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"Analysis of Dissimilar Metal Welding of Mild Steel and Stainless Steel"

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Abstract- *Joining of dissimilar metals is using extensively in power generation, petrochemical, nuclear reactors and chemical industries mainly to get custom built properties in a component and weight reduction. However efficient welding of dissimilar metals has faced a major challenge due to difference in chemical and mechanical properties of the materials to be joined under a common welding condition. A variety of problems come up in dissimilar welding like cracking, large weld residual stresses, Voids & Porosity, oxides formation, compressive and tensile stresses, stress corrosion cracking, etc. In the Present study, Stainless Steel grade 304 was welded with Mild Steel grade 1020 by Tungsten Inert Gas (TIG) welding process by taking different stainless steels as the filler metals i.e. ER SS308L, ER SS309L and ER SS316L. The macrostructure of joints were analyzed and tensile strength of dissimilar metal joints was investigated. The results were compared for different joints made by different filler metals and it was observed that TIG welded dissimilar metal with filler metal used ER SS309L have better physical properties than others.*

Keywords-: *AISI, ASME Section IX standard, CTE, DMW, HAZ, MIG.*

I.INTRODUCTION

Dissimilar metal joints are used in various engineering applications such as nuclear power plant, automobile manufacturing and coal fired boilers. As joining of dissimilar metals are typically involving high temperature and pressure welding is favored instead of other joining methods. Welding makes a strong joint but also initiate long term reliability issues in these types of joints. The significant difference in material properties such as modulus of elasticity, CTE i.e. Coefficient of Thermal Expansion, Poisson's ratio combined with the configuration of the joint leads high stresses over the joining interface. Joining of dissimilar metal is a task of formulating different properties of metal together to make the reliable joint [1].

The stainless steel is one of the famous materials for structural applications, due to their exceptional physical properties but rise the structural cost. The extra benefits and the design codes of stainless steels have focused their industrial use for conventional structural engineering applications such as nuclear reactors, civil construction, vessels, thermal power plants, and heat exchangers for several industrial applications. The better joint efficiency, efficient metal joining process, welding reliability simple process and low fabrication cost are essential for production of many engineering and structural components. The metallurgical changes such as precipitation of secondary phases, micro-segregation, solidification cracking, presence of porosities, grain growth in the HAZ and loss of materials by vaporization are the main problems which makes poor mechanical properties in stainless steel welds.

Therefore, for structural applications, the stainless steels are utilized effectively by dissimilar steel welds between stainless steel and carbon steel with economical and effective utilization of the special properties of every steel dependent in the same structure. The Inter granular Chromium rich carbides and coarse grains along the grain boundaries in the heat affected zone, is seen during conventional arc welding which decline the mechanical properties of the joints. The joining of stainless steels with plain carbon steels is common applications in nuclear power plants, stainless steel piping is often exposed to high pressure and temperature steam and carry on passes temperature and pressure may below a certain level, the low-alloy and low-carbon steels pipe line perform adequately and reduce the total cost of the structure. The different coefficients of thermal expansion and the dilution of the weld metal with the two base metals are two major criterions for dissimilar welding of stainless and low carbon steels [2].

Tungsten Inert Gas (TIG) Welding: An arc is truck between a tungsten electrode (non-consumable) and the metal is to be welded. A filler material is optional. An inert gas shields the arc from the ambient to avoid oxidation. Carbon steels, stainless steels, low alloy steels, zinc based copper alloys can be welded using this process. TIG is more suitable for welding dissimilar materials. The TIG process is a slower process compared to the MIG process, but the quality of weld is cosmetically better. There is no weld spatter, and the quality of welds is higher than MIG welding. It reduces the rejection and rework, so production cost is less compared to MIG welding [3].

II. LITERATURE SURVEY

Gyun Na et al. [4] studied the residual stress and its prediction for dissimilar welds at nuclear plants using Fuzzy Neural network models. The factors that have an impact upon fatigue strength are stress concentration, residual stress, the mechanical properties of the material, and its micro and macro structure.

Zenitani et al. reported that the residual stresses have notable effect on the young's modulus of the weld joints. The moduli of elasticity values were observed to be lower on the welds due to the formation of residual stresses and the thermal distortion during welding.

Chung et al. [5] studied microstructure and stress corrosion cracking behavior of the weld metal in dissimilar welds and susceptibility to stress corrosion cracking in terms of ductility loss is dependent in increasing order of severity is; undiluted weld metal, the transition zone and the weld interface. This means that susceptibility to stress corrosion cracking is more related to the case of brittle fractures.

Khan et al. [6] studied laser beam welding of dissimilar stainless steels in a fillet joint configuration and during the study metallurgical analysis of the weld interface was done. Fusion zone microstructures contained a variety of complex austenite ferrite structures. Local micro-hardness of fusion zone was more than that of both base metals.

Jiang and Guan et al. studied the residual stress and thermal stress in dissimilar steels. They told that the large residual stresses are incited by welding in the weld metal and heat affected zone (HAZ), which overlap and increase the thermal stress.

D. K. Ramkumar et al. [7] compared & studied the mechanical properties of the dissimilar combinations of AISI 304 and Inconel 625 obtained from PCGTAW and CCGTAW techniques using ERNi- CrMo-3 filler. The studies showed that the PCGTA welding resulted in the minimum segregation effects at the weld zone and the decreasing of precipitation of chromium carbides at HAZ.

Lundin did his research on dissimilar welds with its emphasis on carbon migration, stress/strain state of welds and transition joint failure mechanism. The study stated that the most of failures have been native with austenitic stainless steel filler metal joints, and it is considered that the failure mode exhibited by the nickel-based filler metals is composition wise different than that with the austenitic stainless fillers.

III. PROBLEM DEFINATION

In India also in the world there are number of process industries. In which number of different joints weld, by using different welding type, different welding parameters, and different welding geometries on different materials or same materials. After some life time there will be failure of weld joints. There are number of reasons for failure.

In contrast to similar material welding, the difference of the base metal and weld must be carefully analyzed. By doing study it is found that the most important consideration is the weld metal composition and its properties.

Currently for Dissimilar Metal joining of Mild Steel (1020) and Stainless Steel (304) most commonly using filler material is ER SS308L in pump industries. So selecting the best filler material from various options available & analyzing there effects on welding strength & other parameters.

IV. OBJECTIVE

The main objectives are listed below:

1) Joining of Dissimilar Metals i.e. Stainless steel & Mild steel by Tungsten Inert Gas (TIG) Welding using different filler wires.

2) Analysis of Weld joint by performing Physical testing i.e. tensile test, Bend test & measure Ultimate tensile strength.

3) Analysis of Weld joint by performing Macro testing for checking Void & Porosity, Cracks, Dendrites, Oxides, Gas holes etc.

V. METHODOLOGY

5.1 Material

The Materials used for experiment will be of Plate Size: 300 x 150 x 5 mm Thk. each made of Stainless Steel 304 grade & Mild steel 1020 grade. The chemical compositions of the mild steel and stainless steels are shown in Table 1. Further, debarring will done with emery paper and the surfaces to be welded were cleaned with acetone prior to welding. TIG welding process will be used for welding Stainless steel (304) with mild steel (1020). The welding joint is designed single 'v' groove with included angle 75°. The ER 308L, ER 309L & ER 316L rod of 2.4 mm diameter filler material will be used for all welding process & its chemical compositions are shown in Table 1.

Table 1. Chemical Composition of Base material & filler material

Alloy %	Cr	Ni	C	Mn	S	P	Si	Mo	N
Stainless Steel (SS) Grade 304	18.210	8.060	0.080	2.000	0.030	0.045	0.750	-	0.100
Mild Steel (MS) Grade 1020	0.069	0.010	0.180	0.800	0.040	0.040	0.400	-	-
Filler Material 1 ER SS309L	24.120	13.440	0.032	1.260	0.012	0.028	0.650	-	-
Filler Material 2 ER SS316L	16.000	10.000	0.030	2.000	0.030	0.045	1.000	3.000	-
Filler Material 3 ER SS308L	19.000	10.000	0.030	2.000	0.030	0.045	1.000	-	-

5.2 Specimen Preparation

5.2.1 Specimen for Macro Testing

Macro Test specimen is the fillet welded sample made of two plates i.e. SS304 of size 60mmX60mm and MS1020 of Size 60mmX65mm. The plates are welded in T shape & welding done from one side only as shown in figure no. 1 as per QW 184. Then section A-A, B-B & C-C cut from the T welded specimen by milling followed by process deburring, lapping, polishing, etching & cleaning [8].

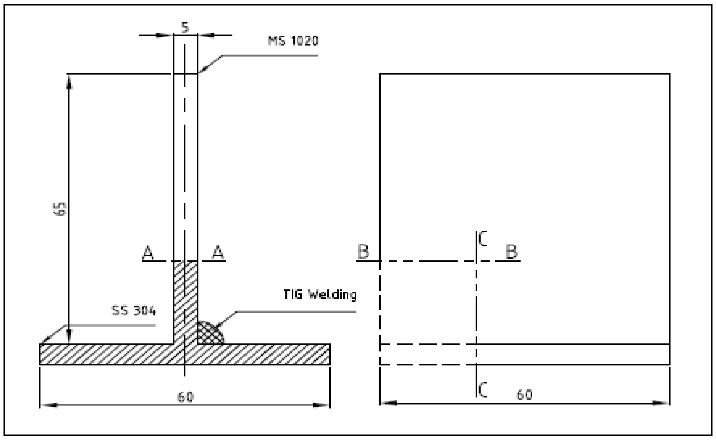


Figure No. 1 Macro Test Specimen as per QW 184

5.2.2 Specimen Preparation for Tensile Testing

Tension test specimens shall conform to the type illustrated in Figures QW-462.1(a) may be used for tension tests on all thicknesses of plate. For thicknesses up to and including 1 in. (25 mm), a full thickness specimen shall be used for each required tension test. Tensile test specimens are T1 & T2 as per Cutting plan. The specimens for the reduced –section tension test of production welds shall be taken perpendicularly across the weld at the end of the plate. The test specimens shall be straightened and tested at room temperature Reduced-section tension test specimens shall be prepared in accordance with Figure 2 [8]

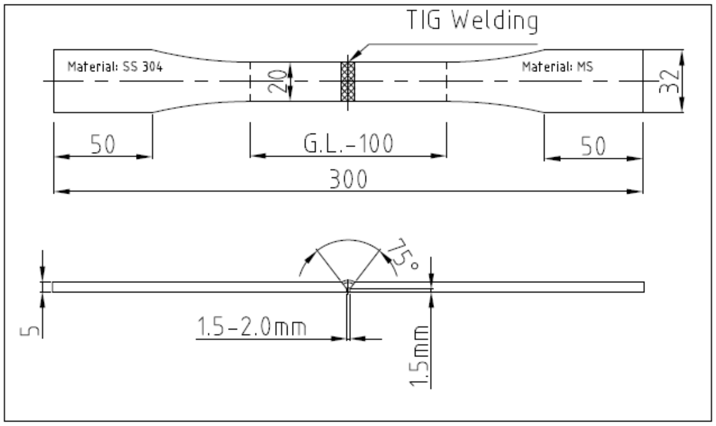


Figure No. 2 Tensile Test Specimen as per QW 462.1 (a)

5.2.3 Specimen Preparation for Bend Test

Bend test specimens (two face bend and two root bend or four side-bends as designed by the welding procedure according to thickness) shall be prepared in accordance with Figure 3. Guided bend test specimens shall be prepared by cutting the test plate to form specimens of approximately rectangular cross section as per ASME Sec. IX standards QW 466.1, QW 466.2 and QW 466.3. The cut surfaces shall be designated the sides of the specimen. The other two surfaces shall be called the face and root surfaces, the face surface having the greater width of weld. Guided bend specimens are of five types, depending on whether the axis of the weld is transverse or parallel to the longitudinal axis of the specimen, and which surface (side, face, or root) is on the convex (outer) side of bent specimen. The bend test shall be acceptable if no cracks or other defects by 180 deg. Bending [8].

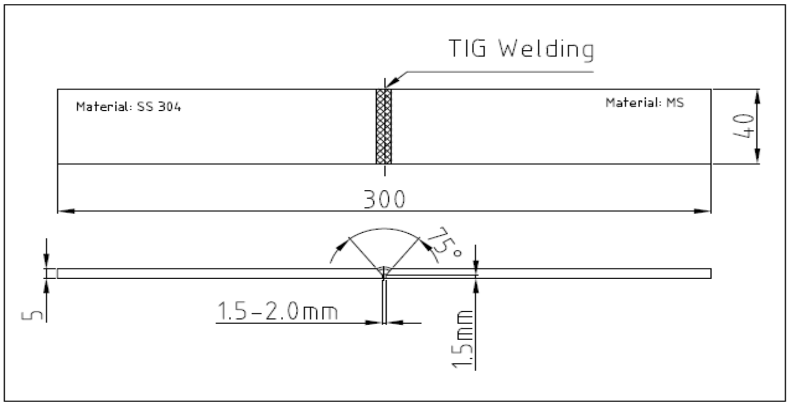


Figure No. 3 Guided Bend Test Specimen as per QW 466

5.3 Test Samples & Process Parameters

Specimen of different grade filler wire for joining of stainless steel and mild steel are tabulated in Table 2

Table 2. Test Samples Prepared by TIG Welding

Test Sample	Material 1	Material 2	Filler Material
A1	SS 304	MS 1020	Rod, SS ER309L
A2	SS 304	MS 1020	Rod, SS ER 316L
A3	SS 304	MS1020	Rod, SS ER 308L

The process parameters selected for TIG process are shown in the Table 3.

Table 3. Parameters used during TIG welding

Sr. no.	Parameters	Specs.	TIG
1	Shielding gas	Type	Ar
		Flow rate	12.5 lpm
2	Current	Type	DC
		Polarity	Electrode positive
		Current Range	100-150 Amp
		Voltage Range	10-14 V
3	Pass	Type	Multiple
4	Electrodes	Number	Single
		Size	1.2
		Type	98 tungsten, 2% thoriated
5	Filler Rod	Type & material	Rod, SS ER308L Rod, SS ER 309L Rod, SS ER 316L

5.4 Tests and Examinations:

Test examination shall be as per ASME section IX, QW 302. We shall prepare a specimen taking plan which contains type, number and location of test specimen as per ASME section IX, QW 463.1(a) of Cutting Plan of welded specimen of MS & SS304.

The nondestructive examinations as required by the Code or contract shall be performed in accordance with the procedure for non-destructive examinations i.e. ASME section IX, QW 183 & QW 184. All nondestructive examinations shall be performed by property trained and qualified personnel.

Physical (Destructive) testing, which shall be carried out to qualify the procedure and performance of welding, shall comprise of tensile tests as per ASME section IX, QW 150 and guided bend tests as per ASME section IX, QW160 [8].

VI. RESULT & DISCUSSION

6.1 Metallography Test

6.1.1 Metallography Macro

Macro test or macro examination is performed on the cross section, longitudinal section or 'Z' direction (through thickness) as an independent test to evaluate subsurface conditions or as an subsequent step of another test to reveal the effects on the subsurface.

We are taking checking T Weld plate section of SS304 & MS of all Specimens A1, A2 & A3 on machine range 10X to 50X at 30X. Macro test was conducted in “Shanmukha Laboratories”; the results are in the following form,

Table 4. Results of Metallography Macro Test

Sr. no.	Description	Results for A1	Results for A2	Results for A3
1	Machine Code	LAMS-01	LAMS-01	LAMS-01
2	Etching agent	MACRO ETCH (30X) Macro General	MACRO ETCH (30X) Macro General	MACRO ETCH (30X) Macro General
3	Voids & porosity	Normal	Normal	Normal
4	Cracks	Nil	Nil	Nil
5	Dendrites	Fine Macro weld	Fine Macro weld	Fine Macro weld
6	Oxides	Nil	Nil	Nil
7	Fusion	Uniform	Uniform	Uniform
8	Gas Holes	Nil	Nil	Nil
9	U/Cut	Nil	Nil	Nil
10	Slag Particles	Nil	Nil	Nil
11	Leg 1	6.45 mm	5.70 mm	7.50 mm
	Leg 2	7.40 mm	6.35 mm	7.80 mm
12	Throat	5.80 mm	3.85 mm	5.20 mm
	Concavity	Minor	Minor	Minor
13	Gap	0.18	0.42	0.18
	Angle	A1: 121°, B1: 128°	A1: 119°, B1: 117°	A1: 116°, B1: 124°
14	Penetration	P1: 1.65 mm, P2: 1.80 mm	P1: 0.58 mm, P2: 0.82 mm	P1: 0.87 mm, P2: 0.92 mm

6.2 Bend Test

Bend Test was conducted to find out whether weld joint get Cracks or Satisfy No Cracks requirement of welding in bending. The results are in the following form,

Bend test was conducted in "Shanmukha Laboratories"; the results are in the following form,

6.2.1 Bend Test Results

Table 5. Bend Test results for all specimens

Sample No.	Number given to Specimen (for identification)		Bend test	Jig Dia.	Position	Cracks	Remark
1	A1	FB1	Face Bend	20 mm	180°	No Cracks	Satisfactory
		RB1	Root Bend	20 mm	180°	No Cracks	Satisfactory
		FB2	Face Bend	20 mm	180°	No Cracks	Satisfactory
		RB2	Root Bend	20 mm	180°	No Cracks	Satisfactory
2	A2	FB1	Face Bend	20 mm	180°	No Cracks	Satisfactory
		RB1	Root Bend	20 mm	180°	No Cracks	Satisfactory
		FB2	Face Bend	20 mm	180°	No Cracks	Satisfactory
		RB2	Root Bend	20 mm	180°	No Cracks	Satisfactory
3	A3	FB1	Face Bend	20 mm	180°	No Cracks	Satisfactory
		RB1	Root Bend	20 mm	180°	No Cracks	Satisfactory
		FB2	Face Bend	20 mm	180°	No Cracks	Satisfactory
		RB2	Root Bend	20 mm	180°	No Cracks	Satisfactory

Remark: Satisfactory

6.3 Tensile Test

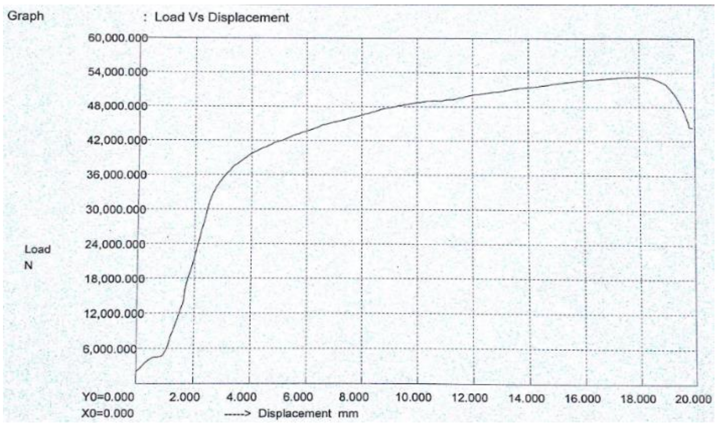
Tensile testing was carried out using Universal Testing Machine and the geometry of the test specimen is as shown in Fig. 1. Mechanical proprieties of TIG welded dissimilar welds of stainless steel and mild steel after tensile test is be tabulated in Table 4; From experimental data, for load Vs displacement graph, it shows that, at initial stage 2000N load applied on specimen that time no displacement found in the specimen As specimen material is mild steel & Stainless steel the relation between load and displacement is proportional up to maximum loads. But after that due to ductile property of material there were no any large changes in displacement and it fails.,

6.3.1 Tensile Test Results:

Tensile test was conducted in in "Shanmukha Laboratories"; the results are in the following form,

1. Tensile Test of Sample No-A1 for T1

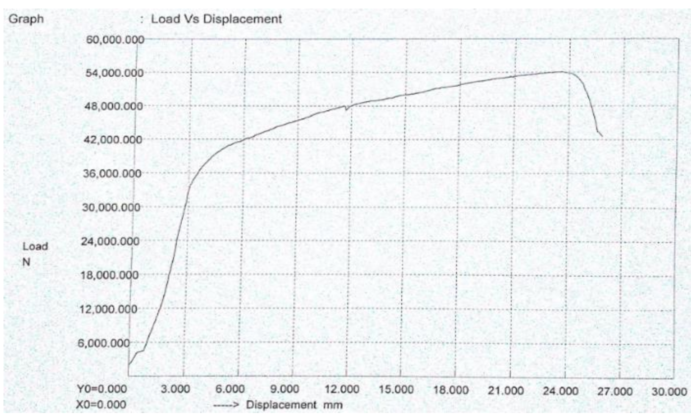
Tensile Test Specimen at T1		
Maximum Force	Tensile Strength	Failure Point
53250 N	549.005 mpa	Weld (at 44500 N)



Graph 1: Load Vs Displacement for sample No. A1 for T1

2. Tensile Test of Sample No-A1 for T2

Tensile Test Specimen at T2		
Maximum Force	Tensile Strength	Failure Point
54060 N	560.468 mpa	Weld (at 43000 N)

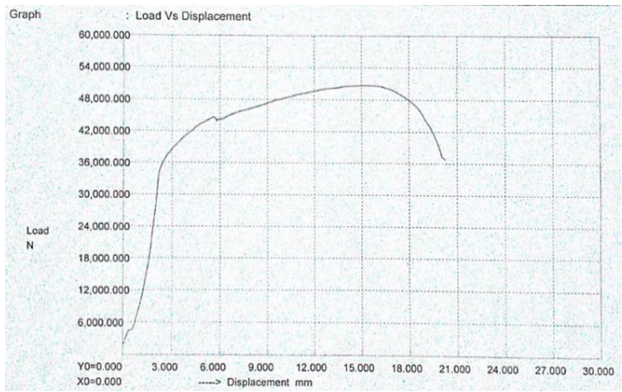


Graph 2: Load Vs Displacement for sample No. A1 for T2

3. Tensile Test of Sample No-A2 for T1

Tensile Test Specimen at T1		
Maximum Force	Tensile Strength	Failure Point

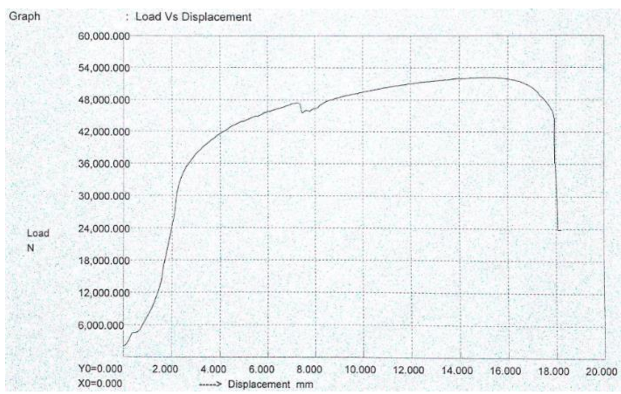
50730 N	527.29 mpa	Weld (at 37000 N)



Graph 3: Load Vs Displacement for sample No. A2 for T1

4. Tensile Test of Sample No-A2 for T2

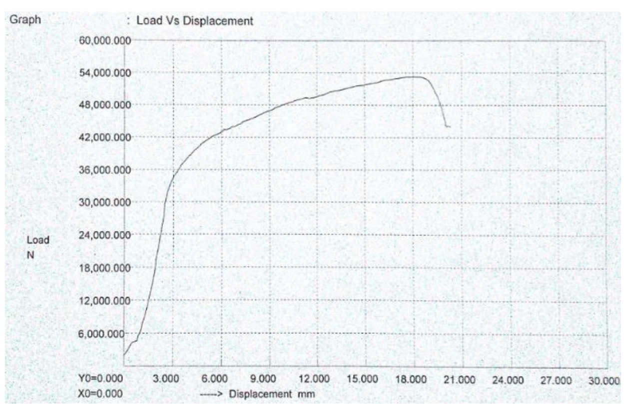
Tensile Test Specimen at T2		
Maximum Force	Tensile Strength	Failure Point
52170 N	539.995 mpa	Weld (at 24000 N)



Graph 4: Load Vs Displacement for sample No. A2 for T2

5. Tensile Test of Sample No-A3 for T1

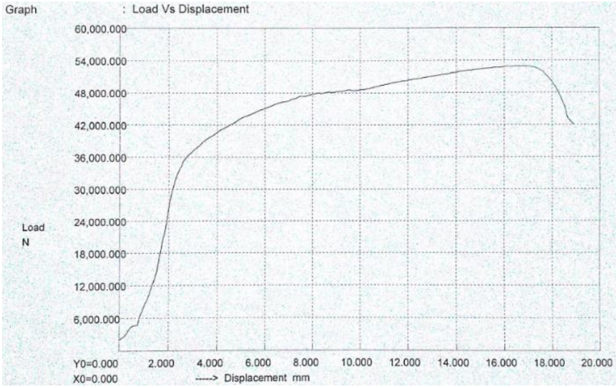
Tensile Test Specimen at T1		
Maximum Force	Tensile Strength	Failure Point
53340 N	550.723 mpa	Weld (at 44000 N)



Graph 5: Load Vs Displacement for sample No. A3 for T1

6. Tensile Test of Sample No-A3 for T2

Tensile Test Specimen at T2		
Maximum Force	Tensile Strength	Failure Point
52980 N	549.512 mpa	Weld (at 42000 N)

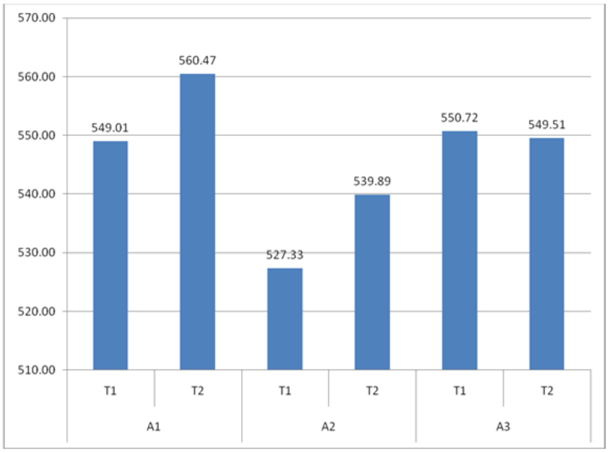


Graph 6: Load Vs Displacement for sample No. A3 for T2

6.3.2 Comparison of results after tensile test

Table 6. Comparison of results after tensile test for true area for all specimens

Specimen from plate	C/S Area of Specimen at breaking place (mm^2)	Maximum Tensile Force (KN)	Ultimate Tensile Strength (mpa)	Break at
A1T1	96.9936	53.55	549.01	Weld
A1T2	96.4551	54.06	560.47	Weld
A2T1	96.1653	50.73	527.53	Weld
A2T2	96.612	52.16	539.89	Weld
A3T1	96.8545	53.34	550.72	Weld
A3T2	96.4128	52.98	549.51	Weld



Graph 7: Comparison of results after tensile test

Remark: Satisfactory

VII. CONCLUSION

From the results of this present investigation and the discussion presented in the earlier chapters, the following conclusions are drawn.

1. TIG Welding is suitable for Joining Stainless Steel grade 304 & Mild Steel grade 1020 using various filler metals available i.e. ER SS308L, ER SS309L & ER SS316L.
2. The ultimate tensile strength has observed more by 6.28% for welded specimens of filler rod SS309L as compared to of filler rod SS316L.
3. It is observed that, by changing of filler rod i.e. ER SS308L, ER SS309L & ER SS316L there were no effect on weld strength in bending.
4. It is observed that, for macro test results for penetration of weld metal ER SS309L in base metals is 2-3 times more than that of other filler metals ER SS308L and ER SS316L.
5. Welding Process recommended for joining of dissimilar material i.e. Stainless Steel grade 304 & Mild Steel grade 1020 is TIG welding & filler material recommended is SS309L.

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REFERENCES

[1] Rakesh Chaudhari, Riddhish Parekh et al (2014), Reliability of Dissimilar Metal Joints using Fusion Welding, Paper presented at the International Conference on Machine Learning , Dubai, United Arab Emirates, 8-9 January 2014.
[2] Radha Raman Mishra et al (2014), A Study of Tensile Strength of MIG & TIG welded dissimilar joints of MS & SS, International Journal of Advances in Materials Science and Engineering Vol. 3, No.2:23-32.
[3] N. Arunkumar, P. Duraisamy et al (2012), Evaluation Of Mechanical Properties Of Dissimilar Metal Tube Welded Joints Using Inert Gas Welding, International Journal of Engineering Research and Applications Vol. 2, Issue 5:1709-1717.
[4] Man Gyun Na, Jin Weon Kim et al (2007), Prediction of Residual Stress for dissimilar metals welding at nuclear plants using Fuzzy Neural Network Models, Nuclear Engineering and Technology, Vol. 39:337-348.
[5]Wei-Chih Chung, Jiunn-Yuan Huang et al (2011), Microstructure and Stress Corrosion Cracking Behavior of the Weld Metal in Alloy 52-A508 Dissimilar Welds, Journal of Materials Transactions Vol. 52:12-19.
[6] M.M.A. Khan, L. Romoli et al (2012), Laser beam welding of dissimilar stainless steels in a fillet joint configuration, Journal of Materials Processing Technology Vol. 212:856-867.
[7] Devendranath K. Ramkumar et al (2014), Characterization of microstructure and mechanical properties of Inconel 625 and AISI 304 dissimilar weldments, ISIJ Int. 54(4):900–908.
[8] ASME Boiler and Pressure vessel code (2015), Section IX Qualification standard for welding, brazing & fusing procedures, United States of America.