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# Analysis of Welding Parameters on TIG with 316 Stainless Steel Alloy

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***Abstract-*** **Austenitic Stainless Steel is commonly ultised in aviation engine parts, heat exchangers and furnace parts among other applications. It has chromium and nickel in it. Nickel and Chromium contributes to austenitic stability across a wide temperature and good corrosion resistance respectively. It is frequently used in chloride or halide containing process streams. For tungsten inert gas welding of 316 austenitic stainless Steel, the effect of parameters on weld joint quality was explored in this work. Welding settings influence the weld's mechanical qualities. The goal of optimization was to determine the best welding conditions for achieving maximum tensile strength.**

***Index terms-*** **316 Austenitic Stainless Steel, A TIG Welding, Parameter Optimization, Tagauchi Method, Vickers-Hardness Test.**

## 1. INTRODUCTION

Procedures all across the world arc welding as we know it now first arrived in the industrial world in the 1880s.Despite the fact that there are contradictory accounts about who invented this procedure; however it is frequently attributed to a Russian name Slavianoff. In 1881, he claimed to have patented it. Arc welding on the other hand was not acceptable for essential component production until recently. Coating for electrodes had advanced to a point about 1920 at which time they were highly developed.[1] However the demand is high. The metallurgical changes that occur due to the welding, changes in hardness in and around the weld, gas development and absorption, the level of oxidation and the effect on the joints cracking tendency are all factors that affect the materials weldability. Plain low carbon steels (C 0.12 percent) have the best weldability among metals based on these parameters quite frequently weldability is frequently poor in materials with high castability. Oxy-acetylene, manual metal arc or shielded metal arc, submerged arc, gas metal arc gas tungsten arc welding, resistance welding, thermit welding and cold pressure welding are all common welding methods in the industry[2]. The majority of these procedures have unique fields of influence, such as resistance welding which is popular among engineers. Thermit welding is used in the automobile sector to join rails[3]. GMAW is particularly well adapted to the welding of stainless steel and aluminium structures as well as the welding of low carbon steel structures. GTAW is more prevalent in the aerospace and nuclear industries although SMAW and oxy-acteylene welding are general purpose techniques with a wide range of applications. Welding is commonly used in the manufacturing of ships, automotive body work, pressure vessels and the sealing of nuclear fuel and explosives among other things [4,5].

Figure 1. TIG Welding Machine

## 2. OBJECTIVES OF RESEARCH

1. To determine the TIG welding process parameters for stainless steel 316.

2. To investigate the effects of process variables such as gas flow rate, filler material, and voltage on tensile strength and weld joint firmness.
3. Determine the mechanical characteristics of stainless steel-316 weldments using the best gas flow rate and welding current combination.
4. To find the best parametric settings for TIG welded joints that maximize tensile strength and percentage elongation.

## 3. METHODOLOGY

Table 3.1 Welding parameters of experiment

| Parameters | Range |
|---|---|
| Welding current | 80-200 Ampere |
| Voltage | 250 Volts |
| Gas flow rate | 10-14 liters/minute |
| Distance of trip from weld centre | 3mm |
| Current type | AC |

Table 3.2 TIG welding machine

| Parameters | Range |
|---|---|
| Welding current | 80-200 Ampere |
| Voltage | 250 Volts |

### 3.1 Materials to be used

#### 3.1.1 Stainless Steel Alloy 316

Following a review of a large number of research articles, a variety of materials are chosen or employed based on a variety of characteristics, such as the strength we require to meet our requirements. Stainless steel 316 is the material used in this project.

#### 3.1.2 Filler Material SS-316 L

316L is the material utilized in this project. Stainless steel 316L is a low-carbon version of SS316 that reduces the formation of hazardous carbides during welding. The chemical make-up of SS316L may be found in the table below.

Table 3.2 Filler Material SS316L Chemical Composition

| C | Si | Mn | Cr | Ni | Mo | N | P | S | Fe |
|---|---|---|---|---|---|---|---|---|---|
| 0.03 | 1.00 | 2.00 | 16.50 | 11.00 | 2.18 | 0.10 | 0.045 | 0.015 | 68.06 |

#### 3.2.1 Experimentation Design

The experiment will be constructed using the Taguchi Method. More information on the Taguchi Method may be found below, as well as a table outlining the entire experiment's planning. Planning of work is a vital part because it gives us an overall picture of what we should do in the future for our research job, as well as what materials, tools, and equipment we will need. The following table 4.5 depicts the work planning.

#### 3.2.2 Taguchi Method

These are mathematical methodologies, also known as rigorous design approaches, developed by Genichi Taugchito to reduce the cost of manufacturing items, and more recently used to engineering, biotechnology, [20-22], marketing [23-24], and advertising [24-28]. Professional statisticians praised Taguchi's goals and improvements, particularly the introduction of Taguchi designs to analyze variance, but criticized some of Taguchi's recommendations as inept [29-32]. All statics data are formulated using this method [33].

### 3.3 Procedure for Experimentation

1 For current operations, a Stainless Steel (SS316) plate welding button (10mm thick) keeps the voltage constant at varied current settings, soldering velocity, and carbon dioxide flow rates. The filler is made of Super MIG SS 316.
2 For the current experiment, a commercial Stainless Steel 316 (SS-316) 10mm plate was chosen as the work piece material. The SS-316 plate was cut to a size of 6011010 mm using a band screw and edge polishing to smooth the joined surface.
3 After cleaning the surfaces, use emery paper to remove any dirt or dust. Following the preparation of the sample, SS-316 plates are placed on the work table with adaptive clamping side by side and welding to join the butt. In trials, TIG welding with Direct Current Electrode Positive (DCEP) was used because it concentrated more heat on melting the filler material in the welding area [34].
4 As welding speed varied, the filler material was fed at variable speeds from a spool of electrode. Furthermore, the gas flow rate was modified, and the combinations for each sample are listed in the table.
5 A number of trial tests were carried out prior to the actual experiment to determine the appropriate parameter range for welding and to ensure that no apparent flaws such as undercutting or porosity occurred.

6 For this experiment, Super MIG-316L electrodes with a diameter of 4mm were used as filler material. Due to the high nickel content, the average tensile strength of wire is 250 Mpa, and the composition of SS-316L is listed in the table.

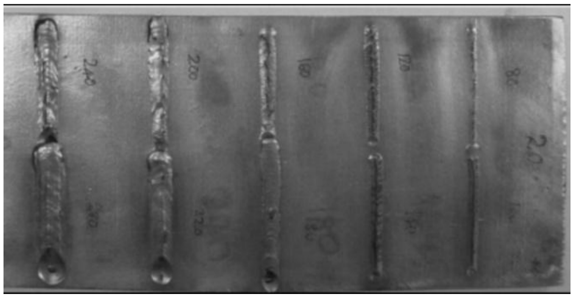

Figure 3.3 (a) TIG welded stainless steel types

## 4. RESULT AND ANALYSIS

Tensile Strength Test of Specimens:- The tensile strength test was carried out on a welded specimen by tugging it and stretching it until it fractured. Its ultimate tensile strength is the maximum stress it can withstand before breaking. This is expressed in Mpa, which stands for Mega Pascal. The Taguchi method is used to read the text.

Table 4.1 ultimate tensile strength per unit volume of all welded specimens

| Sample no. | Welding current (Amperes) | Gas Flow Rate (liters/min) | Welding Speed (mm/min) | Ultimate Tensile Strength (Mpa) | Elongation up to fracture (%) |
|---|---|---|---|---|---|
| 1 | 80 | 12 | 3.5 | 555 | 5.3 |
| 2 | 80 | 14 | 4.2 | 562 | 6.1 |
| 3 | 80 | 16 | 5.6 | 560 | 4.4 |
| 4 | 140 | 12 | 4.2 | 588 | 4.2 |
| 5 | 140 | 14 | 5.6 | 591 | 5.1 |
| 6 | 140 | 16 | 3.5 | 572 | 3.9 |
| 7 | 170 | 12 | 5.6 | 590 | 4.8 |
| 8 | 170 | 14 | 3.5 | 575 | 6.1 |
| 9 | 170 | 16 | 4.2 | 577 | 5.6 |

### 4.1 Tensile Strength of Specimens as a Function of Welding Current

The ISI608 standard is used to tensile test all samples on the Universal Testing Machine. The stress strain curves were evaluated at different gas flow rates and at different current levels. It shows how the soldering current affects the ultimate strength of welded specimens at varied gas flow rates and soldering speeds. By comparing these figures, it is clear that the higher welding current yields the best tensile strength in every case.

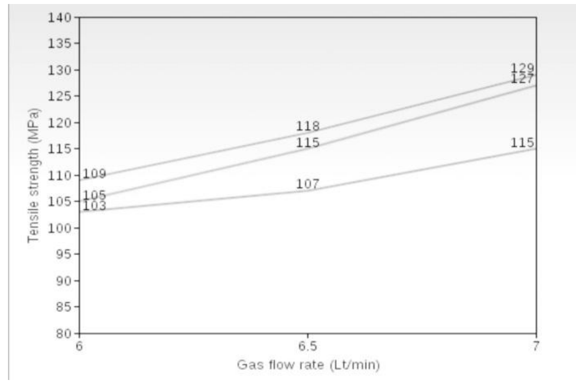


Figure 4.1 Ultimate Tensile Strength variation as a Function of Gas Flow Rate

This could be due to the creation of increased heat in the HAZ (heat affected zone) and microstructure of the specimens' welding pool, allowing for proper and uniform fusing of the metal filler with the base metal. The ultimate tensile strength is achieved in all cases using a 10 litre/min gas flow rate at 140,170 A welding current, followed by 12 litre/min and 14 litre/min gas flow rates. There is a higher gas concentration around the welding pool at a much higher gas flow rate, which lowers the oxidation process of the welding pool. We know that aluminium oxide has a high tensile strength and is typically more brittle than the metal. This could explain why samples welded at high gas flow rates have poor tensile strength whereas those welded at low gas flow rates have high tensile strength.

### 4.1.2 Tensile Strength of Specimens as a Function of Welding Speed

The welding speed refers to how quickly the arc passes across the work piece. It is usually used for semi-automated welding with a welder and automatic welding with a computer. The effect of travel speed is the same as the effect of arc voltage. Figure 5.1 shows the variation in the weld zone's ultimate tensile strength solely at welding speed.

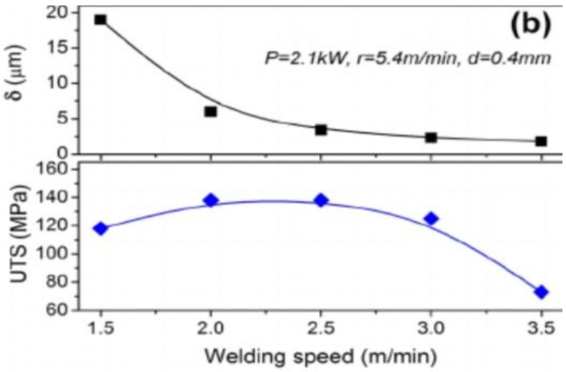


Figure 4.2 Variation in specimen ultimate tensile strength as a function of welding speed

It has been demonstrated that when welding speed increases, ultimate tensile strength decreases in all conditions. Slower transit speeds correspondingly offer base metal with more bead and greater thermal input for a constant current because to its long heating period. The higher the temperature, the more weld metal is deposited per unit length and the deeper the weld penetrates, resulting in a wider bead contour and a lower thermal gradient at the heat affected zone and impacted pool. If the movement is too sluggish, welds clump together, resulting in poor fusion, porosity, lower penetration, rough uneven beading, and slag inclusions. In contrast, we were unable to proceed to very low welding speeds throughout this trial, as evidenced by the findings. Due to increased porosity that could achieved at a welding speed of 4.6mm/min at 80 amps current. If the heat affected zone of a specimen and the microstructure of the weld pool have a high current value, more heat is produced, allowing the filler metal to fuse properly with the base metal. Even so, the maximum tensile strength is achieved in all circumstances with a maximum welding current of 140 amperes and a gas flow rate of 12 litres per minute. The gas concentration around the weld pool is higher at a high flow rate, which reduces oxidation of the weld pool. This could explain why samples welded at a low gas flow rate show up as high strength, while ones soiled at a high gas flow rate show up as poor tensile strength.

4.2 Vickers Hardness Tests of Specimens

The Vickers hardness test was carried out on welded specimens by indenting them with a diamond indenter in the shape of a right pyramid with a square base and a 136-degree angle between opposing faces under a weight of 1 to 100 kgf. The Taguchi method is used to take the readings.

Table 4.2 All Welded Specimens' Hardness

| Sample No. | Welding Current (Amperes) | Gas Flow Rate (litres/min) | Welding Speed (mm/min) | Hardness (HV) On Weld Pool | Hardness on HAZ |
|---|---|---|---|---|---|
| 1. | 80 | 12 | 3.5 | 225 | 265 |
| 2. | 80 | 14 | 4.2 | 200 | 263 |
| 3. | 80 | 16 | 5.6 | 194 | 241 |
| 4. | 140 | 12 | 4.2 | 190 | 186 |
| 5. | 140 | 14 | 5.6 | 203 | 210 |
| 6. | 140 | 16 | 3.5 | 200 | 194 |
| 7. | 170 | 12 | 5.6 | 185 | 186 |
| 8. | 170 | 14 | 3.5 | 199 | 210 |
| 9. | 170 | 16 | 4.2 | 186 | 178 |

Figure 4.4 Variations in Specimen Hardness as a Function of Welding Speed

This more direct action, which is primarily on the base material results in more weld penetration by reducing the weld pool's cushioning effects. The welding samples' hardness variation at 170 amperes on the weld pool and HAZ. Figures 4.5 and 4.6 show how the hardness in the weld pool varies little with welding speed at 100 amperes, but at HAZ, the hardness varies greatly at 3.2mm/min welding speed due to variation in the reliability of samples with welding speed at 140 amperes and 80 amperes of welding current with respect to the welding pool and HAZ. The average hardness of samples with a welding current of 150 amperes is lower than that of other samples. The lowest hardness is achieved with 3.2mm/min welding speed in the case of a 140 ampere. On the other hand, optimum durability is achieved with a welding speed of 2.5mm/min and a welding capacity of 80 amperes.

Figure 4.5 Hardness Test Specimens

Furthermore, at 80 amperes welding current, the optimal hardness in the heat affected zone is achieved, which can be attributed to the low heat input and rapid cooling rate formation of small grains. Variation in sample durability on the heat affected zone and welding pool with a welding current of 10 litres/min gas flow rate and a welding speed of 4.6mm/min. Because this correct penetration occurs at a lower weld speed and the weld pool is ductile and tougher, the hardness is lower in this case than in the previous example. Conversely, the hardness of the welding pool is lower than that of the base metal or heat affected zone, with a maximum hardness of 80 amperes and a minimum hardness of 170 amperes, and thus it can be deduced that welding of such an alloy must be performed at 170 amperes welding current in order to achieve welded samples with low hardness with this mixture of gas flow rate and welding speed. On the welding pool and heat affected zone, it shows the difference in durability of samples with a welding speed of 3.2mm/min and welding current of 14 litres/min gas flow rate. In this case, the hardness value is lower on average than in previous cases due to sample welding at a faster pace, resulting in insufficient penetration, improper fusion, and porosity, which may be seen and addressed in sample microstructure analysis. With a welding current of 12 litres/min gas flow rate and a welding speed of 2.4 mm/min on the heat affected zone and welding pool, it also displays variance in the hardness of samples.

## 5. CONCLUSION

The impact of TIG welding process factors such as current, welding speed, and gas flow rate on tensile strength and Vickers hardness in AISI 316 stainless steel welding has been investigated. The following conclusions can be drawn from this research:

1. The welding strength or tensile strength of SS-316 weld joints dependent on welding conditions such as welding current, welding speed, and filler material.
2. Welded SS-316 specimens demonstrate good tensile strength but limited ductility at low gas flow rates.
3. Welding flaws such as porosity can have a significant impact on the characteristics of welded SS-316 alloy specimens.
4. Welding errors and incorrect weld metal penetration are more likely to occur at high welding speeds.
5. The hardness value of the weld zone fluctuates with distance from the weld centre, resulting in variations in microstructure, particularly grain size. Hardness can rise for two reasons: one, due to metal oxide production at low gas flow rates, and the other, due to proper fusing of filler metal with base metal.
6. For a 150 ampere welding current, the lowest hardness is achieved at 2.5 mm/min welding speed, and for a 180 ampere welding current, the highest hardness is achieved at 4 mm/min welding speed.
7. Welding current has a stronger impact on both ultimate tensile strength and Vickers hardness test than welding speed. At greater welding speeds and currents, the ultimate tensile strength is found to be low.

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