EXPERIMENTAL INVESTIGATION OF TIG WELDING ON STAINLESS STEEL AND MILD STEEL PLATES

[1]Keyur Panchal
[1]Lecturer in Metallurgy Department
[1]Dr. S. & S .S. Ghandhy College of Engineering & Technology. Surat, India.

Abstract: - The main focus of this paper is to study the effect of TIG welding on stainless steel and mild steel plates. TIG welded plates majorly used in industries purpose. The welding of dissimilar metals is most useful in structural applications. But the difficulty arises due to welding such plates because of the loss of carbon from mils steel and precipitation of chromium in stainless steel during welding. TIG welding is best suitable process used to control these problems occur during welding on base metals joints. Here main purpose of this paper is to discuss about effect of welding on MS and S.S plate and study the result like hardness, tensile, bend test etc. In this experimental test it is seen that there is nothing problematic to weld such plates carry different composition. All result shown satisfactory. It is evaluate that TIG welding perform best on S.S and MS welding.

Index Terms – Stainless steel, mild steel, TIG, hardness, bend test.

I. INTRODUCTION:

Gas tungsten arc welding (**GTAW**), also known as **tungsten inert gas** (**TIG**) **welding**, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding power supply produces electrical energy, which is conducted across the arc through a column of highly ionized gas and metal vapors known as plasma.

GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding, uses a slightly different welding torch to create a more focused welding arc and as a result is often automated.

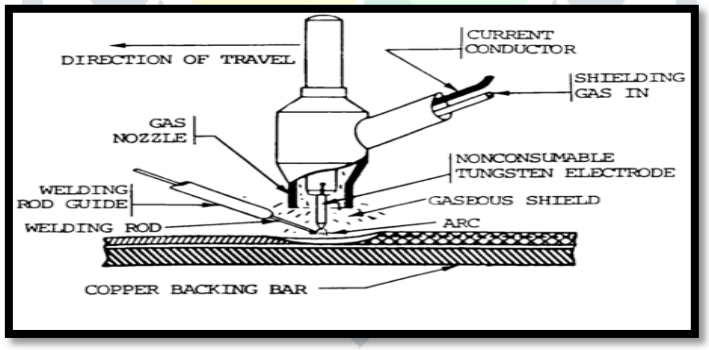


Figure- 1 TIG Welding

II. SELECTION OF MATERIAL:

Austenitic is the most widely used type of stainless steel. It has a nickel content of at least of 8.01 %, 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 large of applications of austenitic stainless steel includes house wares, containers, industrial piping and vessels, architectural facades and constructional structures. By its very nature, austenitic stainless steel is a poor conductor of heat. The presence of nickel (6-22%), along with chromium (16-26%), enhances its corrosion and/or stain resistance, but these and other elements—often titanium or molybdenum—also cause it to react to heat differently than other materials. Effectively, austenitic stainless steel conducts heat at around half the rate of mild steel, but has a much higher rate of thermal expansion when welded.

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 **(ASTM A 240 GRADE 304 WITH RESPECT TO ATTACHED CHEMICAL ANALYSIS BY OPTICAL EMISSION SPECTROMETER METHOD)** because of its low cost, easy availability in the market.

Mild Steel used as second plate to be welded with the stainless steel plate to perform TIG welding and fulfill the desired experimental work. We select mild steel for best result with the stainless steel joint by TIG welding because these kind of join nowadays most preferable in to the industrial purpose. We select **(IS 513 GRADE CR1 ANALYSIS BY OPTICAL EMISSION SPECTROMETER METHOD).**

III. METHODOLOGY:

Stainless steel and mild 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 (Grade 304) because of its low cost, easy availability in the market.
2. TIG welding process is chosen to carry out the experimental analysis on austenitic stainless steel with mild steel plates.
3. Procedure for carrying out the project

We have taken six samples plates (3 pieces of ASTM 240 Grade 304 and 3 pieces IS 531 Grade CR1 of authentic stainless steel and mild steel plates, the material specifications are as follows:

Table: 1. Specification of the specimen of welding process

Material	**Austenitic stainless steel (304) & Mild steel**
Thickness	**6 mm**
Length	**100 *100 mm**
No of pieces : 6	

Figure: 2. Specification of the specimen of welding process.

Table No: 2.Chemical composition for 304 & grade CR1

ELEMENT	ASTM A 240 GRADE 304	IS 513 GRADE CR1
Carbon	0.048	0.042
Sulphur	0.014	0.004
Phosphorous	0.030	0.020
Manganese	1.090	0.189
Silicon	0.406	-
Chromium	19.12	-
Nickel	8.01	-
Nitrogen	0.052	-

A. Procedure for carrying out the TIG process:

TIG: The main advantages of this process when used on stainless steels and mild steel 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.

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

Figure: 3. TIG welded Plates.

There are following steps we do for our experimental work.

1) **Selection of sample as per standard specification**
   - ✓ Chemical Analysis for evaluation of chemistry of each plates
2) **Preparation of specimen (MS and SS-304)**
   - ✓ Cutting sample
   - ✓ Surface cleaning
   - ✓ Applying Groove at different angle
   - ✓ Placing on welding clamping stand
3) **Perform TIG welding**
4) **Inspection of TIG welded plates**
   - ✓ Visual test
   - ✓ Tensile test
   - ✓ Bend Test
   - ✓ Hardness Test
   - ✓ Spectro Test
   - ✓ Dye penetrant Test

Selection of sample as per standard specification

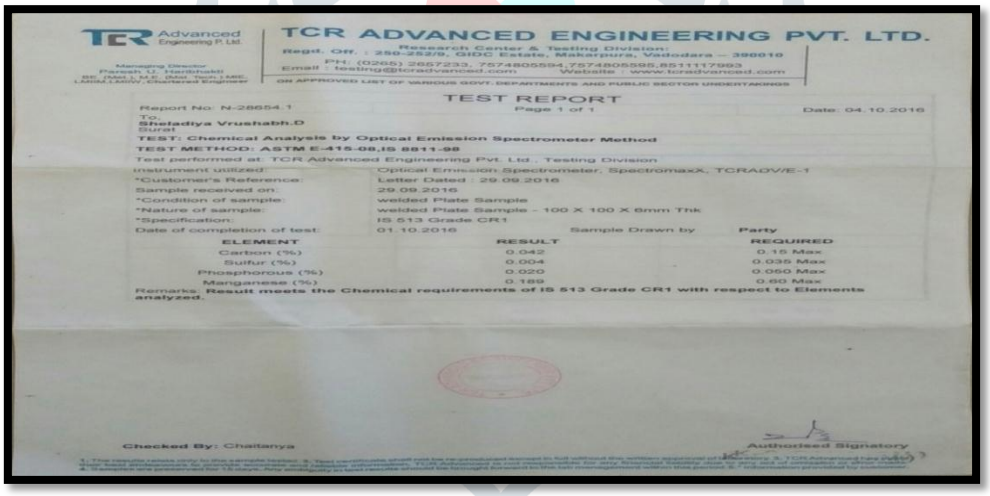
Selection of standard specimen is the best way to perform and to get the exact result. In this our experimental work we should introduce the different two type of specimen for example **ASTM 240 GRADE 304 and IS 513 GRADE CR1.** We used such grade of specimen to do TIG welding because nowadays such kind of welding is majorly preferred for industrial purpose. Also stainless steel welding is much easier than other metal weld by TIG welding.

We have collected plates of each metal from market but the problem is that how to idealize the exact chemistry to Perform our experimental investigation. For study the actual composition rest on metal we go for **OPTICAL EMISSION SPECTROMETER METHOD.** We get the result here by laboratory test and go further work.

Except chemical analysis here there are numbers of factor to choose standard specification to do better.

1) Chemical analysis
2) Size and Shape of component
3) Surface roughness
4) Cross section area Measurement

Here we get the result from laboratory:



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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Page 1 of 1

Report No: N-28654.1 Date: 04.10.2016

To,
Sheladiya Vrushabh.D
Surat

TEST: Chemical Analysis by Optical Emission Spectrometer Method

TEST METHOD: ASTM E-415-08,IS 8811-98

Test performed at: TCR Advanced Engineering Pvt. Ltd., Testing Division

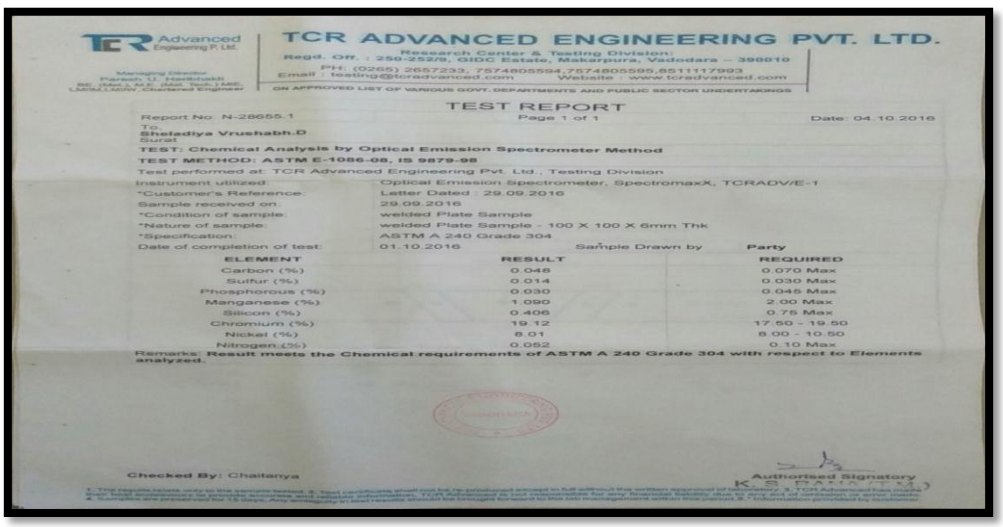
Instrument utilized:	Optical Emission Spectrometer, SpectromaxX, TCRADV/E-1
*Customer's Reference:	Letter Dated : 29.09.2016
Sample received on:	29.09.2016
*Condition of sample:	welded Plate Sample
*Nature of sample:	welded Plate Sample – 100 X 100 X 6mm Thk
*Specification:	IS 513 Grade CR1
Date of completion of test:	01.10.2016 Sample Drawn by : Party

ELEMENT	RESULT	REQUIRED
Carbon (%)	0.042	0.15 Max
Sulfur (%)	0.004	0.035 Max
Phosphorous (%)	0.020	0.050 Max
Manganese (%)	0.189	0.60 Max

Remarks: **Result meets the Chemical requirements of IS 513 Grade CR1 with respect to Elements analyzed.**

Checked By: Chaitanya Authorised Signatory

Figure: 4. Laboratory report of chemical analysis for M.S



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TEST REPORT

Page 1 of 1

Report No: N-28655.1 Date: 04.10.2016

To,
Sheladiya Vrushabh.D
Surat

TEST: Chemical Analysis by Optical Emission Spectrometer Method

TEST METHOD: ASTM E-1086-08, IS 9879-98

Test performed at: TCR Advanced Engineering Pvt. Ltd., Testing Division

Instrument utilized:	Optical Emission Spectrometer, SpectromaxX, TCRADV/E-1
*Customer's Reference:	Letter Dated : 29.09.2016
Sample received on:	29.09.2016
*Condition of sample:	welded Plate Sample
*Nature of sample:	welded Plate Sample – 100 X 100 X 6mm Thk
*Specification:	ASTM A 240 Grade 304
Date of completion of test:	01.10.2016 Sample Drawn by : Party

ELEMENT	RESULT	REQUIRED
Carbon (%)	0.048	0.070 Max
Sulfur (%)	0.014	0.030 Max
Phosphorous (%)	0.030	0.045 Max
Manganese (%)	1.090	2.00 Max
Silicon (%)	0.406	0.75 Max
Chromium (%)	19.12	17.50 - 19.50
Nickel (%)	8.01	8.00 - 10.50
Nitrogen (%)	0.052	0.10 Max

Remarks: **Result meets the Chemical requirements of ASTM A 240 Grade 304 with respect to Elements analyzed.**

Checked By: Chaitanya Authorised Signatory

Figure: 5. Laboratory report of chemical analysis for S.S

Preparation of specimen (MS and SS-304)

Specimen preparation is very important step. After getting the specimen chemistry and took the permission for further step we need to perform preparation on it before TIG welding. There are many way to perform preparation on standard specimen among all those we choose to cut it first.

Cutting Operation:

Here for the cutting of sample on given standard length, width and height. (100*100*6 mm). We took grinding machine to perform cutting action on plate. We remind care during the cutting operation because there were number of problems appear for example burning, uneven cutting, scratch, stress formation etc.

Groove Making:

Groove making is most important step to perform on weld base plates. The groove helps us to better joint and strength for thick plates. Moreover for the above 6 mm plates we always go for groove at different angle and depth.

Surface Cleaning:

After performing cutting and grooving on specimen we go for surface cleaning operation. Here we used fine emery paper to remove unwanted scale, uneven cut mills, surface roughness, sharp edges etc.

Perform TIG welding

TIG welding:

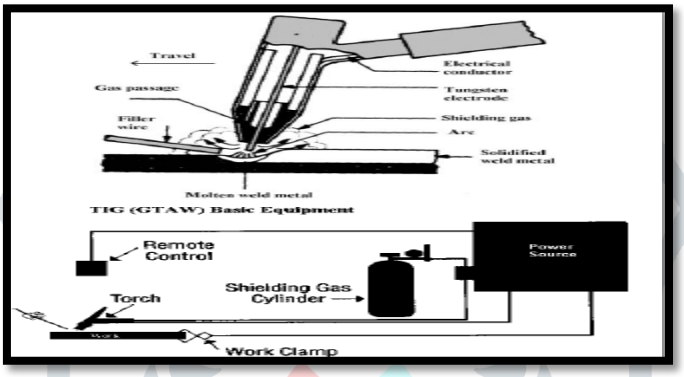


Figure: 6. TIG welding machine.

Experimental Steps to perform TIG welding:

After sample preparation step done, we go for TIG welding. In the TIG welding process we used tungsten electrode and filler metal (ER 309). In our experiment we perform TIG welding on different parameter like Groove, Gap between two plates, Gas pressure, current, position (2G and 3G), travel speed etc.

Here we study the actual what going on by the TIG welding experimentally at different condition.

Following steps performed for experimental route:

1) First we placed Stainless steel and mild steel plates together on clamp shown in Fig,

Figure: 7. Clamped Plates.

2) After complete placing the plates on clamp board, the sample cleaned by the wire brush to remove the unwanted impurities present on the surface and at the groove of the plates.
3) Before the start of final welding on plates. It is compulsory to idealize the welding position either 2G or 3G. Here in our performance we go for all position. In the 3G welding position we have to joint backside of plates over the welding side. There are 3 or 4 spot applied on the back side of plates to support welding plates. In 2G welding position such steps does not required to do.
4) Table shows the different parameter taken for experiment.

Table: 3. Standard parameters taken

PARAMETERS	SAMPLE -1	SAMPLE-2	SAMPLE-3
Groove	30 to 35^0	25^0	30^0
Gap	4 mm	2.5	3.5
Gas Pressure	10 to 15 lpm (liter/min)	5 lpm	12 lpm

Current	80 to 100	105 to 110	85 to 100
Voltage	115 to 120	10 to 11	8 to 10
Filler Metal	ER 309 grade thorium+ zirconium	ER 309 grade thorium+ zirconium	ER 309 grade thorium+ zirconium
Position	3G flat	2G flat	2G flat

5) In the TIG welding, we prepared 3 welded samples on the bases of different parameter as shown on above table. In first stage of welding tungsten rod inserted through the nozzle in to the gun and filler metal used during welding running. When we started supply on welding gun tungsten electrode first struck to the weld plate and maintains the current and gap between the electrode and base plates.

6) Further when heat is generated filler metal inserted in between electrode and base metal to melt filler metal to create joint. In 2G welding it is very simple to perform TIG by passing the flame toward the end. But in the 3G welding position samples placed in the vertical tilted position to make faster capillary action. More the capillary action more the chances to solve defects occur in the weldment.

7) In the final welding done we go for the different test and observe results. For this experiment we performed different test on weld plats like hardness test, bend test, Spectro test etc.

Inspection of TIG welded plate:-

Inspection of welded plates is must to complete our experimental work. By this step we learn what exact changes appear by the welding on Stainless and mild steel by TIG process. In the inspection method we used number of methods to get more sound study about the result.

First we make a contact to laboratory named TCR Advance Engineering PVT LTD for our test. We performed number of test like hardness to evaluate the hardness at different four point each specimen taken 2 point where hardness checked for example One at HAZ zone of S.S area and other one at MS area also we found hardness at base plate of MS and S.S. to know exact changes at different Four points.

We used to study bend property of weldment therefore we used to apply 2 types of bend test one is face bend other one is root bend test. Bend test gives idea about their property to resist and to rest their ability to retain max bending condition. Bend test check strength of weld. Weld ability is proven by this test here.

Furthermore, at last and least we go for tensile test. Tensile specimen prepared in standard shape and then apply tensile test. Here in result we attached fractured specimen.

IV. RESULT AND DISCUSSION.

RESULT OF TENSILE TEST:-

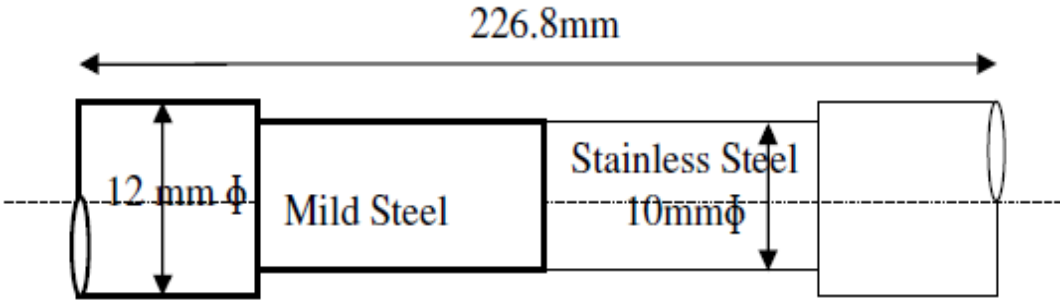


Figure: 8. Standard Tensile specimen

Table: 4. Test sample prepared by TIG

Test Sample	Material 1	Material 2
TS 1	304 S.S	MS CR1 Grade

Dilution in welded zone:

In the table percentage of dilution observed.

Table No:5. Dilution in TIG welding of SS and MS.

Test Sample	Welded length (mm)			Diameter(mm)	Percentage Dilution		
	Weld zone	In SS	In MS		of SS	of MS	in weld zone
TS 1	13	2.5	2.5	10	19.23	19.23	38.46

Tensile testing was carried out using Universal testing machine of 400 KN capacity and the geometry of the test specimen is as shown in above fig. -- . Mechanical properties of TIG welded dissimilar welds of S.S and MS after tensile test are tabulated below.

Table: 6. Result of tensile test specimen.

Test Sample	UTS(Mpa)	Avg. UTS(Mpa)	Yield Strength (Mpa)	Avg. Yield strength (Mpa0	% elongation	Avg.% elongation	Fracture Location
TS1	397	398.8	282	282.2	4.9	5.10	weld
	402		286		5.3		
	400		274		5.0		
	401		289		5.3		
	394		280		5.3		

Tensile test of the different specimen vary based on the different welding condition. Here we see that result is vary from 394 to 402. Also the elongations of different specimen were differing.

Figure: 9. Tensile tested Specimen

Figure: 10. Tensile tested Specimen

RESULT OF BEND TEST:

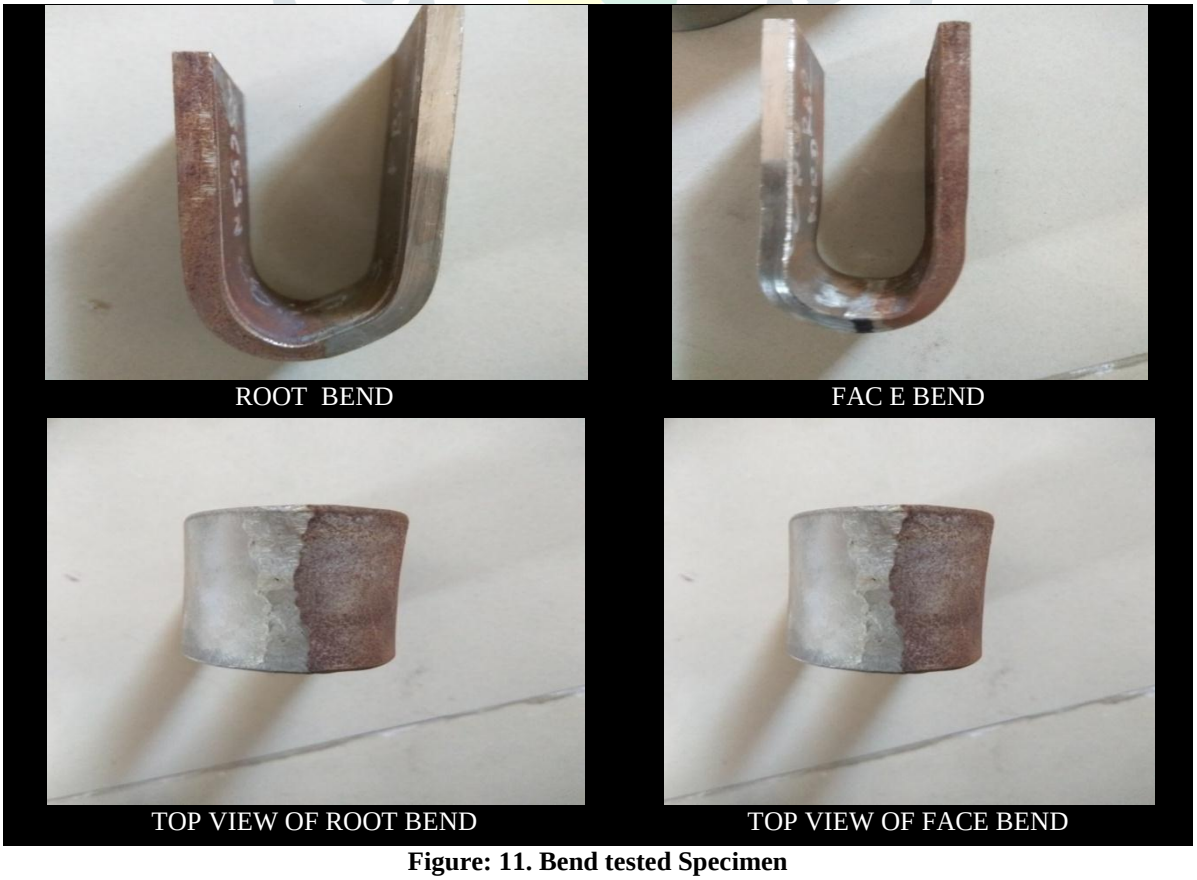
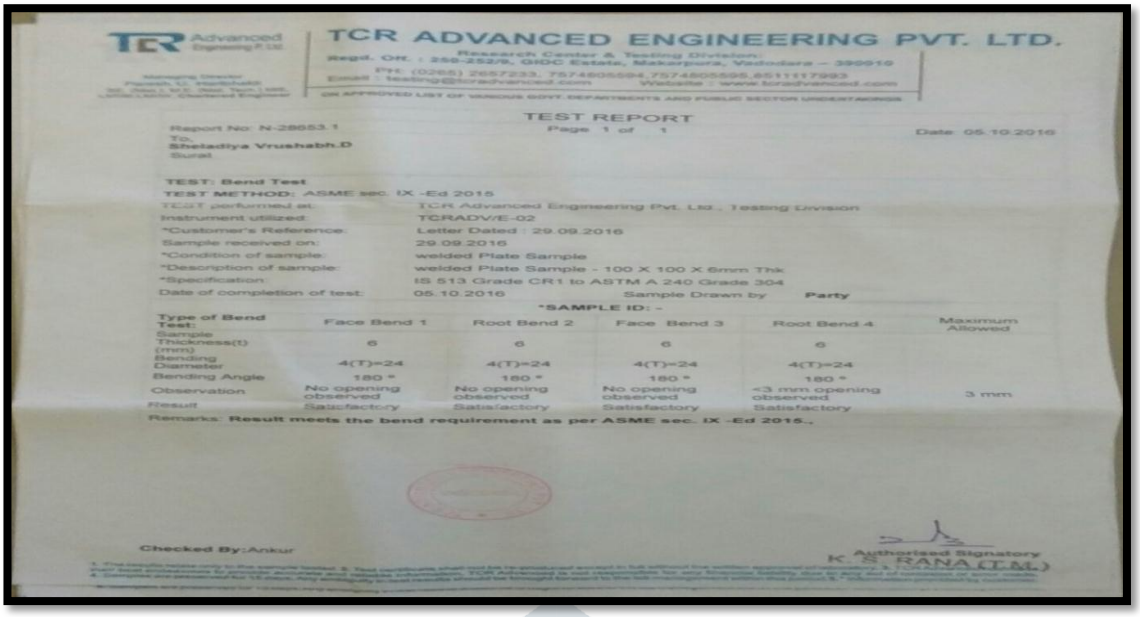


Figure: 11. Bend tested Specimen



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ON APPROVED LIST OF VARIOUS GOVT. DEPARTMENTS AND PUBLIC SECTOR UNDERTAKINGS

TEST REPORT

Page 1 of 1

Report No: N-28853.1 Date: 05.10.2016

To,
Sheladiya Vrushabh.D
Surat

TEST: Bend Test
TEST METHOD: ASME sec. IX -Ed 2015
Test performed at: TCR Advanced Engineering Pvt. Ltd., Testing Division
Instrument utilized: TCRADV/E-02
*Customer's Reference: Letter Dated : 29.09.2016
Sample received on: 29.09.2016
*Condition of sample: welded Plate Sample
*Description of sample: welded Plate Sample - 100 X 100 X 6mm Thk
*Specification: IS 513 Grade CR1 to ASTM A 240 Grade 304
Date of completion of test: 05.10.2016 Sample Drawn by Party

*SAMPLE ID: -

Type of Bend Test:	Face Bend 1	Root Bend 2	Face Bend 3	Root Bend 4	Maximum Allowed
Sample Thickness(t) (mm)	6	6	6	6	
Bending Diameter	4(T)=24	4(T)=24	4(T)=24	4(T)=24	
Bending Angle	180 °	180 °	180 °	180 °	
Observation	No opening observed	No opening observed	No opening observed	<3 mm opening observed	3 mm
Result	Satisfactory	Satisfactory	Satisfactory	Satisfactory	

Remarks: Result meets the bend requirement as per ASME sec. IX -Ed 2015..

Checked By:Ankur

Authorised Signatory
K. S. RANA (T.M.)

Figure: 12. Laboratory result of Bend test on welded plates.

In our experiment we performed bend test on welded stainless steel and mild steel plates. Here we performed bend test with some standard parameters like thickness of plate, angle of bend, bending diameter etc. In the final we have seen the result of bend test.

Bend test of welded S.S and MS plate is successive in our experiment. Seen the above result their nothing damaged due to bend test on specimen. So it is observed that metal to be welded by TIG welding on S.S and MS together is able to resist bending up to 180^0.

There is nothing observed problematic by bend test like crack on HAZ, more elongation at certain metal, etc. we performed two bend test technique like root bend and face bend. In root test we applied load at the side of beside to weld joint and vice versa.

RESULT OF HARDNESS TEST:

After successive welding on related base metals we go for hardness test to idealize the hardness of plate and weld metal at different places. By the hardness test we can understand the effect of welding on hardness of base metal as well as at the weld zone. For this we have choose vicker cum Brinnel hardness test.

For this we performed harness indentation at different point, first point at S.S plate, second at HAZ of S.S, third at HAZ of MS and last point at MS base plate. We can see the different hardness observed at different points. We used 10 Kg load at every places.

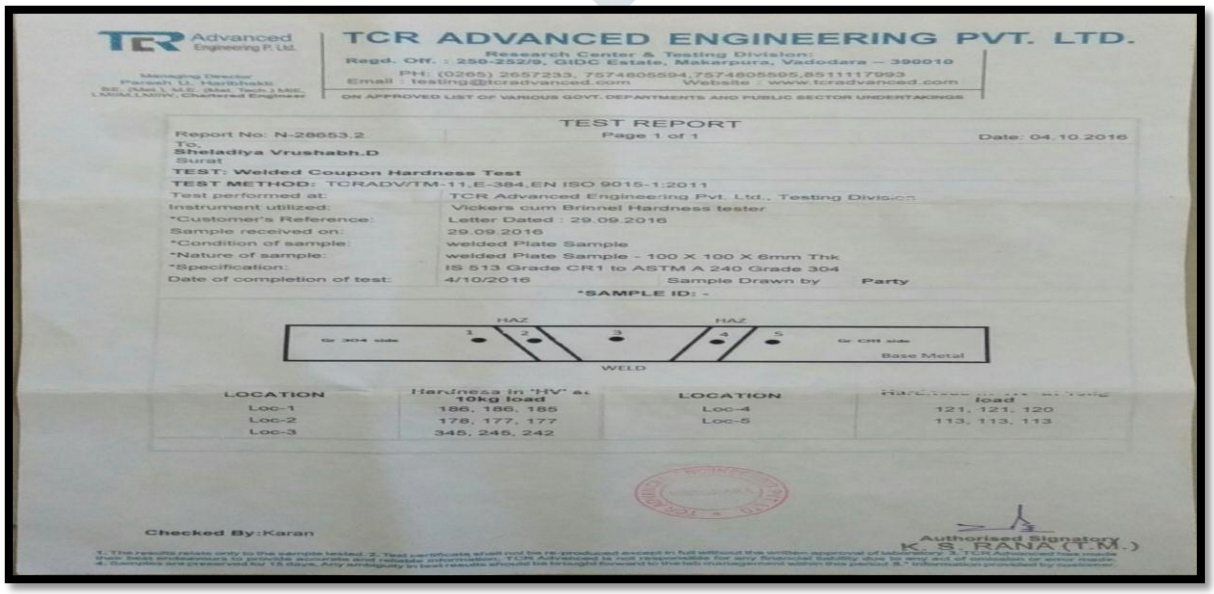
At location 1- Vicker hardness test result at place one on S.S base plate is 186, 186, 185. We performed 3 indentations at on metal plate to get accurate result.

At location 2- Point two, shown the indentation result in the range between 177 to 178. This point is HAZ of S.S. Here we have seen that the hardness of S.S is greater than MS HAZ. So, we can idealize that the grain coarsening of MS is less S.S.

At location 3- At this point we penetrate diamond indenter in to the filler metal i.e. at the point where filler metal bond the S.S plate with MS plate. Here hardness reach is 345, 245 and 242. It means the hardness value is more than all other points' hardness.

At location 4- HAZ hardness of MS side. Hardness arrive 121,121 and 120. In this zone grain coarsening happen at welding temperature also the zone is larger than S.S HAZ area. Because of high size grain hardness value will be low. As the same we taken hardness value at base plate of MS to check it hardness level and result said the value of hardness is lower than HAZ value of MS side. So we can idealize that the effect of welding heat on metal hardness.

We used IS 513 grade CR1 to ASTM 240 grade 304 plates for hardness with V grooved welded plates.



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TEST REPORT

Page 1 of 1

Report No: N-28853.2 Date: 04.10.2016

To,
Sheladiya Vrushabh.D
Surat

TEST: Welded Coupon Hardness Test
TEST METHOD: TCRADV/TM-11,E-384,EN ISO 9015-1:2011
Test performed at: TCR Advanced Engineering Pvt. Ltd., Testing Division
Instrument utilized: Vickers cum Brinnel Hardness tester
*Customer's Reference: Letter Dated : 29.09.2016
Sample received on: 29.09.2016
*Condition of sample: welded Plate Sample
*Nature of sample: welded Plate Sample - 100 X 100 X 6mm Thk
*Specification: IS 513 Grade CR1 to ASTM A 240 Grade 304
Date of completion of test: 4/10/2016 Sample Drawn by Party

*SAMPLE ID: -

LOCATION	Hardness in 'HV' at 10kg load	LOCATION	Hardness in 'HV' at 10kg load
Loc-1	186, 186, 185	Loc-4	121, 121, 120
Loc-2	178, 177, 177	Loc-5	113, 113, 113
Loc-3	345, 245, 242		

Checked By:Karan

Authorised Signatory
K.S. RANA (T.M.)

Figure: 13. Laboratory report of hardness test on welded plates

CONCLUTION:

During the study, mild steel and grade of stainless steel were joined using TIG welding. The tensile strength, dilution of welded joints, hardness and bend test were investigated. The

Selection of different grades of stainless steel used for welding play an important role in deciding the properties of the weld. From the study, following conclusions can be drawn –

- Tungsten Inert gas welding process is best for S.S and MS plate joint. In the welding we can seen there is nothing defect found due to welding like porosity, cracks, etc. Also bend test proven best result for this work. Result was satisfied and clears an idea about welding under bend load.
- During TIG welding the loss of Cr from S.S is very low so it resist from corrosion action in field. Furthermore, welding done under inert atmosphere to protect weld from hydrogen and other environmental threats.
- The strength of dissimilar metal welded by TIG welding is excellent as per report.
- Hardness value at the point of filler metal is maximum that is only the result to make experiment successive. Including all the test reports we get best result with TIG welding on related metals plates.

REFERENCES:

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