface roughness (Ra), Micro hardness (HV) & UTS

I. INTRODUCTION

Welding is a permanent joining process used to join different materials like metals, alloys or plastics, together at their contacting surfaces by application of heat and or pressure. During welding, the work-pieces to be joined are melted at the interface and after solidification a permanent joint can be achieved. Sometimes a filler material is added to form a weld pool of molten material which after solidification gives a strong bond between the materials. Weld ability of a material depends on different factors like the metallurgical changes that occur during welding, changes in hardness in weld zone due to rapid solidification, extent of oxidation due to reaction of materials with atmospheric oxygen and tendency of crack formation in the joint position.

GTAW or TIG welding process is an arc welding process uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere with a shielding gas generally Argon or Helium or sometimes mixture of Argon and Helium. A filler metal may also feed manually for proper welding. GTAW most commonly called TIG welding process was developed during Second World War. The use of TIG today has spread to a variety of metals like stainless steel, mild steel and high tensile steels, Al alloy, Titanium alloy. Like other welding system, TIG welding power sources have also improved from basic transformer types to the electronic controlled power source today.

TIG welding process has specific advantages over other arc welding process as follows -
narrow concentrated arc, able to weld ferrous and non-ferrous metals, does not use flux or leave any slag, no spatter and fumes during welding. This type of welding process is best suited for metal plate of thickness around 5- 10 mm. Thicker material plate can also be welded by TIG using multi passes which results in high

heat inputs, and leading to distortion and reduction in mechanical properties of the base metal. In TIG welding high quality welds can be achieved due to high degree of control in heat input and filler additions separately. TIG welding can be performed in all positions and the process is useful for tube and pipe joint. The TIG welding is a highly controllable and clean process needs very little finishing or sometimes no finishing. This welding process can be used for both manual and automatic operations.

II. SELECTION OF MATERIALS & EQUIPMENT

MATERIALS USED SS304L & SS410:

2.1 MATERIAL SS304L

SS304L is austenitic chromium – nickel stainless steel offering the optimum combination of corrosion resistance, strength and ductility. These attributes make it a susceptibility to carbide precipitation during welding. SS304L austenitic steel with a chemical composition presented below table 1 with dimensions 75mm x 45mm x 10mm were used to conduct the experiment.

Table:1 Composition of SS304L

ELEMENTS	CONTENT(%)
CARBON	0.15
CHROMIUM	18.2
NICKEL	8.5
MANGANESE	1.6
SILICON	0.5
PHOSPHORUS	0.045
SULPHUR	0.03

Table:1 Composition of SS410

ELEMENT	CONTENT(%)
CARBON	0.15
CHROMIUM	12.3
NICKEL	0.75
MANGANESE	1
SILICON	1
PHOSPHOROUS	0.04
SULFHUR	0.03

2.2 MATERIAL SS410

This stainless steel offers good corrosion resistance due to the presence of large amounts of chromium in it and it has high mechanical characteristics. It is also called as straight chromium steel. SS410 martensitic steel with a chemical composition presented in table 2 and with dimensions 75mm x 45mm x 10mm were used to conduct the experiment.

Fig 1: TIG welding setup

III. EXPERIMENTAL PROCEDURE:

Commercial SS304L & SS410 plates were selected as work piece materials for the present experiment. The plates are cut with dimension of 75 mm x 45 mm with the help of band-saw and grinding done at the edge to smooth the surface to be joined. After that surfaces are polished with emery paper to remove any kind of external material. After sample preparation, the two plates are fixed in the working table with flexible clamp side by side and welding done so that a butt join can be formed.

TIG welding with Alternate Current (AC) was used in experiments as it concentrates the heat in the welding area. Zirconated tungsten electrodes of diameter 3.0 mm were taken as electrode for this experiment. The end of the electrode was prepared by reducing the tip diameter to 2/3 of the original diameter by grinding and then striking an arc on a scrap material piece. This creates a ball on the end of the electrode.

For the experiment welding parameters selection and planning are shown in table 3&4. Before performing the actual experiment, a number of trial experiments have been performed to get the appropriate parameter range where welding could be possible and no observable defects like undercutting and porosity occurred.

Table 3: Welding parameters for experiments

Parameters	Welding current	Voltage	Speed	Distance of tip from weld center	Gas flow rate	Current type	Dimensions
Range	(100-140) A	50 v	(3.5-4) mm/s	3 mm	(8-10) L/min.	AC	75mm*45mm*10mm

Further, the specimens were cut at the cross section for micro-hardness measurement from each sample. Before micro hardness measurement cross section of the welded specimen mounted and polished with 220, 600 and 800 grit size polishing paper sequentially. Micro-hardness was measured with Vickers micro-hardness tester.

Table 4: Experimental planning

Exp. No.	**Current (A)**	**Voltage (V)**	**Welding Speed (mm/s)**	**Electrode Work piece Distance (mm)**	**Argon-Gas flow rate (l/min)**
1	100	50	4.50	3	10-12
2	110	50	4.50	3	10-12
3	120	50	4.50	3	10-12
4	130	50	4.50	3	10-12
5	140	50	4.50	3	10-12
6	100	50	5.0	3	10-12
7	110	50	5.0	3	10-12
8	120	50	5.0	3	10-12
9	130	50	5.0	3	10-12
10	140	50	5.0	3	10-12

Fig 2: TIG welding Sample

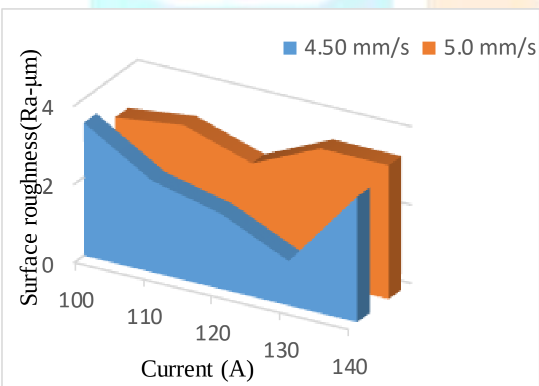
IV. RESULTS AND DISCUSSIONS

4.1 Surface roughness

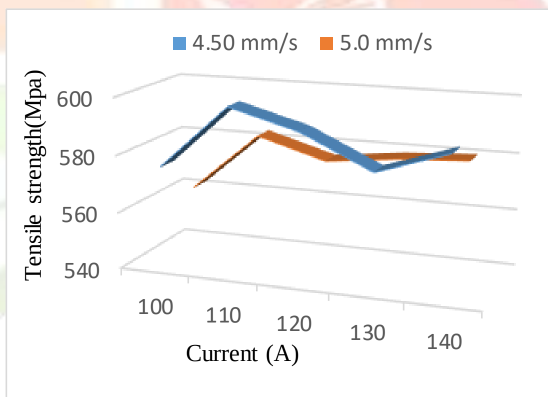
Surface roughness of the weld zone for all the samples were measured and average surface roughness value was calculated from the mean values which is tabulated in Table 5. Roughness value found in the range of 1.13 to 3.41 micron, is quite low for a welded specimen. Therefore, it can be say that the quality of welding is not possible in manual setups which may require further finishing operation. But using an automated system a good quality ma possible These roughness values are plotted against applied current in plot 1 and has been observed that applied current has no effect on surface roughness.

Table 5: Surface roughness value for different welded samples

Sample No	Observation 1 (µm)	Observation 2 (µm)	Observation 3 (µm)	Mean Value (µm)
1	3.67	3.33	3.18	3.393333
2	2.11	2.5	2.39	2.333333
3	1.82	1.79	2.17	1.926667
4	0.91	1.2	1.29	1.133333
5	2.94	3.22	3.45	3.203333
6	2.77	2.97	3.09	2.943333
7	1.9	4.33	3.27	3.166667
8	2.36	2.61	2.88	2.616667
9	3.23	3.71	3.32	3.42
10	2.84	3.15	4.25	3.413333



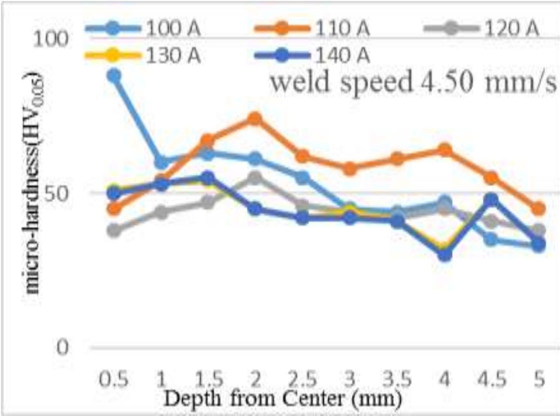
Plot 1: Avg. surface roughness Vs Applied current

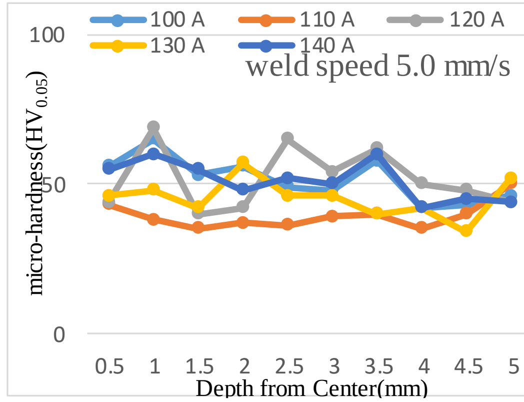


Plot 2: Tensile strength Vs Applied current

4.2 Micro-hardness test

Micro-hardness value of the welded zone was measured for all the welded specimens at the cross section to understand the change in mechanical property of the welded zone. Plot. 3 and 4 shows the micro-hardness value at the welded zone taken from the center of the welding zone towards the base material for different samples performed with different welding speed and welding current. From the graph it is found that for almost all the sample micro hardness value increases in the welding zone than the base material and these values are in the range of 30 to 80 $HV_{0.05}$ in the welded zone. After a certain distance these value reduces to the hardness of the base material for the sample processed with welding speed 4.5 mm/s and different current settings.





Plot 3(a): Micro hardness Vs vary case depth Plot 3(b): Micro hardness Vs vary case depth

4.3 Tensile test:

Tensile test of the welded joint was performed with universal tensile testing machine with maximum load capacity 600 kN. Table 6 shows the tensile strength value for all the welded joints produced at different welding speed and current setting.

Table 6: Tensile strength based on model and experimental data for each of the samples

Sample No	Mean tensile strength (methodical model)	Mean tensile strength (experimental)	(%) Error
1	570.9	575.5	0.80
2	594.65	597.91	0.54
3	576.89	591.23	2.42
4	574.28	579.82	0.96
5	585.93	588.1	0.37
6	577.38	561.96	2.74
7	593.55	582.87	1.83
8	579.19	575.8	0.59
9	588.1	578.64	1.63
10	590.36	580.06	1.77

Table 6 shows the response changes as the two of the control factors (current and flow rate shielding gas) were varied. The tensile strength of the base material of SS 304 L & SS 410 were measured as 561.96 MPa while the theoretical tensile strength of the SS 304 L & SS 410 was 577.38 MPa. Based on the observation, the tensile strength of the weld was higher than that of the base material, fracture occurred at the base material. On the other hand, fracture occurred in the welding zone or heat affected zone (HAZ) when the tensile strength is less than the base metal. The experimental data from confirmation test run was almost the same as the model value for tensile strength since the value differs within 5% only.

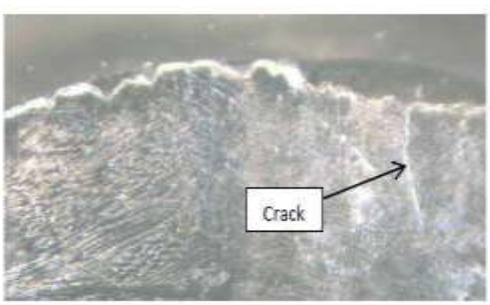


Fig: Crack yields in tensile test

Fig: Weld sample HAZ

In plot 2- tensile strength of the welded joints are plotted against applied current for welding speed of 4.5 mm/s. From the it is also found that tensile strength value almost increasing for increasing current setting when welding speed is 4.5 mm/s (except for welding current form

120 A to 130 A). Similarly, in plot 2 tensile strength of the welded joints are also plotted against applied current for welding speed of 5 mm/s. From this graph it is found that, welding done with 4.5 mm/s there is no specific trend in change of tensile strength due to change in current. Comparing the plot 3(a) and (b) it is clearly seen that for almost all current setting condition (except 120 A current setting) tensile strength values of the welded joint performed with welding speed 4.5 mm/s are larger than the tensile stress values of the welded joint performed with welding speed 5 mm/s.

V. CONCLUSIONS

The processed joints exhibit desired mechanical and surface characteristics. Interestingly, weld current used should be suitable with filler size in order to achieve good joint. Process parameters play a vital role in eliminating the defects. High welding current (140-A) with filler (3-mm) and constant flow rate is beneficial for high strength joint since weld uniformity become poor. At lower welding speeds, strength is more due to more intensity of current. With the increase in current, tensile strength of the weld joint increases. Using manual welding system on single side gives desired results. With the automated welding system, uniform welding of plate can be possible.

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