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INVESTIGATION OF VARIOUS DISSIMILAR METALS WITH AUSTENITIC STAINLESS STEEL BY USING TIG WELDING

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Abstract

There is a growing need for dissimilar welding of steel due to its various benefits such as the production of lightweight machine parts, production of less expensive engineering components with acceptable corrosion resistance, high strength, and recyclability in the power generation, chemical, petrochemical, and automotive industries. Welding of dissimilar steels is very challenging due to the dissimilarities in their chemical, physical, and metallurgical properties. The objective of work done here is to understand the various welding parameter like welding current, voltage, gas flow rate, inert gas, welding speed, type of electrode etc. In this work we discuss about the Tungsten Inert Gas Welding of joining heat treatable of stainless steel (304), Mild steel (IS2062 E250 A) and Carbon Steel (EN8). To evaluate the Output parameters such as tensile strength of welding, hardness of welding, Chemical test and Radiography of welding. The main purpose of this work is to investigate optimal machining parameters for attaining the best weld quality

KEY WORDS: welding material, Stainless steel, Mild steel, Carbon steel

1 Introduction:

Welding is a joining of two or more parts by the application of heat and pressure; such joints are permanent in nature. In which process coalescence of materials is produced by heating them to re-crystallization temperature with or without use of pressure and with or without the use of filler material. Welding is used for permanent joints of metals. TIG welding is a welding process which is widely used in modern industries for joining either similar or dissimilar materials. By the using TIG welding joining of Stainless steel plate and mild steel plate is possible whose applications are such as nuclear reactor, civil construction, thermal power plant, vessels and heat exchangers and it is also used for various industrial applications

1.1 Types of welding

Based on the heat source used welding processes can be follows are arc welding,Gas welding, Resistance welding, High energy beam welding, and solid-state welding

1.2 Basic mechanism of TIG welding:

TIG welding is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere by an inert shielding gas (argon or helium), and a filler metal is normally used. The power is supplied from the power source (rectifier), through a hand-piece or welding torch and is delivered to a tungsten electrode which is fitted into the hand piece. An electric arc is then created between the tungsten electrode and the work piece using a constant- current welding power supply that produces energy and conducted across the arc through a column of highly ionized gas and metal vapors .The tungsten electrode and the welding zone are protected from the surrounding air by inert gas. The electric arc can produce temperatures of up to 20,000°C and this heat can be focused to melt and join two different part of material. The weld pools can be used to join the base metal with or without filler material. Schematic diagram of TIG welding and mechanism of TIG welding are shown.

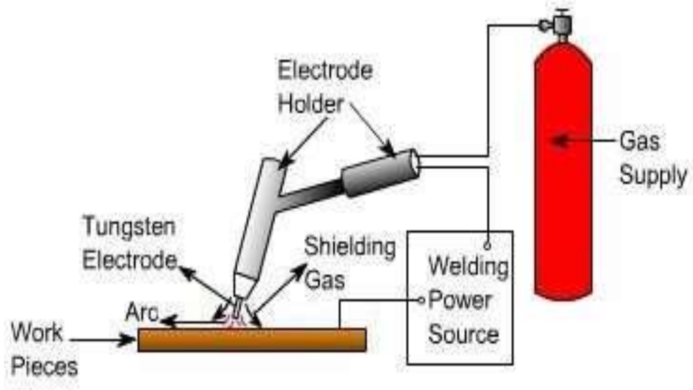

Figure.1 Tig welding

Tungsten electrodes are commonly available from 0.5 mm to 6.4 mm diameter and150 - 200 mm length. The current carrying capacity of each size of electrode depends on whether it is connected to negative or positive terminal of DC power source. The power source required to maintain the TIG arc has a drooping or constant current characteristic which provides an essentially constant current output when the arc length is varied over several millimeters. Hence, the natural variations in the arc length which occur in manual welding have little effect on welding current. The capacity to limit the current to the set value is equally crucial when the electrode is short circuited to the work piece, otherwise excessively high current will flow, damaging the electrode. Open circuit voltage of power source ranges from 60 to 80 V.

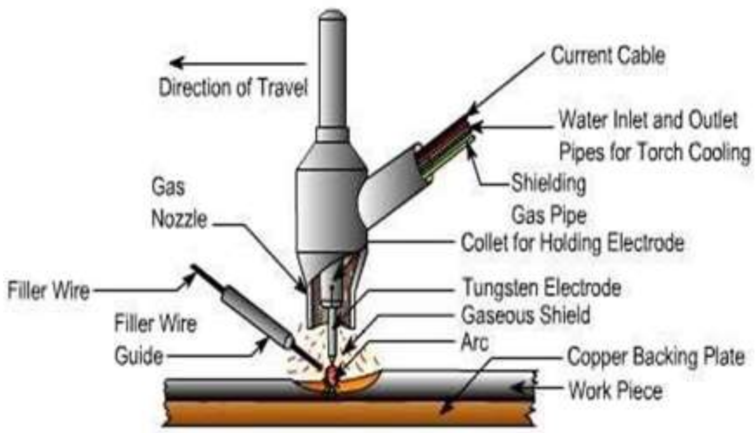

Figure.2 Tig welding with tungsten electrode

2. Methodology

2.1 Materials and properties

After the completion of the literature, following three materials are identified as the materials in the present work:

1. Stainless Steel (304)
2. Carbon Steel (EN8)

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3. Mild steel (IS2062 E250A)

Base metal: Stainless Steel (304)

Material combination for sample preparation

Based on the above selection the combinations of materials have been taken as mentioned below by keeping the stainless steel as the base materials.

Table.1 combined material details

S.No	***Material Combinations***
1	Stainless Steel (304) + Stainless Steel (304)
2	Stainless Steel (304) + Carbon Steel (EN8)
3	Stainless Steel (304) + Mild steel (IS2062 E250 A)

Stainless Steel (304):

304 grade stainless steel is an austenitic form of stainless steel known for its 2- 3% molybdenum content. The added molybdenum makes the more metal resistant to pitting and corrosion, as well as improves resistance when exposed to elevated temperatures.

This type of stainless steel (304) is particularly effective when used in acidic environments. With the use of this metal, corrosion that is caused by acetic, hydrochloric and forms of acids can be prevented.

Figure.3 Raw material for stainless steel 304

Table.2 Tabulation for Stainless steel material details

Chemical Composition of Stainless Steel 304	
%	304
Chromium, Cr	18.0 min. – 20.0 max.
Nickel, Ni	8.0 min. – 10.5 max.
Carbon,C	0.08- 0.030
Manganese,Mn	2.0
Phosphorous, P	0.0450
Sulfur, S	0.030
Silicon,Si	0.75
Nitrogen, N	0.10
Iron, Fe	Balance

Mechanical Properties of Stainless Steel 304	
Grade	304
Tensile Strength (MPa)	520 - 720
Proof Stress (MPa)	210 Min
Elongation	45 Min %

Physical Properties of Stainless Steel 304	
Property	Value
Density	8.00 g/cm3
Melting Point	1450 °C
Modulus of Elasticity	193 GPa
Electrical Resistivity	0.72 x 10-6Ω.m
Thermal Conductivity	16.2 W/m.K
Thermal Expansion	17.2 x 10-6/K

Carbon Steel (EN8):

EN8 is an unalloyed medium carbon steel which is used in applications where its properties are better than mild steel. But the costs do not justify the purchase of a steel alloy. EN8 can be heat treated to provide a good surface hardness and moderate wear resistance by flame or induction hardening processes.

Figure.4 Raw Material for Carbon Steel(EN8)

Table.3 Tabulation for Carbon steel material details

Chemical Composition of Carbon Steel EN8	
%	Carbon steel EN8
Carbon, C	0.36 - 0.44
Silicon, Si	0.10 - 0.40
Manganese, Mn	0.60 – 1.00
Phosphorous, P	0.05
Sulfur, S	0.05 max

Mechanical Properties of Carbon Steel EN8	
Max Stress	700-850 n/mm2
Tensile Strength	485 min
Yield Strength	465 n/mm2 Min
Elongation, %	16% Min
Hardness Brinell	201-255

2.2 Methods of testing

Types of testing methods

- Destructive tests
- Non-Destructive tests

2.2.1 Destructive tests

Destructive testing is accomplished by forcing the material to fail under various load factors. The destructive testing method is used to find mechanical properties of material Such as Tensile Strength, yield strength, hardness, impact toughness, elongation etc

2.2.2 Non-Destructive tests

Non-destructive testing is used as part of a manufacturing or installation inspection to check if quality demands are being met. As an example, welded steel joints are x-rayed to check the quality of the welding. The radiographic test reveals if the joint is fully welded or contains unacceptable faults.

3.1 Experimental and analysis

3.1 V-Groove

The material has been cut into two half's and the V-Groove has been made with the help of Milling machine and Blur has been removed with the help of grinding machine.

Joint Detail : Plate to Plate, Single
V Butt Root Gap : 2-4 mm
Root Face : 1-2 mm Angle : 60°

Figure.5 Machining for V-Groove

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Table.4 Tabulation for welding properties

Weld Run Details	**Pass No**	Root	Hot	Fill
	Side	Single	Single	Single
	Process	GTAW	GTAW	GTAW
	Filler Dia Ø (mm)	2.4	2.4	2.4
	Inter Pass Temp (°c)	Ambient	85 Max	64 Max
Weld Parameters	**Amp (I)**	95 - 100	120 – 160	145 - 160
	Volt (V)	10.0 – 10.2	10.1 – 10.5	10.2 – 10.5
	Current/ Polarity	DC/EP	DC/EP	DC/EP
	Speed (mm/min)	32.3	68.2	59.3
	Heat Input (KJ/mm)	1.89	1.48	1.70

Figure.6 Stainless steel material with weld joint of Stainless steel

Figure.7 Carbon steel material with weld joint of Stainless steel

3.1 Tensile test

Sample1: Stainless steel 304 + Stainless steel 304

Testing was carried out on universal testing machine to analyse the parameters such as ultimate load (N), tensile strength (MPa).

Testing was done on welded specimen. This methodology was adopted for testing the similar materials where both parent metal and base metal are the same.

Table.5 Tensile test stainless steel 304 + stainless steel 304

Area (mm)	124.426
Width (mm)	12.480
Thickness (mm)	9.970

Gauge Length (mm)	50.000
Final Gauge Length (mm)	61.400
Maximum Force (N)	89000.000
Displacement at FM(mm)	30.340
Maximum Displacement (mm)	33.840
Ultimate Tensile Strength (Mpa)	715.278
Elongation %	22.800
Yield Load (N)	48920.000
Yield Stress (Mpa)	393.167
YS/UTS Ratio	0.550

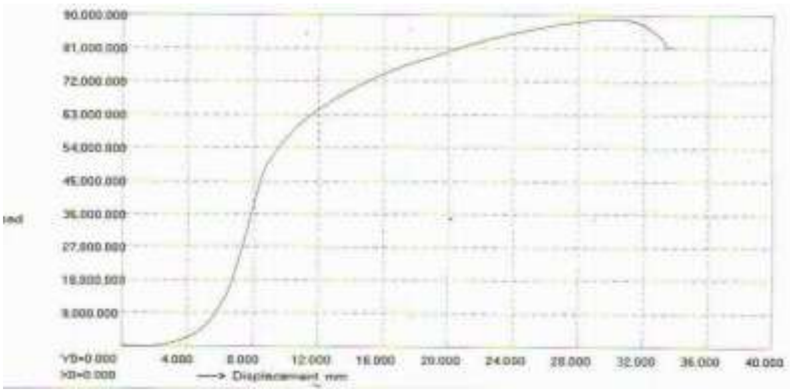

Figure. 8 Graph for load vs displacement

Sample 2: Stainless steel 304 + Carbon steel EN8

The testing method which was carried for the first sample is applied for the second sample which small change where the base metal is SS and CS is carried to analyze the test results

Table.6 tensile test stainless steel 304 + Carbon steel EN8

Area (mm)	123.599
Width (mm)	12.51
Thickness (mm)	9.88
Gauge Length (mm)	50.00
Final Gauge Length (mm)	60.75
Maximum Force (N)	53820.00
Displacement at FM(mm)	16.070
Maximum Displacement (mm)	21.520
Ultimate Tensile Strength (Mpa)	435.441
Elongation %	21.500
Yield Load (N)	40780
Yield Stress (Mpa)	329.939
YS/UTS Ratio	0.758

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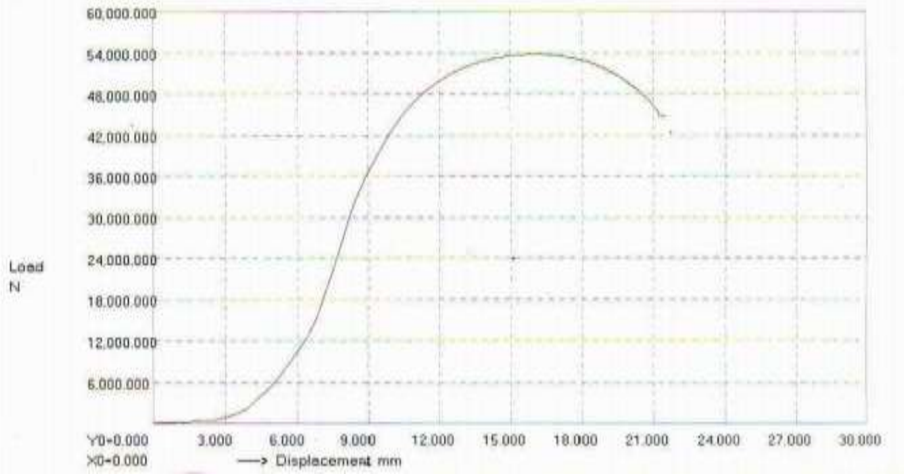

Figure.8 Graph of load vs displacement

3.4 Rockwell hardness test

Sample 1: Stainless Steel (304) + Stainless Steel (304)

Table.7 Hardness test stainless steel 304 + Stainless steel 304

Room Temperature	27.5°c
Observed Values	59.5,61.5,63.5
Average Values	61.5

Sample 2: Stainless Steel (304) + Carbon Steel (EN8)

Table.8 Hardness test stainless steel 304 + Carbon steel EN8

Room Temperature	27.5°c
Observed Values	68.5,71.0,71.5
Average Values	70.33

3.5 Chemical test

Sample 1: Stainless Steel (304) + Stainless Steel (304)

Table.9 Chemical test stainless steel 304 + Stainless steel 304

Components name	%
Carbon ,C	0.0689
Silicon ,Si	0.409
Manganese , Mn	1.61
Phosphorus , P	0.0226
Sulphur ,S	0.00411
Chromium ,Cr	18.37
Molybdenum ,Mo	0.104
Nickel ,Ni	9.21
Copper ,Cu	0.196
Aluminium ,Al	0.00402

Boron ,B	0.0005
Cobalt ,Co	0.132
Niobium ,Nb	0.001
Lead ,Pb	0.01
Tin ,Sn	0.00177
Titanium ,Ti	0.00225
Venadium ,V	0.0323
Tungsten ,w	0.001
Selenium ,Se	0.005
Iron ,Fe	69.5896

Sample 2: stainless steel 304 + Carbon steel EN8

Table.10 Chemical test stainless steel + Carbon steel EN8

Components name	%
Carbon ,C	0.0325
Silicon ,Si	0.342
Manganese , Mn	1.66
Phosphorus , P	0.0131
Sulphur ,S	0.0031
Chromium ,Cr	16.77
Molybdenum ,Mo	0.0484
Nickel ,Ni	8.89
Copper ,Cu	0.0503
Aluminium ,Al	0.0109
Boron ,B	0.0005
Cobalt ,Co	0.124
Niobium ,Nb	0.001
Lead ,Pb	0.01
Tin ,Sn	0.001
Titanium ,Ti	0.0019
Venadium ,V	0.0249
Tungsten ,w	0.001
Selenium ,Se	0.005
Iron ,Fe	71.79

3.6 Radiography test

Sample 1: Stainless Steel (304) + Stainless Steel (304)

Table.11 Radiography teststainless steel 304 + stainless steel 304

Test method		**Stainless Steel (304) + Stainless Steel (304)**
Thickness (mm)		13
IQI (Image Quality Indicator)	**S**	1B11
	F	
Density	**Min**	2
	Max	4
Sensitivity		W7
SFD (Source to Flim Distance)		12"
Flim Size		6x4
Finding		NSD
Remark		Acceptable

Figure.9 Radiography value for SS 304 + SS 304

Sample 2: Stainless Steel (304) + Carbon Steel (EN8)

Table.12 Radiography test stainless steel 304 + Carbon steel EN8

Test method		**Stainless Steel (304) + Carbon Steel (EN8)**
Thickness (mm)		**13**
IQI (Image Quality Indicator)	**S**	**1B11**
	F	**-**
Density	**Min**	**2**
	Max	**4**
Sensitivity		**W7**

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SFD (Source to Flim Distance)	**12"**
Flim Size	**6x4**
Finding	**NSD**
Remark	**Acceptable**

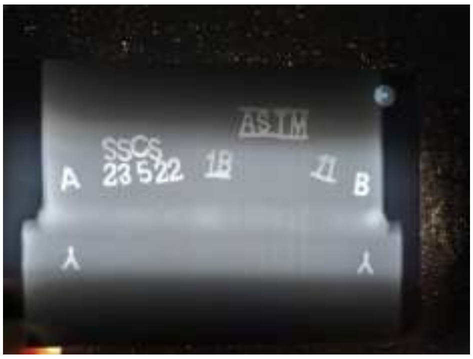

Figure.10 Radiography test for SS 304 + CS EN8

4. Result and discussion

4.1 Bar chart for tensile test

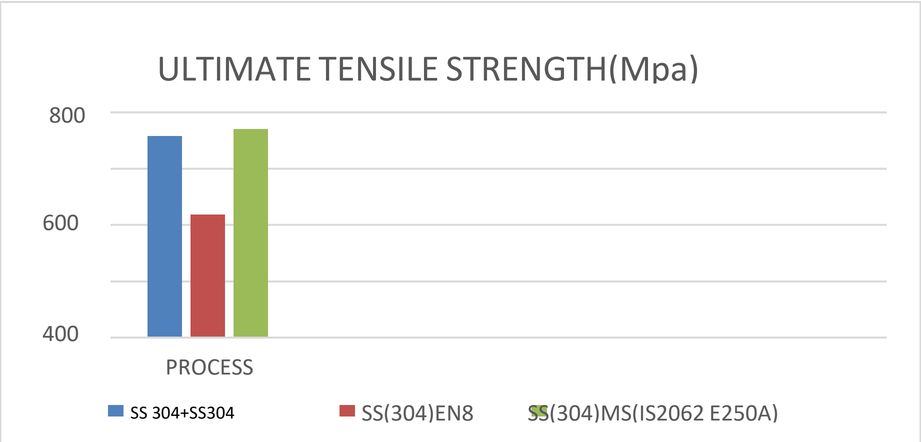

Figure.11 Bar chart for tensile test

From the above results indicate that the specimens that braked outside that weld i.e. in mild steel possess high strength welded joint and the specimens that cracked inside the welded joint possess less strength than the mild steel base metal. The reason for the break point inside the weld may be the improper welding, formation of weld defects, improper base metal delusion etc. So to get the strength of the weld the specimens where made to crack inside the weld joint.

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4.1.1 Tensile test

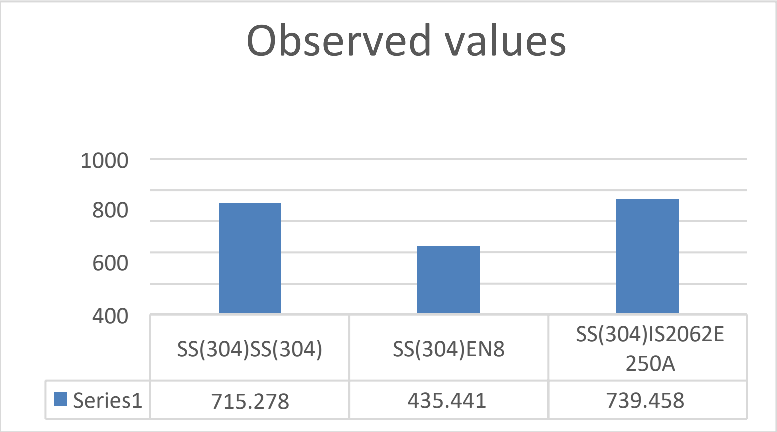

Figure.12 Observed values for tensile test

The above results indicate that a satisfactory weld joint, when welding mild steel with stainless steel can be achieved with both TIG and MIG welding process. So overall tensile test results indicate that the best tensile strength can be achieved with TIG welding process using SS (304) MS (IS2062E250A) filler when compare to other specimen.

4.2 Bar chart for Rockwell hardness test

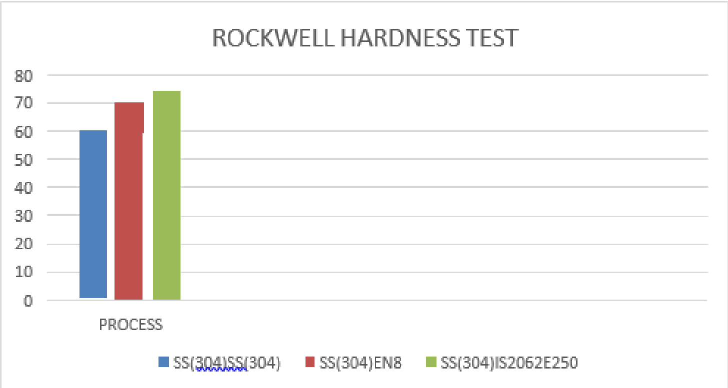

Figure.13 Bar chart for Rockwell hardness test

In this test for each specimen three test samples have been taken to find the hardness at the weld zone. The hardness is as indicated in the Table and the corresponding chart is indicated in figure.

4.2.1 Rockwell hardness test

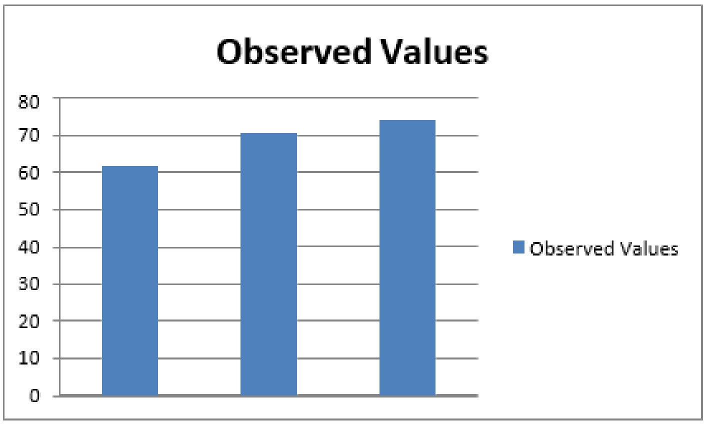

Figure.14 Observed values of hardness test

The above data indicates in all aspects of processes the welded joints have high hardness. And the TIG welded specimen with SS (304) MS (IS2062E250A) filler possess high hardness when compare to other specimen.

4.Conclusion

The current experimental work has investigated the effect of TIG welding process and also effect of welded part with different specimen combinations but when welding mild steel with stainless steel. The major results can be summarized as follows.

a) High strength welded joint can be achieved by TIG welding process using mild steel (IS2062E250A) with stainless steel (304).
b) TIG welding gives a better surface finish with less weld defects in combination of SS (304) MS (IS2062E250A).
c) A perfect welded joint can be achieved by using mild steel filler for welding mild steel with stainless steel.
d) In all scenarios, the welded joints have high hardness and are brittle in nature.
e) Welding parameters are vital when welding dissimilar steels.

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