EXPERIMENTAL INVESTIGATION ON ACTIVATED-TIG WELDING PARAMETERS USING AISI316L

H.Ramakrishnan1*, A.Vigneshwaran2, A.D.Venkatesh2, E.V. Santhakumar2, S.Ranjith2.

1- Assistant Professor, Mechanical Engineering, K.Ramakrishnan College of Engineering, Samayapuram, Trichy

2- Department of Mechanical Engineering, K.Ramakrishnan College of Engineering, Samayapuram,Trichy

ABSTRACT

An attempt has been made to study the strength of welded joints of stainless steel 316-L by ACTIVATED-TIG WELDING process. The present research paper contributes to the ongoing research work on the use of SS 316-L austenitic stainless steel in industrial environments. The 316-L stainless steel is selected over other materials because of its distinct properties, cheaper cost and its availability in the market. 316-L stainless steel used is a boiler grade steel used in pressure vessels. This grade has high corrosion resistance and can be operated at elevated temperature.According to this type of welding the depth of penetration is high and HAZ is very low when compared to the other conventional welding methods. The analysis has been performed on the base metal. By using L9 Taguchi orthogonal arraytensile strength was taken as output response and Optical microscopy was also performed to correlate this process.The test results show that ANOVA models for ultimate tensile strength are significant to prove the weld efficiency of AISI316L austenitic stainless steel and to meet the requirements of oil and gas industries. The best parameters for A-TIG were found.

Keywords: *A-TIG , L9 Taguchi method , ultimate tensile strength, optical microscopy.*

1.0 INTRODUCTION

Welding is one of the fabrication processes that is used for joining the metals, by causing combination which replaces other joining processes like bolting, riveting[1]. A good joint will be obtained through A-TIG welding and a preferred and hardness, microstructure test was carried out by most of the manufactures for mechanical gatherings[1][2]. Generally filler material is used in metal joining processes, even in A-TIG welding. 316L is more resistant than 304 in range of atmospheric environments and many corrosive media due to the increased chromium and molybdenum content. The addition of molybdenum improves general corrosion and chloride pitting resistance[2][3]. This grade has high corrosion resistance and can be operated at elevated temperature.They find application on exhaust manifolds, furnace parts, heat exchangers, jet engine parts, pharmaceutical and valve and pump trim, chemical equipment.The shielding gas can be both inert gas like argon and active gases like argon oxygen mixture and argon-carbon-dioxide which are chemically reactive[2].

It can be used on nearly all metals including carbon steel, stainless steel, alloy steel and Aluminum. The study was concerned with the activating flux gas metal arc welding [3]. The flux ingredient, which is in organic compound are available in variety of range and compositions. Some of fluxes have been reported effective for particular materials. Activating fluxes contain oxides and halides. Oxide coating consists of iron, chromium, silicon, titanium, manganese, nickel, cobalt, molybdenum and calcium are reported to improve weld ability and increase the welding speed[4][5]. The acceptance of the welded samples is most important. In order to meet its requirements and criteria, non destructive evaluation of these materials is done in various stages to evaluate weld quality. The weld joint inspected found that it does not meet its requirements due to lack of dispersion, under cuts, cracks etc[5]. Even though necessary precautions were taken during welding process.Some of the procedures used in non destructive evaluation are Radiography, Ultrasonic tests, Acoustic testing. These tests can be done in a simpler way to find out the defects in the weldments. Mostly these tests are preferably done on the products that are produced using casting process [4]. In A-TIG welding inert gases like argon, helium are used which acts as shielded gases because they prevent atmospheric toxification of molten weld pool and also they do not react with the base metal. This shielding gas acts as a blanket to the weldments and excludes active properties surrounded in the air [1]. A-TIG welding results in increase in the weld dissemination in the austenitic stainless steel and penetration overcomes as a result of chemical composition. TIG and MIG welding are recognized as the choices for welding small components. But it requires skill and has some disadvantages [2]. To overcome this, advance A- TIG welding is found to be beneficial for welding 316L SS.

Taguchi method is a powerful tool that uses a special design to study the parameter space with small number of experiments through orthogonal arrays. This technique provides an efficient, simple and systematic approach to optimize design for quality, performance and cost [4]. To solve the problem, an orthogonal array is developed in Taguchi method to study entire parameters. This research studies the influence of various input parameters on the tensile strength and bending strengthof AISI 316 welded joint. The influence of speed, current, electrode, root gap is identified by ANOVA method.

2.0 MATERIALS AND METHODS

In this work we choosen SS316 L austentic stainless steel.Its primary alloying elements of chromium(16-18%),nickel(10-12%),molybdenum(2-3%) and primary element of iron.The chemical compostion shown below table 1.

Table no : 1 Chemical Composition of 316-L stainless Steel

ELEMENTS	WEIGHT PERCENTAGE
CARBON	0.08
MANGANESE	2.00
PHOSPHORUS	0.045
SULPHUR	0.030
SILICON	0.75
CHROMIUM	16-18
NICKEL	10-14
NITROGEN	0.10
MOLYBDENUM	2-3

3.0 EXPERIMENTAL PROCEDURE

3.1 SPECIMEN PREPERATION

About SS316L -IG, SS means stainless steel, and IG means ITER Grade. In this study the specimens were prepared with the dimensions of dimensions 150mm x 100 mm x 3 mm thickness. The 316-L stainless steel is selected over other materials because of its distinct properties, cheaper cost and its availability in the market. 316-L stainless steel used is a boiler grade steel used in pressure vessels. This grade has high corrosion resistance and can be operated at elevated temperature.

3.2 SELECTION OF MACHINING PARAMETERS

The current, voltage, flow rate, speed and diameter are controlled to get effective result. Among the various input parameters, we select current, voltage and root gap for this work. The output response selected are ultimate tensile strength and hardness.

Table no : 2 Machine parameters

Process Parameter	Values
Current	110A
Voltage	10 v
Electrode	diameter - 1.5 mm
Electrode tip angle	65◦
Flow Rate	15 L
Welding speed	70 mm/min

The table 2 shows the ATIG welding machine characteristics which was used for this work and the table 3 shows various levels of input parameters.

Table no : 3 Levels of welding input parameters

Parameters	Level 1	Level 2	Level 3
Current	40	50	60
Voltage	20	25	30
Root gap	0.5	0.6	0.7

The table 4 shows the Experimentation values of input parameters based on the L9 Taguchi orthogonal array method and the output response of ultimate tensile strength were tabulated.

Table no :4 Experimental values

Experiment No.	Current (amp)	Voltage (volts)	Rootgap (mm)	Ultimate tensile strength (N/mm^2)
1	40	25	0.7	171
2	60	20	0.5	65
3	50	30	0.7	110
4	60	25	0.5	78
5	50	20	0.6	180
6	50	30	0.6	107
7	40	20	0.7	72
8	60	25	0.5	118
9	40	30	0.6	59

3.3 WELDING PROCEDURE

The welding experiments were conducted in autogenously mode with ACTIVATED-TIG welding (A-TIG) power source having capacity of 350A-31.5V.The arc was moved along the centre line of the welds and all the welding parameters were controlled, however Current may found important control parameter [6]. In order to compare the effect of oxide fluxes, samples were welded with same operating conditions by applying two oxide fluxes individually as well as normal A-TIG welding without flux[6].

3.4 METALLURGICAL AND MECHANICAL CHARACTERIZATION

Microstructure investigation of the weldments was carried out on machined (Perpendicular to the welding direction) of dimensions 75 mm x 100mm x 3mm which covered all the composite zones such as Parent metals, Weld zone. As per ASTM-E3 procedure, sample is polished up to 2000 grit with emery sheet and finish it with alumina slurry. Electrolytic etching was used to expose the microstructures at various zones of the weldments. It is similar to chemical etching, in which acids and bases are used for modifying the pH. However, the electrochemical potential is controlled electrically by varying either the voltage or currentexternally. Electrolytic etching is often used for harder-to-etch specimens that do not respond well to basic chemical etching techniques. Even though Optical Microscope (OM) and Scanning Electron Microscope (SEM) techniques were engaged to examine the microstructure changes on the weldments. The optical microscopy was carried out in this work. The elemental validation of the weldments was determined using Ultimate Tensile strength conducted on the fabricated weld-ment as per the ASTM: E8/8M standards, using Instron Universal Testing Machine. Micro hardness measurements were also taken on the weldments, using Vicker's micro hardness tester. The hardness computations were done at steady intervals across the entire width of the dissimilar weldments base metal in order to estimate the precise changes. The microstructure of the weld cross-section is observed using Metzer optical microscope. The images of the welded region,left and right zone shown in figure. Three samples have been tested for repeatability and it is selected based on best results obatined from tensile testing.

4.0 RESULT AND DISCUSSION

4.1 MECHANICAL INVESTIGATIONS

In this work we have carried out the mechanical testing of ultimate tensile strength and hardness. Here we have carried out nine different experiment based on taugchi L9 orthogonal array based on different parameterof A-TIG weld ie, three levels

Table no : 5 best values of tensile strength

Specimen	Current	Voltage	Root gap	Ultimate tensile strength
1	40	25	0.7	171
5	50	20	0.6	180
8	60	25	0.5	118

After the weld the nine samples are taken for the testing of ultimate tensile strength in ultimate tensile testing machine.In that we found the result from lower value to higher value.From this ultimate tensile strength value we infer that the sample specimen 1,5,8 are taken for hardness testing in Vickers hardness test.

4.2 METALLURGICAL INVESTIGATIONS

In the 8th sample we found that there is a unfill of weld seems due to lack of flow. From the optical microscopic view we carried out from optical microscope (50X). We found the structures of ss316L and the weldment area, also found the weldment flow through optical microscopic view upon the specimen 1,5,8. The 8th sample found Weld gap due to lack of fusion in the weld and the figure 1 shows the microstructure view of SS316 l material with weld.

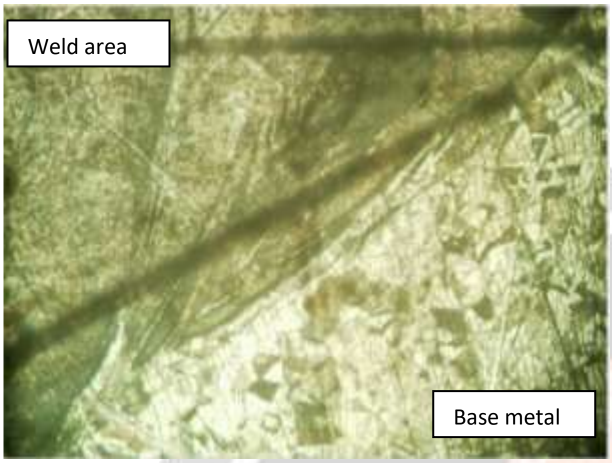

Figure no 1 Microstructure of SS 316LWeld

Table no : 6 Hardness values of Sample :1

LOCATION	HARDNESS (HV5Kg)
BASE	135,129,132,178,160,164
HAZ	166,154,160,197,180,184
WELD	349,341,325

Table no : 7 Hardness values of Sample: 5

LOCATION	HARDNESS (HV5Kg)
BASE	161,135,145,175,169,172
HAZ	162,165,171,190,208,204
WELD	206,221,252

Table no : 9 Hardness values of Sample: 8

LOCATION	HARDNESS (HV5Kg)
BASE	137,148,143,218,178,192
HAZ	169,172,162,175,177,178
WELD	182,206,195

4.3 INFERENCE FROM HARDNESS

From the above result the hardness for specimen on the case,heat affected zone and weld area was checked and seems hardness of sample 5 is more than the sample 1 and 8.Also the ultimate tensile strength of sample 5 is 180 N/mm^2 is greater that of sample 1 and 8. The macroscopic view also shows that the fusion,weldments are good in sample 5. Hence the process parameter for specimen 5 may select as better parameters for this weld.

4.4 ANOVA ANALYSIS

From the experimentation value the L9 orthogonal array was made using thedesign expert software 7.0 and the ANOVA Table was shown below,

Table no : 10 Analysis Of Variance Table for Ultimate tensile strength

Source	Sum of squares	Degree of freedom	Mean square	F –value	P –value Prob> F
Response	15659	6	2609.833	179.9885	0.0055
A –current	469.7609	1	469.7609	32.3973	0.0295
B –voltage	0.071429	1	0.071429	0.004926	0.9504
C –rootgap	40.02632	1	40.02632	2.760436	0.2385
AB	1384.012	1	1384.012	95.44908	0.0103
AC	91.84783	1	91.84783	6.334333	0.1282
BC	847	1	847	58.41379	0.0167
Pure error	29	2	14.5		
Cor Total	15688	8			

The model F- value of 179.99 implies the model is significant. There is only a 0.55% chance that a model F-value this large could occur due to noise. Value of prob>F less than 0.0500 indicate model terms are significant.

4.5 INFERENCE ON ULTIMATE TENSILE STRENGTH

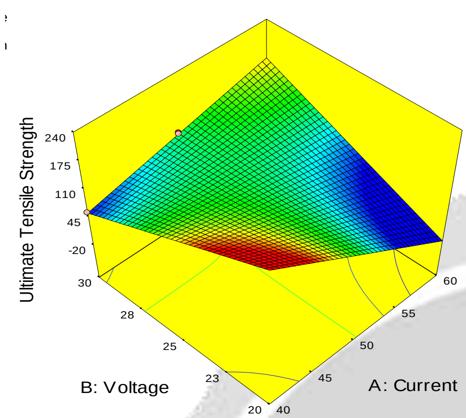

Fig no : 2 current vs voltage

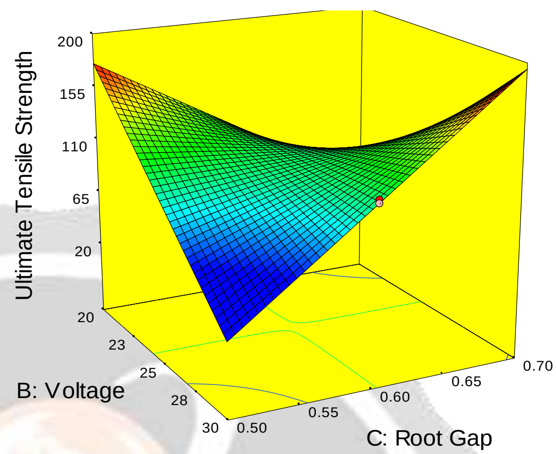

Fig no : 3 current vs root gap

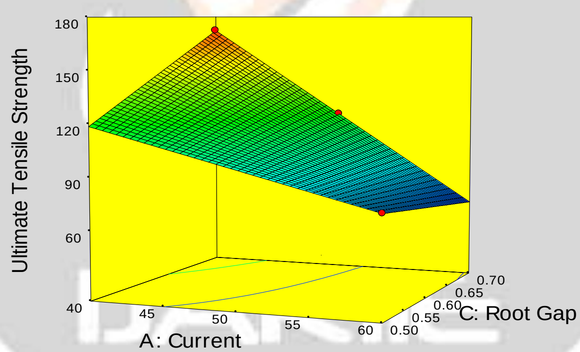

Fig no : 4 voltage vs root gap

From the above figure no 2, it is found that the increasing of voltage value decreases the ultimate tensile strength and the increasing of current also shows the decreasing pattern ultimate tensile strength. Therefore both the current and voltage are inversely proportional to the ultimate tensile strength.From the above figure no 3,When the root gap increase correspondingly the ultimate tensile strength also get increased and the current increased the ultimate tensile strength will getdecreased. Therefore the current is inversely proportional to the ultimate tensile strength and directly proportional to root gap.From the above figure no 4 , When the root gap increase correspondingly the ultimate tensile strength also get increased from and the voltage increased the ultimate tensile strength will get decreased. Therefore the voltage is inversely proportional to the ultimate tensile strength and directly proportional to root gap.

4.6 MATHEMATICAL EXPRESSION IN TERMS OF ACTUAL FACTORS:

Ultimate Tensile Strength = 4211-37.05 * current -178.6 * voltage-2940*rootgap+1.725*current*voltage-16.25*current*rootgap+154*voltage*rootgap.

5.0 CONCLUSION

This study focuses to find the welding parameters of A-TIG by using SS 316 L. Since the SS 316 L having very good industrial application this analysis is carried out to find the optimal welding parameters by using L9 Taguchi Orthogonal array method. The welding parameters selected are current,voltage and root gap. The output response considered in this work is Ultimate Tensile Strength whereas the hardness and microstructure also performed to correlate the results. Based on the result it may be inferred that.

(i) The current and voltage plays the major role for Ultimate Tensile Strength.
(ii) The hardness result shows the experimentation 5 gives good result, in hardness in the area of heat affected zone also having high hardness in the weld zone.
(iii) The tensile strength of experimentation 5 gives higher value and the microstructure and macroscopic view of specimen 5 seems better quality compared to the other specimen .

Hence in this proposed work it is suggested that the welding parameters of current - 50A, voltage – 20V and root gap – 0.6 are best suitable for the work of A-TIG welding in the SS 316 L material.

6.0 REFERENCE

[1]Pavan G. Chaudhari a, Priyank B. Patelb, Jaksan D. Patel Evaluation of MIG welding process parameter using Activated Flux on SS316L by AHP-MOORA method,2017.

[2]Huang Her-Yueh, Effects of activating flux on the welded joint characteristics in gas metal arc welding",Materials and Design 31, pp 2488–2495 ,2010.

[3] Modenesi Paulo J, EustaAquio R. ApolinaArio. Pereira, Iaci M TIG welding with single-component Fluxes",Materials Processing Technology 99, pp260-265,2000.

[4] Lu Shanping, Fujii Hidetoshi, Hiroyuki Sugiyama, and Nog Kiyoshi X," Mechanism and Optimization of OxideFluxes for Deep Penetration in Gas Tungsten Arc Welding", Metallurgical And Materials Transactions A, 34A,2000.

[5] Ruihua Zhang, FAN Ding, Seiji Katayama," Electron Beam Welding with Activating Flux" Transactions ofJWRI, 35,2006.

[6] Qing-ming, WANG Xin-hong, ZOU Zeng-da, WU Jun. " Effect of activating flux on arc shape and arc voltage in tungsten inert gas welding", Trans. Nonferrous Met. Soc. China ,I7, pp486-490,2007.

[7] P. Bharatha,V.G. Sridharb, M. Senthilkumar Optimization of 316 Stainless Steel Weld Joint Characteristics using Taguchi Technique,2007.

[8] Mr.L.Suresh Kumar, Dr.S.M.Verma, P.Radhakrishna Prasad, P.KirankumarDr.T.SivaShanker "Experimental Investigation for Welding Aspects of AISI 304 & 316 by Taguchi Technique for the Process of TIG & MIG Welding", International Journal of Engineering Trends and Technology, Volume2, ISSN: 2231-5381, 28-33,2011.

[9] R.K.Rajkumar, FatinHamimi, NachimaniCharde "Investigating the Dissimilar Weld Joints of AISI 302 Austenitic Stainless Steel and LowCarbon Steel", International Journal of Scientific and Research Publications, Volume 2, Issue 11, November,ISSNpp2250-3153, 1-5,2012.

[10] M.T.Z. Butt, M.S. Ahmad and M. Azhar, "characterization for GATW AISI 316 to AISI 316 & SA 516 grade 70 steels with welded &prewelde annealing conditions", Journal of Quality and Technology Management ,Volume VIII, Issue II, Page 119–133,2012.

[11] Harish Kumar D,,A. Somireddy, K. Gururaj, "A review on critical aspects of 316l austenitic stainless steel weldability", International Journal of Materials Science and Applications 2012; 1(1), December 30, pp1-7,2012.

[12] C.Balaji , S. V. Abinesh Kumar, S. Ashwin Kumar, R. Sathish, "Evaluation of mechanical properties of SS 316 L weldments using tungsten inert gas welding", International Journal of Engineering Science and Technology (IJEST), Vol. 4 No.05 , ISSN : 0975-5462,pp 2053-2057,2012.

[13] H. Ramakrishnan, R. Balasundaram, N. Ganesh, N. Karthikeyan, Experimental investigation of cut quality characteristics on SS321 using plasma arc cutting, Journal of the Brazilian Society of Mechanical Sciences and Engineering (2018) 40:60.

[14] H.Ramakrishnan, "Design, fabrication and analysis of fume extraction and filtration equipment', Pakistan Journal of Bio-technology, Vol.14 (1), 2017, pp 101-103.

[15]Mohammad Chand Khan, J.NoorulAmeen, H.Ramakrishnan, K.Chellamuthu, S.Nandhagopan,"Application Of Six Sigma Principles And Design-Analysis Softwares To Increase The Pass Percentage At The Vehicle Testing Shop", International Journal of Pure and Applied Mathematics, Vol 120 (6), 2018, pp 2593-2608.

[16] N Ganesh, M Udaya Kumar, C Vinoth Kumar, B SanthoshKuma," Optimization of cutting parameters in turning of EN 8 steel using response surface method and genetic algorithm', International Journal of Mechanical Engineering and Robotics Research, vol 3 (2), 2014, pp 75

[17] S. Rajaram, G. RajKumar, R. Balasundaram, D. Srinivasan,"Experimental Investigation of Drilling Small Hole on Duplex Stainless Steel (SS2205) Using EDM", Mechanics and Mechanical Engineering, Vol. 22, No. 1 (2018) 285–293.