STM JOURNALS
Journal of Production Research & Management
ISSN: 2249-4766(online), ISSN: 2347-9930(print)
Volume 5, Issue 3
www.stmjournals.com

# A Review on Process Parameter Optimization of TIG Welding of SS316

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### *Abstract*
*In this audit paper the creator needs to decide the effect of different welding parameters on the weld dot of SS316 welded joint. In this examination the diverse method is utilized to upgrade the distinctive welding parameters like speed, current, gas stream rate on the quality of the material. The outcome demonstrates that speed is the best variable to have most noteworthy twist quality; and current is utilized to get higher rigidity.*

***Keyword**: TIG, parameter, tensile strength*

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## INTRODUCTION

TIG welding is a most preferable technique for SS, Al, and Ti. Filler metal is used for the joint. Inert gas is used (argon or helium) to prevent molten weld pool from atmosphere contamination and prevent reaction of base metal. Tungsten electrode, joint and arc is shielded with inert gas. In TIG welding better penetration is achieved. To achieve quality weld, right choice of process parameter is the basic key. Most effective parameters like current, speed, and gas flow rate; and preferred filler metal is also an affective parameter for quality weld. Weld quality is checked by non-destructive techniques as per ASME.

Kiaee *et al*. carried out the large no. of trials of rolled plate of 11 mm A516-Gr70 to find out the feasible limit of TIG parameter [1]. The results show that if the current is less than 110 A, lack of fusion occurs; and if greater than 150 A undercut occurs. If welding speed is lower than 5 cm\min undercut will occur and if speed is more than 13 cm/min there will be a lack of fusion. If flow rate is lower than 13 l/min and more than 17 l/min porosities occur.

Rao *et al.* did the experimental analysis of joining to similar metal by TIG welding [2]. He did tensile test and bend test for optimize process parameter and find the limit of parameter as, welding current 120 A and SS309l filler rod gave the higher tensile test. In bend test the welding current 120 A and SS316 electrode gave the best bend test.

Juang *et al.* worked on obtaining the process parameter for optimum welds bead geometry [3]. Essentially front tallness, front width, back stature, back width is considered for weld dot geometry. Modified Taguchi method is used for finding process parameters. In this method, parameters are found for optimal bead geometry.

Bharath *et al*. explained the effect of different welding parameters on pool geometry of SS316 [4]. He did different experimental test to determine the current, speed, and root gap. An ANNOVA technique was used to determine the parameter current and speed and mathematical model was created by Minitab 17 software. Band test and tensile test were done to find that they varied with variation in weld bead.

Patel *et al.* did the experimental analysis and studied the design of experiment (full factorial method) for his work; and for experimental data, he used grey relational analysis method for optimization of experimental data [5]. Input parameters for TIG welding were current and wire diameter for AISI 1020 or C20 material.

Hussain *et al.* did test work and explored the impact of welding speed on tensile test of weld joint [6]. In this paper, weld joint is plan with V butt joint with diverse bevel angle and bevel height. Base metal selected was AA6351-Al alloy. Welded joint was tried on general testing machine for tractable test.

Kishore *et al.* analyzed the effect of process parameters on AISI1040 steel using TIG welding [7]. He used the Taguchi method for optimizing the parameters (like current, voltage, speed, nozzle to work distance). Design of experiment, orthogonal array was developed and ultrasonic test was conducted to test the weldments. Optimal parameter was found for minimizing the defect.

Juang *et al.* explained the process parameter optimization of TIG welding for optimal weld pool geometry [8]. Weld pool contains the characteristic like front height and width, back height and width. Modified Taguchi method was used for optimization of parameters. Different experiment was done, and testing was done to illustrate the optimal value.

Choudhury *et al.* explained the process parameter optimization to improve the ultimate load of dissimilar metal (stainless steel-mild steel) [9]. Parameters selected were like current, gas flow rate and rod diameter for TIG welding. Tensile test was conducted for finding the ultimate load. ANOVA technique was used to find the effect of welding parameters on ultimate load.

Sudhakaran *et al*. explained the process parameter optimization of TIG welding to minimize the angular defect in 202 stainless steel [10]. Particle swarm optimization technique was used. Parameter chosen for experimental analysis were like gun angle, current, welding speed, plate length, gas flow rate. MATLAB 7.6 software was used for creating model. From the above literature review we conclude that to achieve required property of weldment, process parameters like current, welding speed and gas flow rate are most effective.

Current has effect on tensile strength and speed has effect on bend strength. So different experiments are done and optimal parameters are found for improving weldment strength. Taguchi method is used to optimize required parameter.

## METHODOLOGY

### Material Selection

First of all the best suitable material was selected for required property. 316 was selected because it had good corrosion resistance property and was cheap and easily available in the market [4]. It was used for boiler and pressure vessel. The chemical compositions are shown in below table.

***Fig. 1:*** *Test Piece Welded Utilizing TIG Welding with 2.0 mm Root Hole.*

***Table 1:*** *Chemical Composition of Base Metal.*

| Element | C | Mn | P | S | Si | Cr | Ni | N | Mo |
|---|---|---|---|---|---|---|---|---|---|
| Weight % | 0.07–0.10 | 1–4 | 0.0040–0.0050 | 0.028–0.032 | 0.72–0.75 | 15–19 | 11–15 | 0.9–0.12 | 1–4 |

### Taguchi Method

In taguchi technique ideal parameters were acquired by utilizing L27 (35). L27 (35) implies that there are three levels and five variables for research. Table 2 gives levels and variables.

***Table 2:*** *Basic Parameters and Levels.*

| | | | |
|---|---|---|---|
| Levels | 0.5–1.5 | 1–3 | 2–4 |
| Speed (mm/min) | 48–52 | 63–68 | 77–83 |
| Current(Amps) | 58–62 | 78–82 | 100–102 |
| Electrode | 316 | 309L | 347 |
| Worker | 1 | 2 | 3 |
| Root space (mm) | 1–1.2 | 1.3–2 | 2–2.5 |

  

**Analysis of Variance (ANOVA)**
From experimental data it is observed that speed and current are the most influence factors in the welding process. From ANOVA Technique and Tables 4 and 5, it is observed that speed influences for bend strength and current influences for tensile strength. First of all mean is calculated from average of tensile strength and bend test. Grand total sum of squares is given as the sum and square of each trail value [4].

***Table 3:*** *Trial Information.*

| Piece No. | Electrode | Current (amp) | Speed (mm/min) | Worker | Root Space |
|---|---|---|---|---|---|
| 1 | 316 | 58–62 | 45–55 | 1 | 0.5–1.5 |
| 2 | 316 | 58–62 | 45–55 | 1 | 1.2–1.7 |
| 3 | 316 | 58–62 | 45–55 | 1 | 1.8–2.3 |
| 4 | 316 | 75–85 | 60–75 | 2 | 0.5–1.5 |
| 5 | 316 | 75–85 | 60–75 | 2 | 1.2–1.7 |
| 6 | 316 | 75–85 | 60–75 | 2 | 1.8–2.3 |
| 7 | 316 | 95–105 | 75–85 | 3 | 0.5–1.5 |
| 8 | 316 | 95–105 | 75–85 | 3 | 1.2–1.7 |
| 9 | 316 | 95–105 | 75–85 | 3 | 1.8–2.3 |
| 10 | 309L | 58–62 | 60–70 | 3 | 0.5–1.5 |
| 11 | 309L | 58–62 | 60–70 | 3 | 1.2–1.7 |
| 12 | 309L | 58–62 | 60–70 | 3 | 1.8–2.3 |
| 13 | 309L | 75–85 | 75–85 | 1 | 0.5–1.5 |
| 14 | 309L | 75–85 | 75–85 | 1 | 1.2–1.7 |
| 15 | 309L | 75–85 | 75–85 | 1 | 1.8–2.3 |
| 16 | 309L | 95–105 | 45–55 | 2 | 0.5–1.5 |
| 17 | 309L | 95–105 | 45–55 | 2 | 1.2–1.7 |
| 18 | 309L | 95–105 | 45–55 | 2 | 1.8–2.3 |
| 19 | 347 | 58–62 | 75–85 | 2 | 0.5–1.5 |
| 20 | 347 | 58–62 | 75–85 | 2 | 1.2–1.7 |
| 21 | 347 | 58–62 | 75–85 | 2 | 1.8–2.3 |
| 22 | 347 | 75–85 | 45–55 | 3 | 0.5–1.5 |
| 23 | 347 | 75–85 | 45–55 | 3 | 1.2–1.7 |
| 24 | 347 | 75–85 | 45–55 | 3 | 1.8–2.3 |
| 25 | 347 | 95–105 | 60–70 | 1 | 0.5–1.5 |
| 26 | 347 | 95–105 | 60–70 | 1 | 1.2–1.7 |
| 27 | 347 | 95–105 | 60–70 | 1 | 1.8–2.3 |

Total of squares is calculated because mean is given as the quantity of tests increased by the square of the general mean and the computed aggregate whole of squares is given as the contrast between great aggregate total of squares and entirety of squares because of mean [4]. Level of flexibility (DOF) blunder is given by the distinction between the DOF for the aggregate whole of squares and total of DOF for different variables [4]. Change proportion is given by the proportion of mean squares because of the component to mean squares blunder. Rate of commitment is the proportion of aggregate of squares to the aggregate entirety of squares and every one of the qualities for every parameter were figured and appeared [4].

***Table 4:*** *ANOVA for Bend Strength.*

| Factors | Degrees of Freedom | Sum of Squares | Mean | Variance | % Contribution |
|---|---|---|---|---|---|
| Root gap | 2 | 5428.14 | 2714.05 | 0.1419 | 0.594 |
| Speed | 2 | 24333.74 | 12166.72 | 0.6355 | 2.659 |
| Current | 2 | 885652.10 | 442826.52 | 23.138 | 96.74 |
| Total | 6 | 915414.9 | - | - | - |
| Error | 20 | 382751.5 | 19137.60 | - | - |

***Table 5:*** *ANOVA for Tensile Strength.*

| Factors | Degrees of Freedom | Sum of Squares | Mean | Variance | % Contribution |
|---|---|---|---|---|---|
| Root gap | 2 | 41735.58 | 20867.9 | 0.2205 | 19.86 |
| Speed | 2 | 97795.85 | 48897.8 | 0.5165 | 46.52 |
| Current | 2 | 70729.90 | 35364.8 | 0.3735 | 33.64 |
| Total | 6 | 210261.5 | - | - | - |
| Error | 20 | 1893814.5 | 94690.8 | - | - |

## RESULT AND DISCUSSION

### Bend Test

The bend test is used for determining the ductility of weldments. This test is carried out in three point bending UTM. From test result, stress-strain diagram of particular specimen can be determined.

### Tensile Test

Tensile test is carried out for determining ultimate tensile strength and modulus of elasticity (E). This test is conducted on UTM and different results were studied. From the observation it is concluded that the tensile strength varies with the speed of the welding.

### Ultrasonic Testing

Ultrasonic testing is non-destructive testing. This test is carried out to find the defect in weldments like internal crack, porosity, lack of fusion etc.

## CONCLUSION

From different tests and experimental data, it can be concluded that current, speed and root gap are the most influential parameters. Speed is most effective for bending strength and current is the most effective for tensile strength. Hence by optimizing above parameters we can obtain maximum bending and tensile strength and there by improve the reliability of weldments.

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**Cite this Article**
Hiren Padhiyar, Kagathra Manhar S, Acharya GD. A review on process parameter optimization of TIG welding of SS316. *A Review Journal of Production Research and Management*. 2015; 5(3):