Analysis of Tensile Strength, Ultimate Tensile Strength and Micro Hardness for TIG Welding on Material AISI 304 Stainless Steel

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Abstract— The experimental work is to be carried out to investigation of tungsten inert gas (TIG) welding for tensile test on AISI 304 Stainless Steel hardness and distortion of V grooves butt weld joint of AISI 304 stainless steel material. Focus of this project work to identify strength of welded joint by changing the welding process. The austenitic grades have well to excellent corrosion resistance and weldability. Their good impact strength at low temperatures is often exploited in cryogenic application. The higher ultimate tensile strength 646 mpa produced at 45 groove angle, 1.5 mm root face and 1.5mm root gap in TIG welding. The ultimate tensile strength of TIG butt welds reaches to 97 % of the base metal ultimate tensile strength (i.e 664mpa). Optimization of response variables is performed by grey relation analysis (GRA). TIG GRA indicates that tensile strength 641 MPa and micro hardness 236 Hv is obtained for optimum process parameter of groove angle 60 degree, root face 1 mm and root gap 1.5 mm. Higher micro hardness 236 Hv produced at 60 groove angle, 1 mm rib thickness and 1.5 root gap in TIG welding.

Key words: TIG, AISI 304, Tensile Strength, Micro Hardness, Ultimate Tensile Strength

I. INTRODUCTION

A. *Basic Mechanism of TIG Welding*

TIG welding is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere by an inert shielding gas (argon or helium), and a filler metal is normally used. The power is supplied from the power source (rectifier), through a hand-piece or welding torch and is delivered to a tungsten electrode which is fitted into the hand piece. An electric arc is then created between the tungsten electrode and the work piece using a constant-current welding power supply that produces energy and conducted across the arc through a column of highly ionized gas and metal vapours.[1] The tungsten electrode and the welding zone are protected from the surrounding air by inert gas. The electric arc can produce temperatures of up to 20,000^{0}C and this heat can be focused to melt and join two different part of material. The weld pool can be used to join the base metal with or without filler material. Schematic diagram of TIG welding and mechanism of TIG welding are shown in fig. 1.2and fig. 1.3respectively.

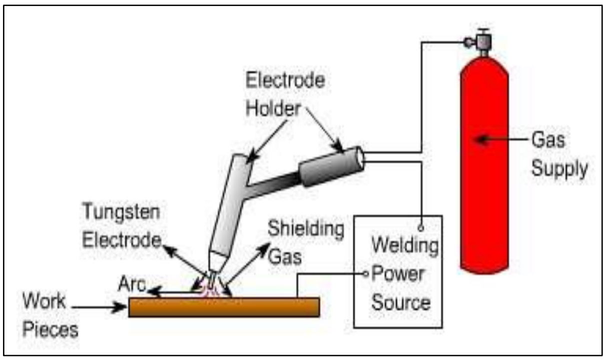

Fig. 1: Schematic Diagram of TIG Welding System [1]

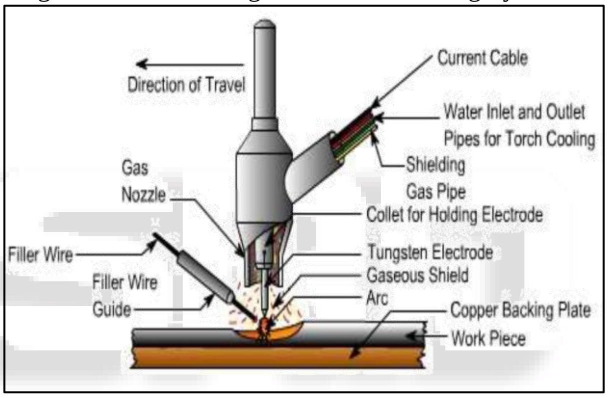

Fig. 2: Principle of TIG Welding[1]

Tungsten electrodes are commonly available from 0.5 mm to 6.4 mm diameter and150 - 200 mm length. The current carrying capacity of each size of electrode depends on whether it is connected to negative or positive terminal of DC power source. The power source required to maintain the TIG arc has a drooping or constant current characteristic which provides an essentially constant current output when the arc length is varied over several millimetres. Hence, the natural variations in the arc length which occur in manual welding have little effect on welding current. The capacity to limit the current to the set value is equally crucial when the electrode is short circuited to the work piece, otherwise excessively high current will flow, damaging the electrode. Open circuit voltage of power source ranges from 60 to 80 V.

B. *Advantages of TIG Welding*

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 (shielding gas is used to protect the weld-pool and tungsten electrode).
- No spatter and fumes during TIG welding.

C. Process Parameters of TIG Welding

The parameters that affect the quality and outcome of the TIG welding process are given below.

1) Welding Current

Higher current in TIG welding can lead to splatter and work piece become damage. Again lower current setting in TIG welding lead to sticking of the filler wire. Sometimes larger heat affected area can be found for lower welding current, as high temperatures need to applied for longer periods of time to deposit the same amount of filling materials. Fixed current mode will vary the voltage in order to maintain a constant arc current.

2) Welding Voltage

Welding Voltage can be fixed or adjustable depending on the TIG welding equipment. A high initial voltage allows for easy arc initiation and a greater range of working tip distance. Too high voltage, can lead to large variable in welding quality.

3) Inert Gases

The choice of shielding gas is depends on the working metals and effects on the welding cost, weld temperature, arc stability, weld speed, splatter, electrode life etc. It also affects the finished weld penetration depth and surface profile, porosity, corrosion resistance, strength, hardness and brittleness of the weld material. Argon or Helium may be used successfully for TIG welding applications.

4) Welding Speed

Welding speed is an important parameter for TIG welding. If the welding speed is increased, power or heat input per unit length of weld is decreases, therefore less weld reinforcement results and penetration of welding decreases. Welding speed or travel speed is primarily control the bead size and penetration of weld. It is interdependent with current. Excessive high welding speed decreases wetting action, increases tendency of undercut, porosity and uneven bead shapes while slower welding speed reduces the tendency to porosity.

II. EXPERIMENTAL WORK

A. Material Selection for Workpiece

1) AISI 304 Stainless Steel

The experimental work is to be carried out to investigation and compare TIG and SMAW welding for tensile test, hardness and distortion of V grooves butt weld joint of AISI 304stainless steel material. Focus of this project work to identify strength of welded joint by changing the welding process. The austenitic grades have well to excellent corrosion resistance, good formability and weldability. Their good impact strength at low temperatures is often exploited in cryogenic application. The austenitic grades are non-magnetic in the solution annealed condition due to the austenitic microstructure. This type is selected for the experimentation purpose because it is highly corrosion resistance and mostly used for aerospace application and can be used from both high temperature applications to cryogenic one. The table 3.1 shows chemical composition of AISI 304 stainless steel.

C	Mn	S	P	Si	Ni	Cr	N
0.057	1.02	0.003	0.036	0.27	8.04	18.29	0.045

Table 1: Chemical Compositionsof AISI 304 Stainless Steel

B. Material Selection for Filler Metal

1) AISI 308L Stainless Steel

Stainless steel 308L has excellent corrosion resistance in wide variety of environments and when in contact with different corrosive media. Pitting and crevice corrosion can occur in environments containing chlorides. Stress corrosion cracking can occur at temperature over 60^0 C.Fusion welding performance for stainless steel 304 is excellent both with and without fillers. Recommended filler rods and electrodes for stainless steel 304 is grade 308L stainless steel. The chemical compositions of AISI 308 L electrodesare given in table 2.2.

C	Mn	Si	S	P	Cr	Ni	N
0.08	2.5	0.65	0.03	0.05	19.50	10.50	11

Table 2: Chemical Composition ofAISI 308 Filler Rod used in SMAW& TIG

The table 2.3 shows the values of the selected process parameters, three parameters with three levels. All these values are selected on the basis of literature review, machine specification. By using Design of Experiments by Taguchi Method, L_9 orthogonal array is selected for experiments. The columns of L_9 orthogonal array are shown in table 2.3.[12,13,14]

Levels	Groove Angle (Degree)	Root Face (mm)	Root Gap (mm)
Level 1	30	1	0
Level 2	45	1.5	1.5
Level 3	60	2	2

Table 3: Process Parameters and their Level for Experimentations SMAW & TIG

III. RESULT & DISCUSSION

A. Analysis of Tensile Strength for TIG Joint

The tensile test samples were prepared using laser cutting process. The tensile test performed on computer interfaced star testing system universal testing machine.The fig. 4.7 shows specimen prepared as per ASTM E8/E8M-09 standards. The fig. 4.8 shows fractured tensile sample of TIG weld sample. The cross-head speed was maintained at 3 mm/min and the strain rate of $0.06^{-2}S^{-1}$ was observed.

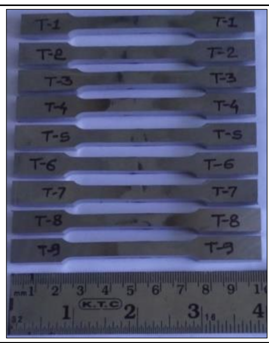

Fig. 3.1: Photograph of Tensile Test Sample for TIG Weld

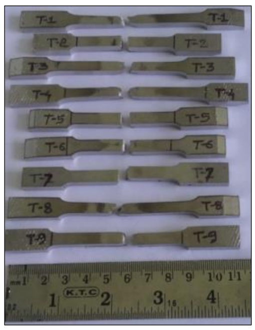

Fig. 3.2: Photograph of Fractured Sample for TIG Weld

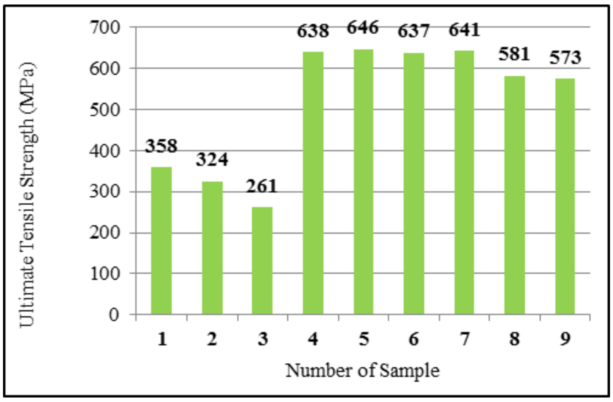

Fig. 4: Analysis for UTS (MPa) of TIG Welding

After performing final experiments, analysis of experimental data is done by using MINITAB-17 software. The effect of various input parameters on output responses will be analysed using analysis of variance (ANOVA). The table 3.3 indicates that one process parameter significant and influencing tensile strength at 98 % confidence level.

Analysis of variance (ANOVA) test is performed to identify the process parameters that are statistically significant and which affect the tensile strength of TIG joints. The ANOVA results for tensile strength are given in table 3.3.

Source	DF	Adj SS	Adj MM	F-Value	P-Value
Groove Angle (Degree)	2	188696	9434.8	68.15	0.014
Root Face (mm)	2	4595	2297.3	1.66	0.376
Root Gap (mm)	2	293	146.3	0.11	0.904
Error	2	2769	1384.3		
Total	8	196352			
S=37.2066 R-sq=98.59 % R-sq=94.36 %					

Table 4: ANOVA for UTS (MPa) of TIG Welding

The results of ANOVA indicate that the considered process parameters are highly significant factors affecting the tensile strength of TIG joints in the order of groove angle. Main effect plot for tensile strength is as shown in fig 3.4. As a groove angle increases tensile strength also increases, highest tensile is obtained at 646 MPa.

Main effect plots for tensile strength are as shown in fig. 3.4. In order to see the effect of process parameter on tensile strength using L_9orthogonal array and experiments are performed and the experimental data are given in table 4.3. It is clear that as groove angle up to 45 degree increasing UTS increase after that UTS decrease. It was observed that as root face goes on increasing the UTS goes on decreasing. The effect of root gap increase to increase UTS as shown in fig 3.4

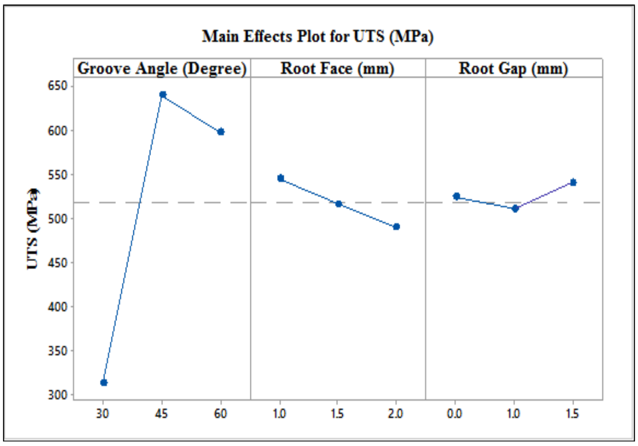

Fig. 5: Main Effects Plot for UTS (MPa) of TIG Welding

Similarly, it can be seen that tensile strength is higher 646MPa at 45 degree groove angle,1 mm root face and 1.5 mm root gap. The tensile strength is very low 261MPa at 30 degree groove angle, 2 mm root face and 0 mm root gap.

IV. CONCLUSION

- The higher ultimate tensile strength 646 mpa produced at 45 groove angle, 1.5 mm root face and 1.5mm root gap in TIG welding. The ultimate tensile strength of TIG butt welds reaches to 97 % of the base metal ultimate tensile strength (i.e 664mpa).
- Optimization of response variables is performed by grey relation analysis (GRA). TIG GRA indicates that tensile strength 641 MPa and micro hardness 236 Hv is obtained for optimum process parameter of groove angle 60 degree, root face 1 mm and root gap 1.5 mm.
- Higher micro hardness 236 Hvproduced at 60 groove angle, 1 mm rib thickness and 1.5 root gap in TIG welding.
- The TIG welding process shows good result as compare to SMAW process.

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