ISSN (online): 2349-784X

# Analysis and Optimization of Parameters of Dissimilar Metal Welding

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## Abstract

The aim of our work is to study the hardness that affects the welding joint of dissimilar metals and what are the parameters that attects the welding strength of dissimilar metals. Stainless Steel 304 was welded to mild steel using a metal inert gas welding which also known as gas metal arc is welding with the help of filler wire of stainless steel and also by electric arc welding. Argon gas was used as shielding gas in this process. Dissimilar metals welding have great scope in advanced technology nowadays owing to their high hardness, high strength and corrosion resistance properties. The welding voltage had a significant effect on the welding process, as higher voltage resulted in poorer appearance of the weld joint and led to defects for both type of samples, such as porosity and incomplete fusion. The hardness values of the welded seams in all the samples range from 249 to 292 HV in Vickers hardness and 29 to 37 HV in Rockwell hardness test, respectively. The fracture in the tensile test yielded the highest tensile strength of 489.1MPa for MIG welded specimen with ER304. The tensile strength of MIG Welded test sample has higher range of tensile strength than electric arc welded specimen. Based on the investigation throughout this study, it can be concluded that the welding voltage had a significant effect on the welding process.
**Keywords: MIG, Butt-Joint, Dissimilar Welding, Mild Steel, Stainless Steel, Mechanical Property**

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## I. INTRODUCTION

The stainless steel is one of the most popular materials for structural applications, due to their excellent physical properties but increase the structural cost. The additional benefits and the design codes of stainless steels have focused their industrial use for conventional structural engineering applications such as civil construction, nuclear reactors, thermal power plants, vessels and heat exchangers for several industrial applications. The better joint efficiency, simple process, low fabrication cost, welding reliability and efficient metal joining process are essential for production of many engineering and structural components. The metallurgical changes such as micro-segregation, precipitation of secondary phases, presence of porosities, solidification cracking, grain growth in the heat affected zone and loss of materials by vaporization are the major problems which produces poor mechanical properties in stainless steel welds. Besides that, this type of joining offers the potential to utilize the advantages of different materials, which often produces a whole structure with unique mechanical properties. Even so, the dissimilar welding process yields unwanted disadvantages in the weld joint, such as brittle intermetallic reaction phase formation at elevated temperatures the defects that may occur in the specimens of this project are due to the large difference between the melting points of the metals, thermophysical properties. Furthermore, differences in thermophysical properties, such as expansion coefficient, conductivity and specific heat, can lead to residual stresses after fusion welding the weld joint is the most important area and is heavily affected by the selection of filler metals. Several researches have shown that the selection of the filler metal to use in the welding process is crucial to the weld joint, as some fillers add to the base metal elements to improve the properties of the weld metals. However, no empirical study has been conducted to compare the effect of mild steel fillers and stainless steel fillers on mild steel-stainless steel metal inert gas (MIG) welding. This project looks into the effect of welding fillers on the quality of the weld joint and optimizing the parameters used for the different welding technique and mechanical properties of the weld joints are also investigated.

## II. EXPERIMENTAL MATERIALS & METHODS

Materials used are stainless steel geade 304 and plates mild steel which of 4mm thickness. These materials are commonly used in industry due to their high corrosion resistance and versatility. The filler metals used are stainless steel based ER 309L, ER308 and mild steel based ER 304,E6014 with a diameter of 2.5 mm for both fillers. Table 1 represents the chemical composition of stainless steel 304 and mild steel.

Table – 1
Composition of SS304 and MS

| COMPOSITION | STAINLESS STEEL 304 (%) | MILD STEEL (%) |
|---|---|---|
| Carbon | 0.08 | 0.18 |
| Manganese | 2.00 | 0.01 |
| Phosphorus | 0.045 | 0.040 |
| Sulfur | 0.030 | 0.040 |
| Silicon | 0.75 | 0.40 |
| Chromium | 18.21 | 0.069 |
| Nickel | 08.06 | 0.01 |
| Nitrogen | 0.10 | - |

Electrode fillers used in MIG and Electric arc welding are copper coated MS wire, ER304, ER308, E6013,and ER309L

Table – 2
Chemical Composition of ER304

| Chemical Composition | C | Si | Mn | Cr | Ni |
|---|---|---|---|---|---|
| | 0.060 | 0.47 | 1.25 | 19 | 9.65 |

ER308, 2.5 mm in diameter, of which chemical composition:

Table – 3
Chemical composition of ER308

| *Fe* | *Cr* | *Ni* | *Mn* | *Si* | *P* | *S* | *C* |
|---|---|---|---|---|---|---|---|
| *Balance* | *19-21* | *10-12* | *2* | *1* | *0.045* | *0.03* | *0.03* |

E6013, 2.5 mm in diameter, of which chemical composition:

Table – 4
Chemical Composition of E6013

| *C* | *Mn* | *P* | *Si* | *S* |
|---|---|---|---|---|
| *0.08* | *0.50* | *0.012* | *0.40* | *0.009* |

ER309L, 2.5 mm in diameter, of which chemical composition:

Table – 5
Chemical Composition of ER309L

| *Cu* | *Cr* | *Ni* | *Mn* | *C* |
|---|---|---|---|---|
| *0.35* | *24.5* | *13* | *1.88* | *0.025* |
| *Si* | *P* | *S* | *Mo* | *N* |
| *0.40* | *0.02* | *0.01* | *0.35* | *0.10* |

Stainless steel and mild steel were butt-welded using an MIG welding and also by electric arc welding. Two different sets of specimens were fabricated during the welding process for the tensile test and as well as a hardness analysis. Total five number of test samples are created with the above described filler metals and welding technique as shown in the table7

### *A. Mild Steel:*

Mild steel is the most common form o steel because its price is relatively low while it provides material properties that are acceptable for many applications. Mild steel contains 0.16–0.29%carbon; therefore it is neither brittle nor ductile. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing. It is often used when large amounts of steel are needed, for example as structural steel. The density of mild steel is approximately 7.85 g/cm3 (0.284 lb/in3) and the Young's modulus is 210,000 MPa (30,000,000 psi).

### *B. Stainless Steels:*

Type 304 Stainless Steels are well known in reference literature and more information can be obtained in this way.304 is a variation of the basic 18-8 grade Type 302, with a higher chromium and lower carbon content. Lower carbon minimizes chromium carbide precipitation due to welding and its susceptibility to inter granular corrosion. 304L is an extra low-carbon variation of Type 304 with a 0.03% maximum carbon content that eliminates carbide precipitation due to welding.

Cleaning up the surface of, stainless steel and mild steel before welding, the specimens were turned and faced to prepare the weld surfaces. Further, debarring was done with emery paper and the surfaces to be welded were cleaned with acetone prior to welding. MIG welding and electric arc welding process were used for welding of stainless steel with mild steel. The copper coated MS wire, ER304, ER308,E6013, ER309L rod of 2.5 mm diameter filler material was used for MIG and Electric arc welding process respectively. Uphill welding progression was used for all joints. The process parameters selected MIG welding processes are shown in the Table 6. The strength of the welds were examined by carrying out tensile tests, and hardness by the help of hardness testing machine.

Table – 6
Parameters used in MIG welding process

| PARAMETERS | SPECIFICATON | MIG |
|---|---|---|
| Shielding Gas | Type | Ar and CO2 (98% & 2% ) |
| Current | Type | DC |
| | Polarity | Electrode Negative |
| | Current Range | 60-400 Amps |
| | Voltage Range | 26-56 Volts |
| Pass | Type | Multiple |
| Electrode | Number | Single |
| | Type of wire | Copper Coated MSWire |

The Vickers hardness test and Rockwell hardness and tensile test were conducted to analyze the mechanical properties of the samples. The Vickers hardness profile across the base metals and fusion zone was observed using the hardness tester with 30 kgf for 10 seconds dwell time. On the other hand, the fracture behavior was analyzed using a Universal Testing machine with 400 kN capacity. The tensile specimens were prepared with reference to ASTM D1002, namely for the lap shear test specimens.

Table – 7
Test sample prepared by MIG and electric arc welding

| TEST SAMPLES | MATERIAL 1 | MATERIAL 2 | FILLER METALS USED |
|---|---|---|---|
| TS1 | SS 304 | MS | COPPER COATED MS WIRE |
| TS2 | SS 304 | MS | ER304 |
| TS3 | SS 304 | MS | ER308 |
| TS4 | SS 304 | MS | E6013 |
| TS5 | SS 304 | MS | ER309L |

TS1,TS2 are prepared by MIG Welding technique and other samples are prepared by electric arc welding techniques.

## III. RESULT & DISCUSSION

The welding of stainless steel was carried out with mild steel, the tensile test and hardness test was carried out for each welded samples of MIG and Electric arc welding processes.

### C. *Tensile Test*

Tensile testing was carried out using Universal Testing Machine of 400 KN capacity and the geometry of the test specimen is as shown in Fig. 1.

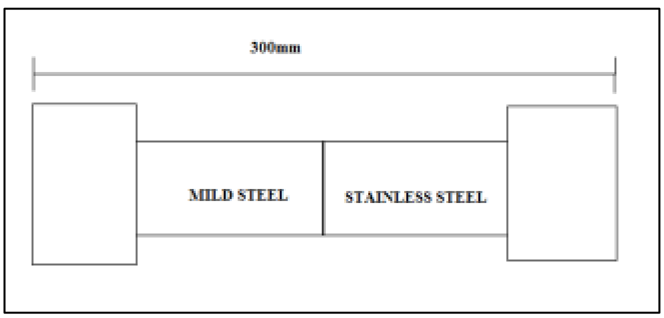


Fig. 1: Schematic diagram of SS and MS for tensile test

Mechanical proprieties of MIG welded and electric arc welded dissimilar welds of, stainless steel and mild steel after tensile test are tabulated in Table 8 and 9 respectively. Tensile strengths of welded test samples vary from 337 to 482MPa depending upon the welding conditions. All the specimens broke in the weld region

Table – 8
Mechanical Properties of MIG welded SS and MS samples

| TEST SAMPLES | UTS(MPA) | YIELDSTRENGTH (MPA) | FRACTURE LOCATION |
|---|---|---|---|
| TS1 | 459 | 380.1 | WELD |
| TS2 | 481.9 | 405.8 | WELD |

Table – 9
Mechanical Properties of MIG welded SS and MS sample.

| TEST SAMPLES | UTS(MPA) | YIELDSTRNGTH(MPA) | FRACTURE LOCATION |
|---|---|---|---|
| TS3 | 337.5 | 146.9 | WELD |
| TS4 | 421.8 | 168.7 | WELD |
| TS5 | 434.3 | 178.1 | WELD |

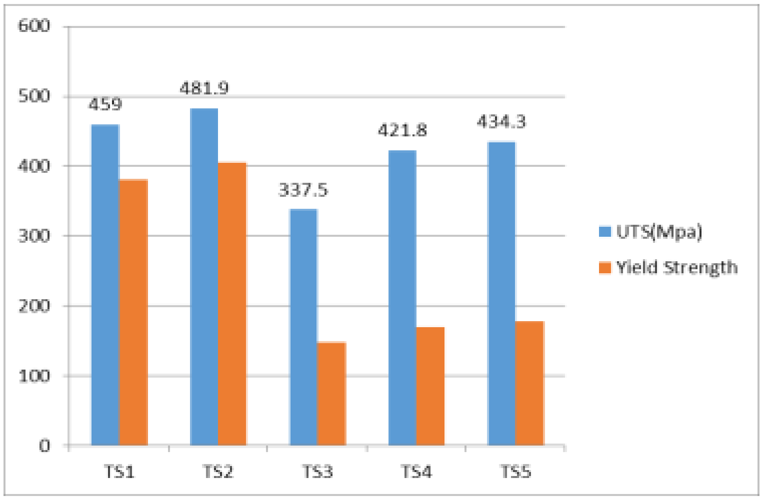

Chart 1: UTS and YS of test samples.

### D. Hardness Test

*1) Vickers Hardness*

The Vickers hardness pattern across the base materials and the welded seam is measured using a macro hardness tester.. For the MIG welded seam, the average hardness value ranges between 275 and 292 HV. As for the Electric arc welding, the average hardness value ranges between 248 and 288 HV. The hardness value for MIG welded samples is higher than that of electric arc welded samples.

Table – 10
Hardness value of the test samples

| TEST SAMPLES | CALCULATED VALUE |
|---|---|
| TS1 | 275 |
| TS2 | 291 |
| TS3 | 288 |
| TS4 | 283 |
| TS5 | 249 |

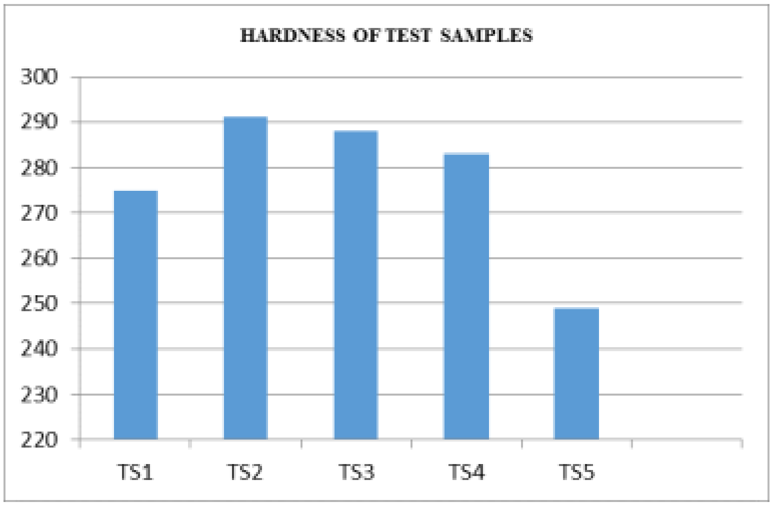

Chart 2: Hardness of test samples.

*2) Rockwell Hardness*

Rockwell scale is a hardness scale based on the indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload. When testing metals, indentation hardness correlates linearly with tensile strength.

Table – 11
Rockwell Hardness of Test Samples

| TEST SAMPLES | ROCKWELL HARDNESS NUMBER | AVERAGE ROCKWELL HARDNESS NUMBER |
|---|---|---|
| TS1 | 28.9,27.9,28.5,32.6 | 29.5 |
| TS2 | 34,35.5,36,33,34.5 | 34.6 |
| TS3 | 37.5,35,37,36.8 | 36.6 |
| TS4 | 34,32,33,35 | 33.5 |
| TS5 | 35,34,34.3,34.6 | 34.5 |

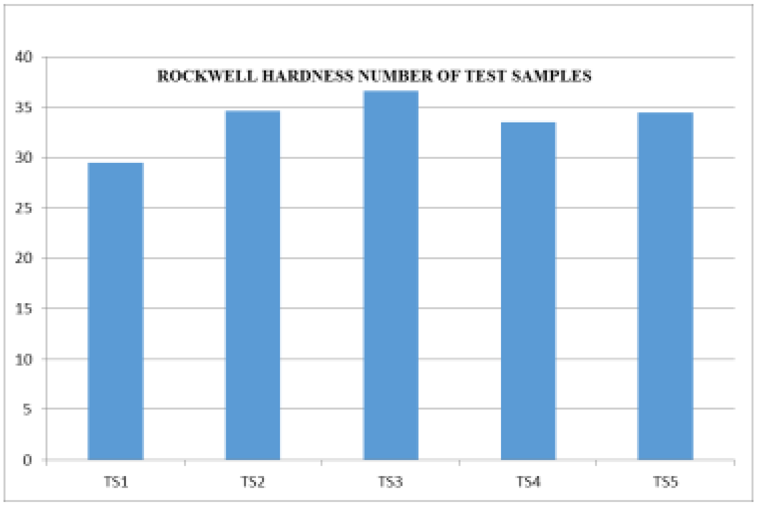


Chart 3: Rockwell Hardness of Test Samples.

## IV. Conclusions

Dissimilar welding between mild steel and stainless steel SS 304 was BUTT-joined successfully by MIG welding and electric arc welding Process. The conclusions from this study can be summarized as follows:

- The welding voltage had a significant effect on the welding process, as higher voltage resulted in poorer appearance of the weld joint and led to defects on all the test samples, such as porosity and incomplete fusion.
- Dissimilar welding butt-joint between mild steel and stainless steel SS 304 by MIG welding process was completed with good quality weld.
- The low percentage of free carbon allows the product (welded stainless steel with mild steel) better corrosion resistivity, ductility and strength.
- The percentage dilution in stainless steel is higher in MIG welded dissimilar joints which may be the reason of chromium loss due carbon precipitation in the joints and lower corrosion resistance.
- The dissimilar metal joint of SS 304 and mild steel has poor ultimate tensile stress for both welding processes when mild steel based electrode are used.
- Optimum penetration is obtained at 24V to 27V voltage
- If we increase voltage more than 30V there is chances of spattering and if decrease the voltage then there is lack of penetration and fusion in base metal.
- Based on the investigation throughout this analysis, it can be concluded that the welding voltage of 24-27 V and stainless steel filler ER309L is the optimum filler in joining dissimilar metal mild steel and stainless steel SS 304.
- MIG Welded sample have better strength as compared to other samples.

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