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Mechanical Assessment of SS 304 & SS316L by using Pulsed TIG Welding Process

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Abstract: Welding is the process of joining two or more similar or dissimilar metals by applying heat and pressure. Among all other welding processes TIG welding is regularly used for joining the components in Nuclear Reactors because it produces high weld strength and involves less cleaning process post welding. In this study SS 304 and SS 316L are joined by using pulsed TIG welding process with SS 316LER as filler wire. Parameters like Welding Current, Gas Flow Rate and Root Gap are varying. These parameters are assessed by means of Taguchi L4 Orthogonal array. Mechanical characteristics like Tensile Test was performed before and after Post Welding Heat Treatment process and Microstructure Analysis was performed by using optical microscope at 500X magnification.
Keywords: Pulsed TIG welding, Heat treatment process, Welding Process in Nuclear Reactors

I. INTRODUCTION

Quality and productivity play a vital role in today's manufacturing industry due to the very stiff and cut-throat competitive market conditions. The main objective of the present manufacturing industry is to produce high-quality products at minimum cost and time. Welding is one of the vital and common operations used for joining similar and dissimilar components. Nuclear reactors are fabricated in general using the TIG welding process and needs no cleaning. The material used for the reactor is required to have high mechanical properties such as high yield strength, ultimate strength and hardness to resist the applied forces.

Iron and steel both come in a form of crystal structure and it is face centered cubic (FCC) or Body Centered cubic (BCC). Heating the iron to high temperature and start cooling, it shifts into Austenite. Austenite is face centered cubic structure which is not as much stressed as martensitic steels.

This type of steel is non-magnetic, they are also called as 300 series steels. Some of 300 series steel contains high chromium and nickel content in them. Which makes them corrosion resistant. Chromium is the primary element which makes this steel as stainless steel. Some if 300 series steels are 302, 304, 304L, 316, 316L, 317L, etc. The letter "L" in 300 series steels refers to low carbon content. Among all this steels grades SS-304 is most popular and also known as Food Grade steel because of "18/8" this ratio stands for 18% of nominal chromium content and 8% of nominal nickel content.

Some grades of Austenitic steels like SS 304 & SS 316L. SS 304 is used in light water reactor and fast breed reactor for many years. They are also considered as the structural material in fusion reactors as they worked extremely good for fission reactor production and operation.

Just like pre heating, Post welding heat treatment process is very important as the part of welding. As the name suggest Post welding heat treatment process is done after completion of the welding of a particular component. It helps to improve welding quality and stress relief [1,2], not only the quality of the weld metal but also increases the quality of the base metal. As said earlier it also releases the stresses which are internally developed during the welding process.

When a weldment is seen directly there is no change, but when observed under the thermal cameras we can see the temperature distribution inside the weldment.

This temperature distribution is different at different locations like the center area is very hot when compared with the edges of the base mental. Because of this nonlinear temperature distribution several stresses are generated which are called as Residual Stresses. Which eventually effects the weld strength.

After completion of the welding of the metals there will be heat transfer between weld metal and base metal due to conduction heat transfer. This heat transfer will take place unevenly, some time the thickness of the base metal will also be the reason for uneven heat transfer. Depending up on the cooling rate weldment's mechanical and microstructure properties gets changed.

II. LITERATURE REVIEW

In a study by Manabendra Saha[3] et al on "Effect of TIG Welding Parameter of Welded Joint of Stainless Steel SS304 by TIG Welding" to obtain a good quality weld it was observed that parameters like current, gas flow rate, welding speed and electrode diameter played an important role. Tensile strength was increased from 515 MPa to 556 MPa because of using optimum parameters.

Evaluation of Mechanical Properties of Stainless Steel (SS 304) by TIG Welding at Heat affected Zone is studied by D. Simhachalam et al[4]. it was observed that the experimentation was conducted in two cases. In case one gas flow rate and welding current are kept constant while diameter of the filler rod is varied which resulted in increasing of depth of penetration and significant decrease in impact strength. In case two gas flow rate and filler rod diameter were kept constant and current is varied in increasing order, which resulted in increasing the hardness at heat affect zone.

Effects of post-weld heat treatments on the microstructure, mechanical and corrosion properties of gas metal arc welded 304 stainless steel was studied by Taiwo Ebenezer et al [5]. It was observed that there is significant improvement of microstructure, mechanical and corrosion properties of the weldment after the post welding heat treatment process. Post tempering process increased the tensile strength to 10%. At the end of the experimentation, it was concluded that post tempering heat treatment process shows the better improvements than that of post annealing because of more refined grains formed during tempering process.

In a study conducted by M. R. Dodo et al [6]. on effect of post-weld heat treatment on the microstructure and mechanical properties of arc welded medium carbon steel. The study comprises of detail description of effect of the three different heat treatment processes i.e., annealing, normalizing and quenching on the weldment. It was concluded that normalizing heat treatment process is the best of the three process. Tensile strength was increased after normalizing and quenched.

III. METHODOLOGY

Design of Experimentation (DOE) is the important process before starting an experiment. Design of Experimentation means arranging the parameters of an experiment in particular order such that the result which is obtained at end is more accurate. In this study Taguchi Orthogonal array is used as DOE because it is one of the widely used technique in the manufacturing data perspective. In Taguchi Orthogonal array the data is balanced. There is no preference given to one particular parameter. Within a column the levels are balanced and between any two columns also the levels are balanced. L4 (2^3) orthogonal array is selected as there are 3 parameters used in the experiment.

IV. EXPERIMENTATION

The experimentation is performed on SS 304 and SS316L by using multi-pass pulsed tig welding process. Welding current, Gas flow rate and root gap are used as parameters. These parameters are arranged in Taguchi's L4 orthogonal array. Table 1 shows the standard table for L4 orthogonal array where A, B, C are parameters and 1,2 are levels. Table 2 shows the parameters and levels. Table 3 shows the parameters arranged in the standard table format.

Table 1. L_4 Orthogonal Array

Test Run	A	B	C
1	1	1	1
2	1	2	2
3	2	1	2
4	2	2	1

Table 2. Parameters and Levels

Character	Parameters	Units	Level 1	Level 2
A	Welding current	Amps	100	105
B	Gas flow rate	cfm	10	13
C	Root gap	mm	1.5	2

Table 3
L_4 Orthogonal Array With Parameters

Test Run	Welding current (A)	Gas flow rate (mm/s)	Root gap (mm)
1	100	10	1.5
2	100	13	2
3	105	10	2
4	105	13	1.5

The work pieces are examined for any irregularities and milled to the required length as shown in Figure 1. In this study Single V-groove but welding joint is used. To produce V groove end milling operation is performed on Vertical milling machine with end milling cutter as shown in the figure 2.

Fig 1: work pieces after removing all irregularities in length

Fig 2: End milling operation on vertical milling machine

Fig 3: workpieces with single V groove

After the machining process welding process is carried on the machined workpieces i.e., SS 304 and SS 316L. Based on the DOE TIG welding is done. The workpieces are held and fixed on the welding table with the help of C-clamp and welding is caried out as shown in the figure 4. Figure 5 shows the weldments.

Fig 4: workpieces held with C-clap

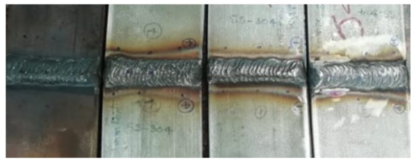


Fig 5: Weldments

A. Post Welding Heat Treatment Process

Post Welding Heat Treatment (Normalizing) [7] is performed on the weldments in order to reduce the internal stress developed during the welding process. The weldments were kept inside Muffle furnace and heated to 800 degree centigrade [8][9] such that recrystallization process takes place inside the weldment.

B. Wire EDM Machining

The weldments are cut into dog bone shape as per ASTM E8 standards [10]. The wire used for cutting is copper with a diameter of 0.2mm.

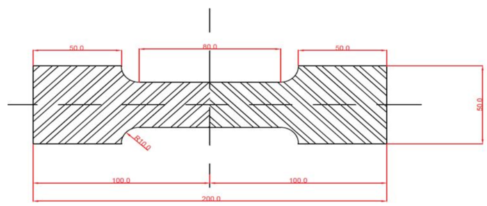


Fig 6: CAD design for wire EDM

Note: Machining of the samples for PWHT must be done after the heat treatment process. If the machining is done before heat treatment process there is a high chance of weldments getting distorted.

C. Tensile Test Before and After PWHT

Tensile test is carried out on Universal Testing Machine before and after PWHT. The results are tabulated below.

Table 4
Tensile Test Results Before PWHT

W. P	Thickness (mm)	Width of sample (mm)	C/A area (mm)	Ultimate load (KN)	UTS (Mpa)	Yield strength (Mpa)	% elongation
1	5	34	170	80.33	472.52	271.08	47.16
2	5	34	170	80.68	474.58	281.28	46.12
3	5	34	170	80.31	472.41	264.80	44.38
4	5	34	170	80.56	473.88	264.19	44.04

Table 5
Tensile Test Results After PWHT

W. P	Thickness (mm)	Width of sample (mm)	C/A area (mm)	Ultimate load (KN)	UTS (Mpa)	Yield strength (Mpa)	% elongation
1	5	34	170	98.12	577.17	341.29	45
2	5	34	170	98.12	577.17	371.21	45.98
3	5	34	170	98.80	581.17	364.80	43.56
4	5	33	170	98.48	579.29	364.02	43.08

D. Microstructure Analysis

Microstructure analysis is performed under optical microscope at 500X magnifications at different location's i.e., at HAZ of 304, HAZ of 316L and fusion zone of workpiece 3 as it had performed very well when compared it with other workpieces after PWHT. It is very difficult task to reveal the microstructure of the welded bimetallic joint due to the existence of the different chemical composition across the weldment. Composite region of the work piece is polished using emery sheet, which was then followed by disk polishing machine with aluminum oxide. Etchant used was modified Fry's reagent consisting of 25ml of hydrochloric acid (HCL), 1g of Cupric Chloride ($CuCl_2$), 150ml of water (H_2O) and 25ml of Nitric acid (HNO_3) [11]. To get the grain size according to ASTM standards Jeffries' formula (1) is used. Fig 7 shows the Jeffries' multiplier(f) values [12].

Magnification Used, *M*	Jeffries' Multiplier, *f*, to Obtain Grains/mm²
1	0.0002
10	0.02
25	0.125
50	0.5
75[A]	1.125
100	2.0
150	4.5
200	8.0
250	12.5
300	18.0
500	50.0
750	112.5
1000	200.0

[A] At 75 diameters magnification, Jeffries' multiplier, *f*, becomes unity if the area used is 5625 mm² (a circle of 84.5-mm diameter).

Fig 7. Values of Jeffries' multiplier

$$N_A = f\left(N\ inside + \frac{N\ intercept}{2}\right) \quad (1)$$

N_A = number of grains per square millimeter.
N_{inside} = number of grains inside the circle.
$N_{intercept}$ = number of grains on the circumference of the circle.

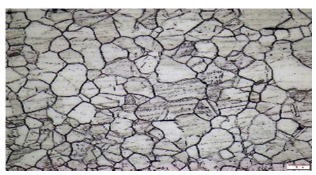


Fig 8: microstructure of SS-304

SS-304 base material consisting of the austenitic grain boundaries with annealing twins showing elongated grains since the material is rolled. The grain size is ASTM No = 8.

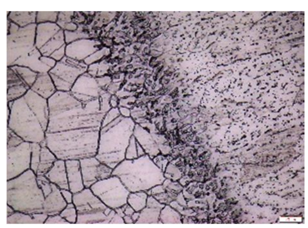


Fig 9: microstructure of SS-304 HAZ

SS-304 HAZ consisting of austenitic grain boundaries with annealing twins showing Equiaxed grains since the material affected by the heat so the grains are recrystallized.

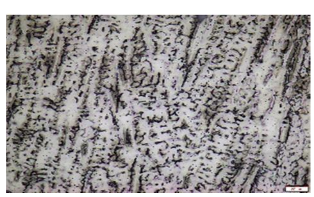


Fig10: microstructure of Fusion Zone

The Fusion zone is showing the dendritic structure (Epitaxial Grain Growth).

Fig 11: microstructure of SS-316L HAZ

SS-316L HAZ structure consisting of austenitic grain boundaries with annealing twins.

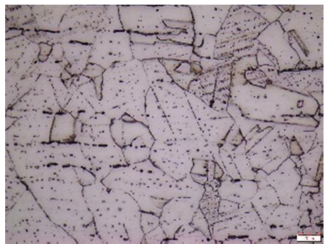


Fig 12: microstructure of SS-316L

SS-316L base material structure consisting of austenitic grain boundaries with annealing twins having the grain size ASTM No = 7.

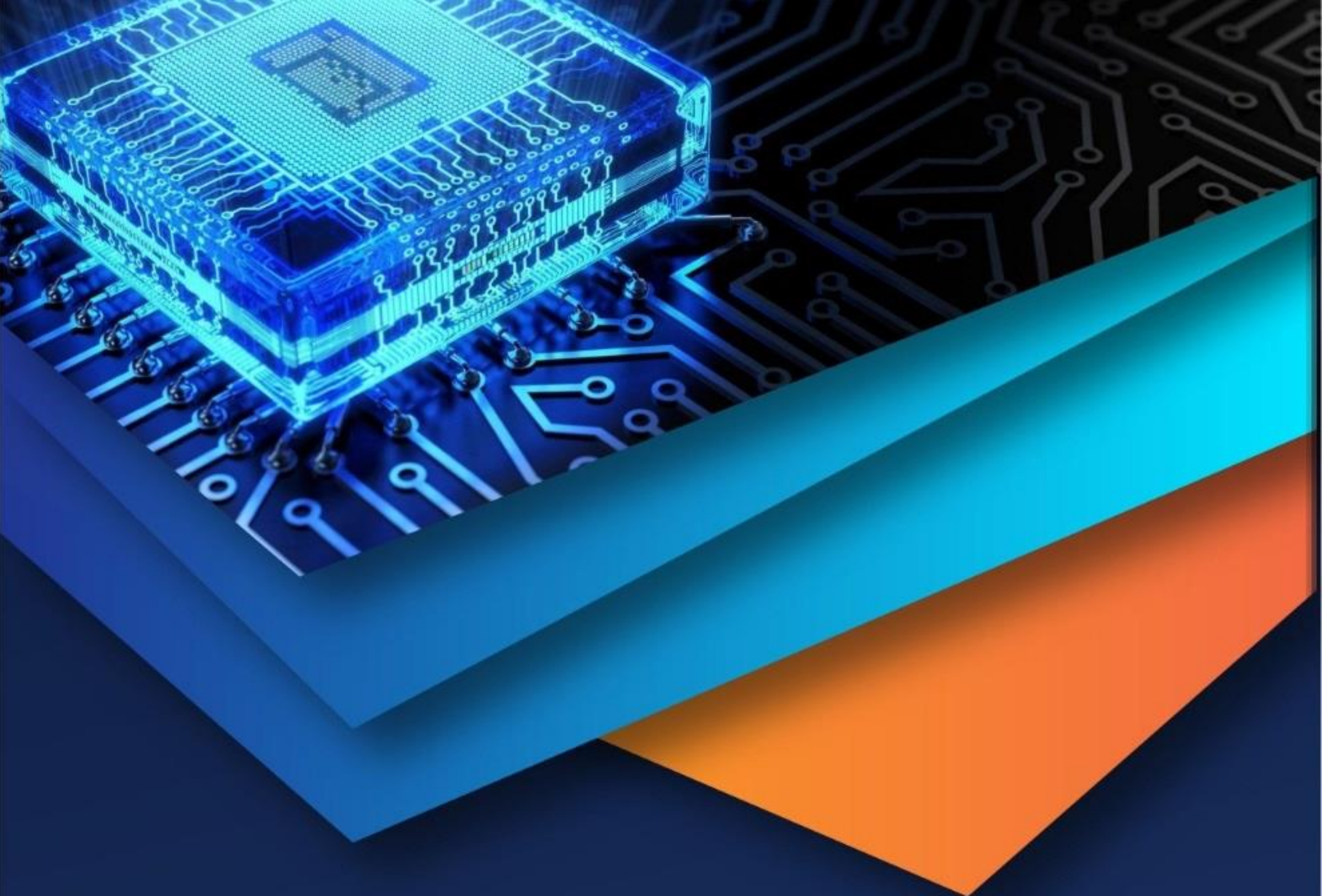
V. CONCLUSION

In this study, an L_4 (2^3) with 3 columns and 4 rows is used. Parameter like welding current, gas flow rate, and root gap are the variables. A significant improvement can be observed in the tensile test results of all four workpieces before and after post welding heat treatment process.

1) *Before PWHT:* Best result was obtained for Workpiece 2 (with welding current 100 amps, Gas flow rate of 13 mm/sec and root gap of 2mm) with a yield strength of 281.28 Mpa.
2) *After PWHT:* Best result was obtained for Workpiece 2 (with welding current 100 amps, Gas flow rate of 13 mm/sec and root gap of 2mm) with a yield strength of 371.21 Mpa. It can be clearly said that Post Welding Heat Treatment process (Normalizing) increases the tensile strength of the weldment.

REFERENCES

[1] Effect of Post Weld Heat Treatment on Mechanical Properties and Microstructure of P11 Weld: A Review, ISSN: 2230-9845 (Online), ISSN: 2321-516X (Print) Volume 8, Issue 3 by Amit R. Patel, G.D. Acharya.
[2] Post-Weld Heat Treatment Case Studies by Khaleel Ahmed and J. Krishnan, Centre for Design and Manufacture Bhabha Atomic Research Centre.
[3] Effect of TIG Welding Parameter of Welded Joint of Stainless Steel SS304 by TIG Welding, Trends in Mechanical Engineering & Technology ISSN: 2231-1793 (Online), ISSN: 2347-9965 (Print) Volume 8, Issue 3 www.stmjournals.com
[4] Evaluation of Mechanical Properties of Stainless Steel (SS 304) by TIG Welding at Heat affected Zone, Volume-5, Issue-4, August-2015 International Journal of Engineering and Management Research Page Number: 214-221, ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962.
[5] Effects of post-weld heat treatments on the microstructure, mechanical and corrosion properties of gas metal arc welded 304 stainless steel by Taiwo Ebenezer Abioye et.al.
[6] Effect of post-weld heat treatment on the microstructure and mechanical properties of arc welded Medium carbon steel by M. R. Dodo1 et.al. Print ISSN: 0331-8443, Electronic ISSN: 2467-8821.
[7] S.H. Avner, Introduction to Physical Metallurgy. (McGraw-Hill Inc., 1974).
[8] Effect of Post-Weld Heat Treatment on Mechanical and Electrochemical Properties of Gas Metal Arc-Welded 316L (X2CrNiMo 17-13-2) Stainless Steel JMEPEG ASM International.
[9] Designing of CK45 carbon steel and AISI 304 stainless steel dissimilar welds Print version ISSN 15161439 Mat. Res. vol.17 no.1 São Carlos Jan./Feb. 2014 Epub Oct 11, 201
[10] Halil İbrahim Kurt et.al / International Journal of Advances in Engineering, Science and Technology (IJAEST) Study on Microstructure, Tensile Test and Hardness 316 Stainless Steel Jointed by TIG Welding
[11] University of Cambridge Chemical Hazard Risk Assessment form.
[12] Standard Test Methods for Determining Average Grain Size, Designation: E112 – 10, ASTM international.



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