

## **IMPACT OF VOLTAGE ON AUSTENITIC STAINLESS STEEL FOR THE PROCESS OF TIG AND MIG WELDING**

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### **ABSTRACT**

In this Paper we discuss about the mechanical properties of austenitic stainless steel for the process of TIG and MIG welding. As with other welding processes such as gas metal arc welding, shielding gases are necessary in GTAW or MIG welding is used to protect the welding area from atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity, and weld metal embrittlement if they come in contact with the electrode, the arc, or the welding metal. The gas also transfers heat from the tungsten electrode to the metal, and it helps start and maintain a stable arc.

We used the TIG and MIG process to find out the characteristics of the metal after it is welded. The voltage is taken constant and various characteristics such as strength, hardness, ductility, grain structure, modulus of elasticity, tensile strength breaking point, HAZ are observed in two processes and analyzed and finally concluded.

**Keywords:** austenitic stainless steel; embrittlement; hardness; ; tensile strength, HAZ.

### **I. INTRODUCTION**

Several situations arise in industrial practice which call for joining of materials. The materials employed are location dependent in the same structure for effective and economical utilization of the special properties of each material.

Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the work pieces to form a bond between them, without melting the work pieces. Only in this way can the designer use most suitable materials for each part of a given structure.

The growing availability of new materials and higher requirements being placed on materials and the welding processes. In general austenitic stainless steels are easily weldable. When austenitic stainless steel joints are employed in cryogenic and corrosive environment the quantity of ferrite in the welds must be minimized/controlled to avoid property degradation during service. In addition these steels are prone to sensitization of their fusion welds. These problems have been addressed by solid state welding processes, such as friction welding.

## **II. SELECTION OF MATERIAL**

Stainless steel is selected for Corrosion is deterioration of essential properties in a material due to reactions with its surroundings. Millions of dollars are lost each year because of corrosion. Much of this loss is due to the corrosion of iron and steel, although many other metals may corrode as well. The problem with iron as well as many other metals is that the oxide formed by oxidation does not firmly adhere to the surface of the metal and flakes off easily causing "pitting". Extensive pitting eventually causes structural weakness and disintegration of the metal.

**Austenitic** is the most widely used type of stainless steel. It has a nickel content of at least of 7%, which makes the steel structure fully austenitic and gives it ductility, a large scale of service temperature, non-magnetic properties and good weld ability. The range of applications of austenitic stainless steel includes house wares, containers, industrial piping and vessels, architectural facades and constructional structures. When welding stainless steels it is advisable to follow the general welding guidelines valid for the type of steel, e.g. austenitic Stainless steels have, due to their chemical compositions, a higher thermal elongation compared to mild steels. This may

increase weld deformation. Dependent of weld metal microstructure they might also be more sensitive to hot cracking and sensitive to intermetallic precipitations compared to mild steels.

Austenitic grades are those alloys which are commonly in use for stainless applications. The austenitic grades are not magnetic. The most common austenitic alloys are iron-chromium-nickel steels and are widely known as the 300 series. The austenitic stainless steels, because of their high chromium and nickel content, are the most corrosion resistant of the stainless group providing unusually fine mechanical properties. They cannot be hardened by heat treatment, but can be hardened significantly by cold-working.

**Type 304** The most common of austenitic grades, containing approximately 18% chromium and 8% nickel. It is used for chemical processing equipment, for food, dairy, and beverage industries, for heat exchangers, and for the milder chemicals.

The special material properties of stainless steels affect all four machinability factors: in general, it can be said that the higher the alloy content of a stainless steel, the more difficult it is to machine. The special properties that make stainless steels difficult to machine occur to a greater or lesser extent in all grades of stainless steels, but are most marked in the austenitic grades. They can be summarized in five points:

- Stainless steels work-harden considerably
- Stainless steels have low thermal conductivity
- Stainless steels have high toughness
- Stainless steels tend to be sticky
- Stainless steels have poor chip-breaking characteristics

As the stainless steel is classified in different categories like austenitic, ferritic, martensitic etc., from this we have chosen austenitic stainless steel (304) because of its low cost, easy availability in the market.

## **SOME RULES OF THUMB FOR MACHINING STAINLESS STEELS**

There are some general rules of thumb that can be applied when machining stainless steels, to avoid (to some extent) the problems described, or at least to minimize them.

These rules are particularly important when machining austenitic stainless steels.

- Always use rigid machine tools, as the machining of stainless steels involves high cutting forces.
- Tools and work pieces must be firmly clamped, and the tool overhang must be as small as possible. (Long overhangs, or unstable machining conditions, increase the already substantial risk of vibration when machining stainless steels.)
- Do not use too great a nose radius, as this can cause vibration.
- Use tools with good edge sharpness and high edge strength.
- Use sufficient cutting depths, so that the cutting edge tip reaches below the work-hardened zone from the previous cut.

### **III METHODOLOGY:**

The standard specimen of austenitic stainless steel is prepared and welding processes of TIG and MIG welding are applied on the material under varied conditions of current, voltage and speed. Mechanical properties such as tensile strength, %of elongation, reduction of area and yield strength are measured with universal testing machine. The hardness of the material is also studied for the different welding processes with effect of the various welding parameters on the material. Corrosion resistance is studied. Microstructure is evaluated by electron microscope. Comparison is to be made between TIG and MIG welding processes under varied conditions and optimize the conditions so as to achieve highest efficiency and better mechanical properties.

The specimen is subjected are subjected to micro structural studies for the grain size analysis, microhardness test, tensile test, and corrosion studies for the stainless steel. All these tests were performed for the different welding parameters. Further, corrosion and the study of the microstructure of the material were carried out on the surfaces of the material for the knowing the grain size, grain structures as well as the grain boundaries.

Table I Chemical composition of austenitic stainless steel (wt.%)

<b>Composition</b>	<b>C</b>	<b>Si</b>	<b>Mn</b>	<b>Cr</b>	<b>S</b>	<b>P</b>	<b>Ni</b>
<b>AISI 304</b>	0.06	0.32	1.38	18.4	0.28	0.4	8.17

TIG and MIG welding process are chosen to carry out the experimental analysis on austenitic stainless steel.

### III. EXPERIMENTAL WORK

A. Procedure for carrying out the TIG process :

TIG: The main advantages of this process when used on stainless steels can be summarized as follows:

1. A concentrated heat source, leading to a narrow fusion zone.
2. A very stable arc and calm welding pool of small size. Spatter is absent and because no flux is required in the process, oxidation residues are eliminated so that any final cleaning operation is very much simplified.
3. An excellent metallurgical quality with a precise control of penetration and weld shape in all positions.
4. sound and pore-free welds.
5. Very low electrode wear.
6. Easy apprenticeship

We have taken sixteen cylindrical rods of authentic stainless steels, the material specifications are as follows:

Material : Austenitic stainless steel (304)  
Thickness : 3 mm  
Length : 150mm  
No of pieces : 6

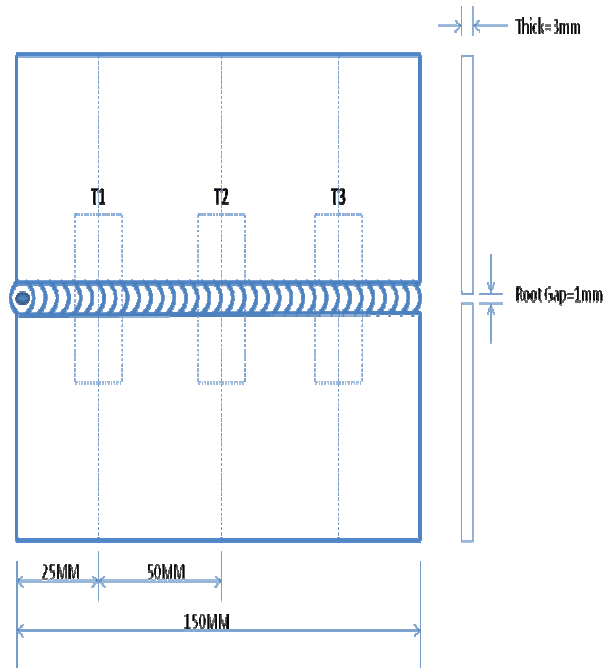


Figure 1 Specification of the specimen of welding process

Irrespective of welding joints, this specimen is then tapered at 45 degree to improve the weld strength



Figure 2 Specimen is tapered for weld strength.

After tapering welding process is selected, from these 3 pieces of austenitic stainless steel 3 pieces are selected for TIG and 3 pieces for MIG process. The three pieces are welded by TIG machine. The welded pieces are shown in Figure 3

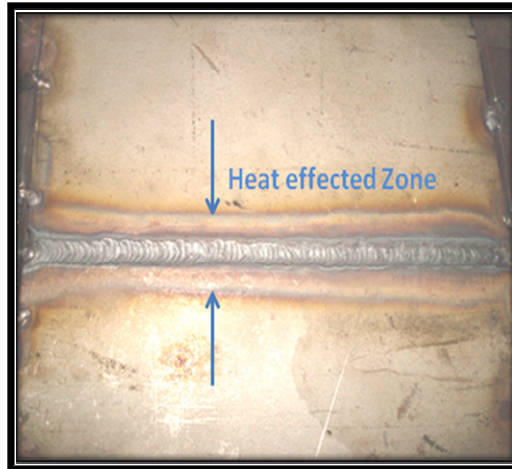


Figure 3 Welded pieces (TIG process)

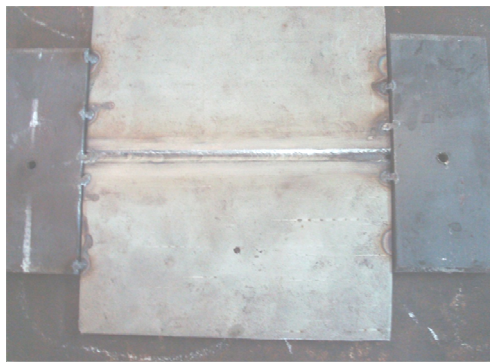


Plate selected at TIG Welding

The following weld parameters while TIG welding.





## B. OPERATIONS UNDER MIG PROCESS:

The three similar pieces of austenitic stainless steel which are tapered, which are shown earlier are taken for this process. The welded pieces under MIG process are represented below.

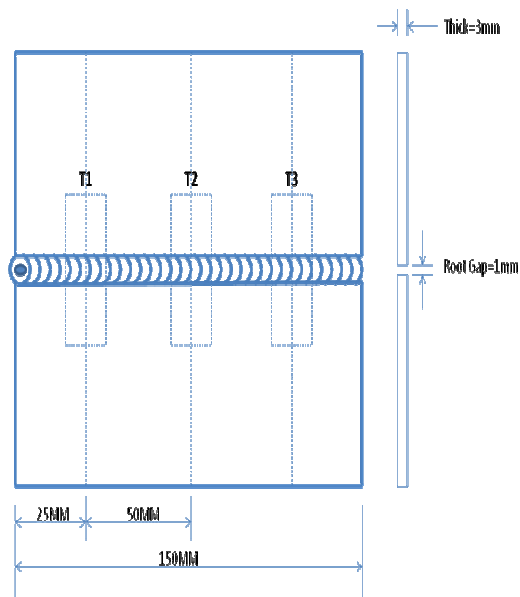


Figure 4 Welded pieces (MIG process)



#### **IV. TESTS CONDUCTED ON THE WELDED PIECES:**

1. Brinell's Hardness Test
2. Tension test on UTM (Universal Testing Machine).

1. Brinell's Hardness Test

Hardness may be defined as resistance of metal to plastic deformation usually by indentation. However the term may also refer to stiffness or temper or resistance to scratching, abrasion or cutting. Indentation hardness may be measured by various hardness tests like Brinell's, Rockwell's etc.

Pieces which are welded by both the process (TIG & MIG) are taken under this test.

$$BHN = \frac{2P}{\pi D [D - \sqrt{D^2 - d^2}]}$$

BHN=Brinells hardness number

P=Load on Indenter in kg.

D=Diameter of steel ball in mm.

d=Average measured diameter of indentation in mm.

Load (P) =3000 Kgs as the material belong to hard categories

Diameter (D) =10mm.

#### **B. RESULTS UNDER THE HARDNESS TEST(TIG):**

##### **1.1 The Brinell's Hardness number for the TIG welded material:**

Average diameter (d) = (5.4+4.4)/2= 4.9mm.

So,

$$BHN = \frac{2P}{\pi D [D - \sqrt{D^2 - d^2}]}$$

$$BHN = 185 \text{Kgs/mm}^2$$

#### **C. RESULTS UNDER THE HARDNESS TEST(MIG)**

##### **1.2 The Brinell's Hardness number for the MIG welded material:**

Average diameter (d) = (5.1+3.6)/2=4.35mm.

So,

$$BHN = \frac{2P}{\pi D [D - \sqrt{D^2 - d^2}]}$$

$$BHN = 349 \text{Kgs/mm}^2$$

**Table II: The hardness values of aisi obtained by tig ans mig process**

PROCESS	BHN			
	TIG	185	198	220
MIG	349	354	387	394

**V. TENSION TEST CARRIED ON UTM (UNIVERSAL TESTING MACHINE)**

It is one of the most widely used mechanical tests.

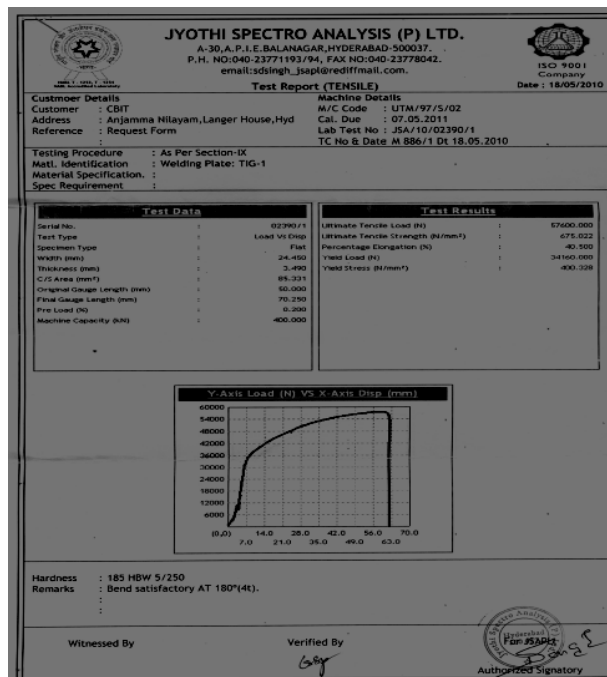
A tensile test helps determining tensile properties such as ultimate tensile strength, yield point or yield strength, % elongation, % reduction in area and modulus of elasticity.

Formulas used in tension test.

1. Yield strength = load at yield/original area (A<sub>0</sub>)
2. Ultimate tensile strength = ultimate load (P<sub>max</sub>)/(A<sub>0</sub>)
3. % Elongation =  $L_f - L_0 / L_0 * 100$
4. % Reduction =  $A_0 - A_f / A_0 * 100$
5. Young`s modulus of Elasticity, E= stress at any point/strain at that point Pieces which are welded by both the process (TIG & MIG) are taken under this test.

Graph indicating for the sample1&2 (TIG Welding)

Sample 1



**JYOTHI SPECTRO ANALYSIS (P) LTD.**  
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ISO 9001  
Company  
Date : 18/05/2010

**Test Report (TENSILE)**

<b>Customer Details</b>	<b>Machine Details</b>
Customer : CBIT	M/C Code : UTM/97/5/02
Address : Anjamma Nilayam, Langer House, Hyd	Cal. Due : 07.05.2011
Reference : Request Form	Lab Test No : JSA/10/02390/2
	TC No & Date M 886/2 Dt 18.05.2010

Testing Procedure : As per Section -IX  
 Matl. Identification : Welding Plate: TIG-2  
 Material Specification :  
 Spec Requirement :

Test Data	Test Results
Serial No. : 02390/2	Ultimate Tensile Load (N) : 54920.000
Test Type : Load Vs Disp	Ultimate Tensile Strength (N/mm <sup>2</sup> ) : 595.519
Specimen Type : Flat	Percentage Elongation (%) : 36.500
Width (mm) : 23.800	Yield Load (N) : 34360.000
Thickness (mm) : 3.870	Yield Stress (N/mm <sup>2</sup> ) : 372.587
C/S Area (mm <sup>2</sup> ) : 92.222	
Original Gauge Length (mm) : 50.000	
Final Gauge Length (mm) : 68.250	
Pre Load (N) : 0.200	
Machine Capacity (kN) : 400.000	

Y-Axis Load (N) VS X-Axis Disp (mm)

Hardness : 182 HBW 5/250

Witnessed By : \_\_\_\_\_ Verified By : *CSG*

Authorized Signatory

Sample2 (TIG)  
 Sample 1(MIG)

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 email:sdsingh\_jsapl@rediffmail.com.

ISO 9001  
Company  
Date : 21/05/2010

**Test Report (TENSILE)**

<b>Customer Details</b>	<b>Machine Details</b>
Customer : CBIT	M/C Code : UTM/97/5/02
Address : Hyd.	Cal. Due : 07.05.2011
Reference : Request Form	Lab Test No : JSA/10/02459/2
	TC No & Date M 904/2 Dt 21.05.2010

Testing Procedure : AS Per Section IX  
 Matl. Identification : MIG Plate-2, 3.48 THX150X177

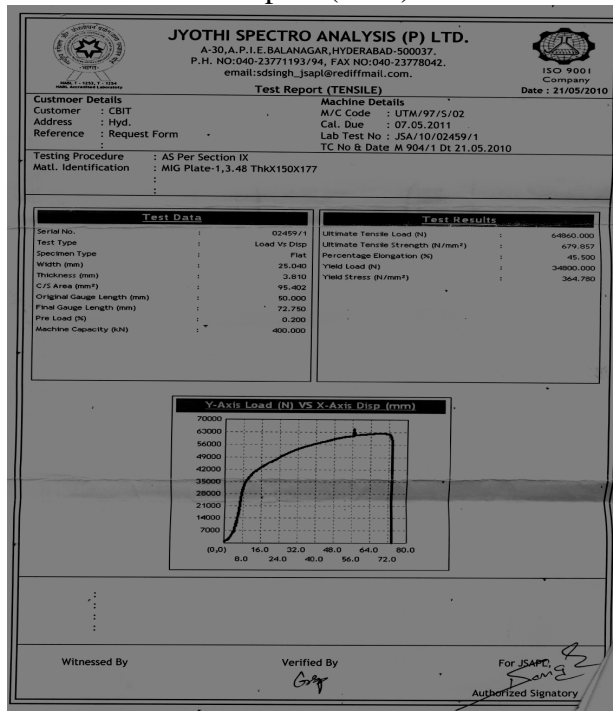
Test Data	Test Results
Serial No. : 02459/2	Ultimate Tensile Load (N) : 56160.000
Test Type : Load Vs Disp	Ultimate Tensile Strength (N/mm <sup>2</sup> ) : 652.029
Specimen Type : Flat	Percentage Elongation (%) : 47.000
Width (mm) : 23.400	Yield Load (N) : 30440.000
Thickness (mm) : 3.840	Yield Stress (N/mm <sup>2</sup> ) : 353.419
C/S Area (mm <sup>2</sup> ) : 86.131	
Original Gauge Length (mm) : 50.000	
Final Gauge Length (mm) : 72.900	
Pre Load (N) : 0.200	
Machine Capacity (kN) : 400.000	

Y-Axis Load (N) VS X-Axis Disp (mm)

Witnessed By : \_\_\_\_\_ Verified By : *CSG*

For JSAPL  
Authorized Signatory

Sample2 (MIG)



Graph indicating for the samples 1 & 2 (MIG Welding)

**HEAT AFFECTED ZONE:**

The heat-affected zone (HAZ) is the area of base material, either a metal or a thermoplastic, which has had its microstructure and properties altered by welding or heat intensive cutting operations. The heat from the welding process and subsequent re-cooling causes this change in the area surrounding the weld. The extent and magnitude of property change depends primarily on the base material, the weld filler metal, and the amount and concentration of heat input by the welding process.

The thermal diffusivity of the base material plays a large role—if the diffusivity is high, the material cooling rate is high and the HAZ is relatively small. Alternatively, a low diffusivity leads to slower cooling and a larger HAZ.

To calculate the heat input for arc welding procedures, the following formula is used:

$$Q = \left( \frac{V \times I \times 60}{S \times 1000} \right) \times \text{Efficiency}$$

Where  $Q$  = heat input (kJ/mm),

$V =$  voltage (V),

$I =$  current (A),

And  $S =$  welding speed (mm/min)..

**Heat input rate for the sample 1:**

$$Q = V \cdot I / S$$

$$15 \cdot 40 / 80 = 7.5 \text{ KJ/m}$$

**Heat input rate for the sample 2:**

$$Q = V \cdot I / S$$

$$10 \cdot 50 / 75 = 6.6 \text{ kJ/m.}$$

## V. CONCLUSIONS

1. **Hardness of the austenitic stainless steel when welded with TIG process is obtained as BHN is 185 HBW 5/250, where as for the MIG welding the BHN is 349 HBW 5/250.**

From this we can conclude that hardness of MIG welding is greater than the hardness of TIG welding. Therefore MIG welding is suitable where the hardness is the main criterion.

**2. From the tension test conducted on the specimen we can conclude that**

2.1 The ultimate load of TIG welded specimen is 57600 N where as for the MIG welded specimen is 56160N. Therefore we can say that TIG welded specimen can bear higher loads than MIG welded specimen.

2.2 The ultimate tensile strength of TIG welded specimen is 675.22 MPa where as for the MIG welded specimen is 652.029 N/mm square. Therefore we can say that TIG welded specimen has higher tensile strength.

2.3 Percentage elongation of TIG welded specimen is 40.500% where as for the MIG welded specimen is 47.8%. Therefore we can conclude that the ductility is higher in MIG welded specimen.

Note: According to the standards the percentage of reduction in area should be 40%. But we got more than the standard. So, that the weld joint is more strength.

2.4 The yield stress of the TIG welded specimen is 400.238 N/mm square whereas for the MIG welded specimen is 353.419 N/mm squared. Therefore we can conclude that TIG welded specimen can bear high yield stress.

2.5 In the corrosion resistance, the alloy material of 304 can be successfully welded by the following process.

- 1) TIG Welding.
- 2) MIG Welding.

The Microstructure consists of Austenite in Grain size 5 to 6 in the Matrix, No Delta Ferrite observed in TIG Welding and The Microstructure consists of Austenite in Grain size 5 to 6 in the Matrix, No IGC (Inter Granular Corrosion) Observed in MIG Welding.

Therefore the welding parameters must be optimized to obtained a controlled Ferrite level 20 to 70%. Typical recommended heat inputs are 10 to 25 KJ/cm with a 150 degree centigrade (302F) Max interpass temperature. These conditions must be optimized taking in to account the thickness of the products and welding Equipment (consult is necessary). We do not recommended pre – or post welding heat treatments. Only complete solution annealing heat treatment may be considered.

Finally we have observed all the parameters good results in TIG Welding. So, TIG welding is best process for Austenitic Grade materials.

As the speed decreases and the current increases the heat affected zone increases .

## **VI. FUTURE RESEARCH DIRECTIONS**

T his work can be further extended for other stainless steel to know the comparison of the mechanical properties as well as the different parameters under the microstructure study and conclude for the reduction of the cost and suggestion of suitable materials in different applications of industrial process.

## **VII ACKNOWLEDGEMENT**

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