Experimental Investigation for Welding Aspects of AISI 304 & 316 by Taguchi Technique for the Process of TIG & MIG Welding

Mr.L.Suresh Kumar[1], Dr.S.M.Verma[2], P.RadhakrishnaPrasad[3], P.Kiran kumar[4] Dr.T.Siva Shanker[5]
[1,3,4,5],*Chaitanya Bharathi Institute of Technology, Gandipet, Hyderabad-75, India.*
[2]*Professor & Head, Rayalaseema University, Kurnool, A.P, India*

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 embitterment 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; 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.

II. SELECTION OF MATERIAL

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 adviaisable 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.

The special material properties of stainless steels affect all four mach inability 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, martens tic etc., from this we have chosen austenitic stainless steel (304) because of its low cost, easy availability in the market.

III. METHODOLOGY

Stainless steel is selected for carrying out the experimental analysis because of its many advantages and easy availability in the market.

1. As the stainless steel is classified in different categories like austenitic, ferritic, martenstic etc… from this we have chosen austenitic stainless steel (304 & 316) because of its low cost, easy availability in the market.
2. TIG and MIG welding process are chosen to carry out the experimental analysis on austenitic stainless steel.
3. Procedure for carrying out the project :

We have taken sixteen samples plates (8 pieces of AISI 304 and 8 pieces AISI 316) of authentic stainless steels, the material specifications are as follows:

Material : Austenitic stainless steel (304 & 316)
Thickness : 3mm
Length : 150mm
No of pieces : 16

TABLE I
CHEMICAL COMPOSITION FOR 304 & 316

C **Composition:**	Type 304 %	Type 316 %
Carbon	0.08 max	0.08 max
Manganese	2.00 max.	2.00 max.
Phosphorus	0.045 max.	0.045 max.
Sulfur	0.030 max.	0.030 max.
Silicon	0.75 max.	0.75 max.
Chromium	18.00-20.00	16.0-18.0
Nickel	8.00-10.05	10.0-14.0
Nitrogen	0.10 max.	0.10 max.
Molybdenum	-----------	2.0 – 3.0

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

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

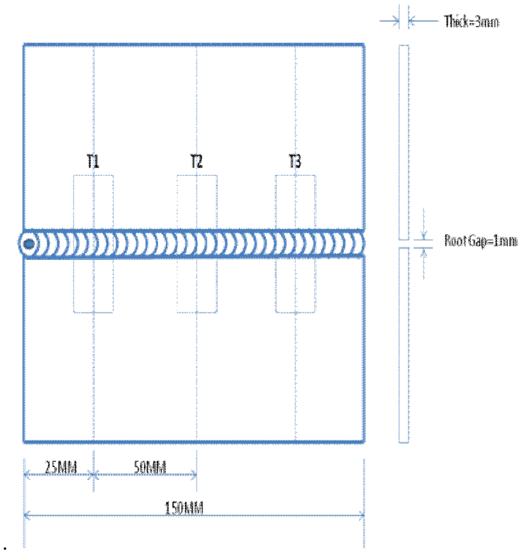


Fig.1 Specification of the specimen of welding process

Fig.2 Specimen is tapered for weld strength.

After tapering welding process is selected, from these3 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 fig.3

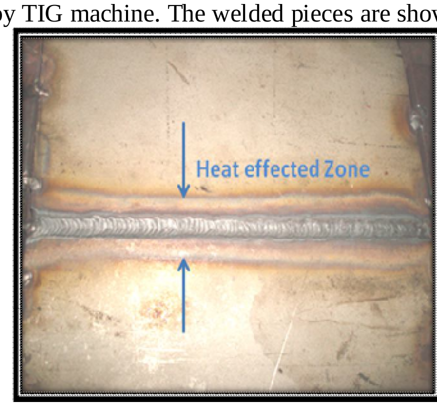


Fig. 3 Welded pieces(TIG process)

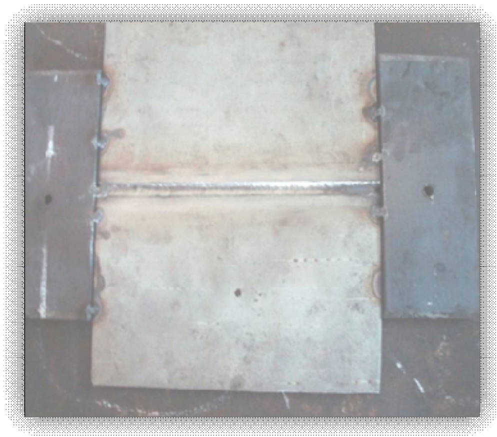


Fig4 Plate selected at TIG Welding

TAGUCHI METHOD OF ANALYSIS

Taguchi uses a different cost model for Characteristic than is typically used ,which places more emphasis on reducing variation, particularly than the total product variation with in the specification limit for the product .The purpose of experimentation should be understand how to reduce and control variation of a product or process, subsequently ,decision must be made concerning which parameters effect the performance of the producer or process the loss function quantifies the need to understand which design factors influence the average and variation on performance characteristic or a process by properly adjusting the average and reducing vibration the product the process can be minimised this approach based on taguchi orthogonal arrays. In this L-9 orthogonal array is used.

Table II Standard L-9 orthogonal array

Runs	1	2	3	4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

The parameters are assigned to orthogonal are shown in table

With help of this technique it helps to determine the which parameter is less influence and which is more influence. In this case the angle and root gap is less influence when compare with current and the speed. Further the experiment is carried based only the speed and current.

Table III: L-9 Orthogonal array after assignment of parameters

	CURRENT	SPEED	ANGLE	ROOTGAP
1	40	30	60	1.6
2	40	35	45	1.3
3	40	65	90	1.9
4	50	30	45	1.3
5	50	35	90	1.9
6	50	65	60	1.6
7	100	30	90	1.9
8	100	35	60	1.6
9	100	65	45	1.3

SNO	CURRENT (amps)	SPEED (mm/min)	WIDTH (mm)	HAZ (mm)	HARDNESS (BHN)
1	40	31.4	11	9	161.56
2	50	30.25	9	8	202.4
3	70	30.74	9	7	190.54
4	100	28.2	12	9	198.36
5	120	31.8	11	9	164.54

Table iv : The following weld parameters while TIG process

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.

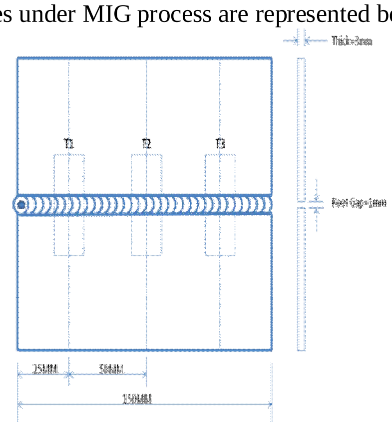


Fig. 4 Welded pieces(MIG process)

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 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=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:

BHN = 2*3000/(∏*10(10-√(10*10)-(4.3*4.3))
= 196.54 *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.

BHN = 2*3000/(∏*10(10-√(10*10)-(4.7*4.7))
= 161.56 *Kgs/mm*^{2}

SNO	CURRENT (amps)	SPEED (mm/min)	WIDTH (mm)	HAZ (mm)	HARDNESS (BHN)
1	40	31.4	11	9	161.56
2	50	30.25	9	8	202.4
3	70	30.74	9	7	190.54
4	100	28.2	12	9	198.36
5	120	31.8	11	9	164.54

TABLEV: THE HARDNESS VALUES OF AISI OBTAINED BY MIG

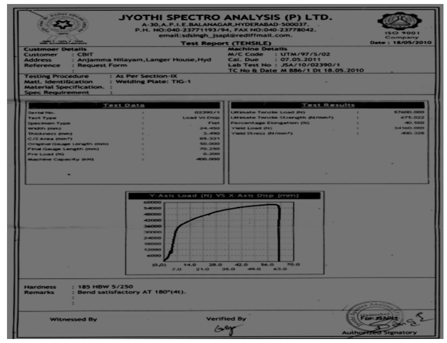
SNO	CURRENT (amps)	SPEED (mm/min)	WIDTH (mm)	HAZ (mm)	HARDNESS (BHN)
1	40	31.4	12	9	196.54
2	50	30.25	10	10	178.54
3	70	30.74	10	9	180.2
4	100	28.2	12	10	206.52
5	120	31.8	11	8	120.62

Tension test carried on UTM (Universal Testing)

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. A sample graph is shown in Fig 5.

Formulas used in tension test.

1. Yield strength = load at yield/original area (Ao)
2. Ultimate tensile strength = ultimate load (Pmax)/(A_0)
3. % Elongation = (L_f – Lo)/Lo*100
4. % Reduction = (Ao-Af)/Ao*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.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P.H. NO:040-23771193/94, FAX NO:040-23778042.
email:sdsingh_jsapl@rediffmail.com.
ISO 9001 Company
Test Report (TENSILE)
Date : 18/05/2010

Custmoer Details
Customer : CBIT
Address : Anjamma Nilayam, Langer House, Hyd
Reference : Request Form

Machine Details
M/C Code : UTM/97/S/02
Cal. Due : 07.05.2011
Lab Test No : JSA/10/02390/1
TC No & Date M 886/1 Dt 18.05.2010

Testing Procedure : As Per Section-IX
Matl. Identification : Welding Plate: TIG-1
Material Specification. :
Spec Requirement :

Test Data	
Serial No.	02390/1
Test Type	Load Vs Disp
Specimen Type	Flat
Width (mm)	24.450
Thickness (mm)	3.490
C/S Area (mm²)	85.331
Original Gauge Length (mm)	50.000
Final Gauge Length (mm)	70.250
Pre Load (N)	0.200
Machine Capacity (kN)	400.000

Test Results	
Ultimate Tencile Load (N)	57600.000
Ultimate Tencile Strength (N/mm²)	675.022
Percentage Elongation (%)	40.500
Yield Load (N)	34160.000
Yield Stress (N/mm²)	400.328

Hardness : 185 HBW 5/250
Remarks : Bend satisfactory AT 180°(4t).

Witnessed By
Verified By
For JSAPL
Authorized Signatory

Fig5 Graph indicating for the sample1&2 (TIG Welding)
Sample 1

HEAT EFFECTED 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:

η

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*I/S

15*40/80 =7.5KJ/m

Heat input rate for the sample 2:

Q= V*I/S

10*50/75 =6.6 kj/m.

V. CONCLUSIONS

1. *Hardness of the austenitic stainless steel when welded with TIG process* the value of Hardness (BHN) at 40amp for TIG process is 162.53 and for MIG it is 196.54. So from this it is concluded that the MIG process is suitable for at lower currents.
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.

1.4 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.

1.5 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

It is also carried out for other stainless steel materials and compared with AISI stainless steels to recommend which material is suitable for the industries for manufacturing of components as well as the durability of the material for its applications.

The work is also extended with other welding process to know the best suitable process for recommending the process at a minimum cost and maximum profit for the organization and to minimize the weld defects as well as welding problems for further future work.

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