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A STUDY ON THE INFLUENCE OF WELDING PARAMETERS IN GAS TUNGSTEN ARC WELDING OF AA 5083 USING ANOVA

ARUN NARAYANAN[1], CIJO MATHEW[2], JOBY JOSEPH[3] & SABU KURIAN[4]

[1]P. G. Scholar, M.A. College of Engineering, Kothamangalam, Ernakulam, Kerala, India

[2,3,4]Assistant Professor, M.A. College of Engineering, Kothamangalam, Ernakulam, Kerala, India

ABSTRACT

The present work deals with the study on the influence of Welding Parameters such as Welding current and Shielding gas flow rate in Gas Tungsten Arc welding of Al 5083 alloy. The working ranges of welding parameters are obtained by conducting large number of trials and from literature review. The present work consists of two factors and two levels, so a two level full factorial experimental design is selected with two replications for each experiment. The experiment is conducted according to the order of experimental matrix obtained from the Design of Experiment (DOE). After conducting the experiment the welded specimens are subjected to various testing's such as Tensile test, Microhardness test, Microstructure study, Macrostructure study and Fractrography (SEM). The test results are analysed using MINITAB software and ANOVA is performed to find out the effect of Welding current and Shielding gas flow rate on Ultimate tensile strength, Percentage elongation and Microhardness.

KEYWORDS: TIG Welding, Aluminium 5083 Alloy, Welding Current, Shielding Gas Flow Rate, Design of Experiment, ANOVA

INTRODUCTION

TIG welding is commonly used for welding aluminium and aluminium alloys. In this study aluminium alloy 5083 is selected as the base material, it comes under aluminium 5000 series. Magnesium is one of the most effective and widely used alloying elements for aluminium. Alloys in this series possess good welding characteristics and good resistance to corrosion in marine atmospheres.

Aluminium alloy 5xxx series are actually Al-Mg alloys; they are the highest strength non-heat treatable alloy in commercial use. Al-Mg alloys are extensively used in defence and aerospace applications. Tungsten inert gas welding is arc welding processes that produce coalescence of materials by heating them with an arc between a non-consumable electrode and the base metal. TIG welding process is generally used for welding of Al-Mg alloys. During welding, vaporization of alloying elements like magnesium can occur and this vaporization loss of any alloying elements can influence the mechanical properties of the welded joints by affecting the chemistry of the weld pool.

The shielding gas is used to protect the finished weld from the effects of oxygen and nitrogen in the atmosphere. Although the weld metal properties are primarily controlled by the composition of the consumable, the shielding gas can influence the weld‘s strength, ductility, toughness and corrosion resistance. When welding thick aluminium sections with pure argon as the shielding gas, porosity, lack of penetration and fusion defects can occur. So in order to obtain a quality weld the shielding gas flow rate should be controlled.

Current has direct influence on weld bead shape, on welding speed and quality of the weld. Most GTAW welds employ direct current on electrode negative (DCEN) (straight polarity) because it produces higher weld penetration depth and higher travel speed than on electrode positive (DCEP) (reverse polarity). Besides, reverse polarity produces rapid heating and degradation of the electrode tip, because anode is more heated than cathode in gas tungsten electric arc. However alternating current is better adapted to welding of aluminium and magnesium alloys, because it allows balancing electrode heating and work-piece cleaning effects.

LITERATURE SURVEY

Literature survey of various works regarding welding of Aluminium alloy 5083 is conducted. From the literature survey, process parameter that affects the weld quality is studied in detail. From the literature survey it is found that the parameters welding current and the shielding gas flow rate has significance importance regarding the quality of weld. So in this work; welding current and shielding gas flow rate are selected. The work deals with the study and the identification of best combination of welding parameter ranges in TIG welding of aluminium alloy 5083.

The study on the effect of temperature and shielding gas mixture is conducted to evaluate fatigue life of the 5083 alloy according to the mixing shield gas ratio and temperature change. The accuracy and quality of welded joints largely depends upon type of power supply, welding speed, type of inert gas used for shielding. The shielding gas is used to protect the finished weld from the effects of oxygen and nitrogen in the atmosphere. In general, for a given welding wire, the higher the oxidation potential of a shielding gas, the lower the strength and toughness of the weld.

This occurs because the oxygen and carbon dioxide in the shielding gas increase the number of oxide inclusions and reduce the level of materials such as manganese and silicon in the weld metal. The addition of helium to the argon shielding gas can significantly reduce these defects. This is because the high thermal conductivity of helium results in more energy being transferred into the weld. This in turn produces a hotter weld pool, resulting in improved fusion and slower freezing times, allowing any trapped gas more time to escape.

The increasing of arc welding current in 5083 aluminium alloy will increase the welding heat input. Accordingly, the chance of defect formation such burns in welded metal also increases. This will affects on the mechanical properties and quality of welded metal badly. Besides that the high welding current also reduces the yield strength, ultimate tensile strength and toughness value of 5083 aluminium alloy welded metal. The relationship between mechanical properties and microstructure of welded joints is evaluated. Results indicate that the ultimate tensile strength of the joints is 72% of that of the base metal. The base metal consists of a typical rolled structure, and the fusion zone (FZ) is mainly made up of dendritic grains.

METHODOLOGY

The present work deals with the identification of the best combination of welding parameter ranges, in the TIG welding of Aluminium alloy 5083. From the literature survey it is found that welding current and shielding gas flow rate has significance in obtaining quality weld. TIG welding is commonly used for welding Aluminium and Aluminium alloys. Aluminium alloy 5083 comes under aluminium 5xxx series and it has wide applications in ship building, Pressure vessels, Vehicle bodies, Tip truck bodies, etc. In the present work Two level full factorial design is selected. It consists of two factors and two levels, and the replication is considered as two.

Table 1: Factors and Their Levels

Welding Parameters	Units	High	Low
Welding Current (A)	Amps	250	200
Shielding Gas Flow Rate (l/min)	l/min	15	10

An experimental design matrix is obtained by using Minitab software. The details of factors and levels of experiments are shown in the Table 1. The experimental design consists of eight sets of experiments including the replication. The ranges of welding current and shielding gas flow rate are obtained by conducting trial and error and from the literature survey. The experiment is performed according to the order of the experimental design matrix and it is shown in Table 2. The specimen after welding is used for tensile testing, Microhardness testing, Macrostructure and Microstructure study. After testing the welded specimen results are obtained and according to the results obtained the sample with better result is find out.

Table 2: Experimental Design Matrix

Sl. No.	Welding Current (A)	Shielding Gas Flow Rate (l/min)
1	250	15
2	200	10
3	250	15
4	200	10
5	250	10
6	200	15
7	200	15
8	250	10

Table 3: Composition of Base Material and Filler Material

Materials	Al 5083	Al 5183
Si	0.4	0.1
Fe	0.4	0.27
Cu	0.1	0.01
Ti	0.14	0.11
Mn	0.7	0.58
Zn	0.25	0.06
Mg	4.45	4.55
Cr	0.15	0.11

In this study the constant process parameters are Filler rod- 5183, Filler rod diameter- 3.14 mm, Frequency-146 Hz, Electrode material- 98%W+2%Zr, Electrode diameter- 3.15mm. The experimental design matrix is also shown in the Table 2. In this work aluminium alloy 5183 is selected as the filler material. The welding specimen is made of dimension 100x75x6 mm and also V groove is prepared at 60^{o} and butt joint is obtained. The composition of base metal and filler material is shown in Table 3. The mechanical properties of Al 5083 is shown in Table 4.

RESULTS AND DISCUSSIONS

Table 4: Mechanical Properties of Al 5083

Property	Value
Hardness, Vickers	96
Ultimate Tensile Strength	317 Mpa
Tensile Yield Strength	228 Mpa
Elongation at Break	16%

Table 4: Contd.,

Modulus of Elasticity	703 Gpa
Fatigue Strength	159 Mpa

Table 5: Test Results of Welded Specimen

Expt No.	Welding Current (A)	Shielding Gas Flow Rate (l/min)	UTS (MPa)	% Elongation	Hardness (VHN)
1	250	15	275	24	65.6
2	200	10	275	25	73.5
3	250	15	268	21	67.6
4	200	10	274	22	68.7
5	250	10	265	20	73.5
6	200	15	284	20	68.7
7	200	15	281	20	68.7
8	250	10	258	20	80.7

Tensile Test

Tensile testing is conducted to determine the ultimate tensile strength and percentage elongation. The tensile sample is prepared as per ASTM standard. The tensile test is conducted for all combination of the welding parameter ranges. The results of the tensile test are shown in the Table 5. From the table it is found that the test result obtained is close to the standard value. The value of UTS very close to the standard value is selected from the four combinations. According to this result microstructure and macrostructure study is conducted. The test result of welded specimen is shown in Table 5.

Microhardness

Microhardness test is performed by using Vicker's Microhardness tester. The hardness of the base metal, weld metal and heat affected zone is measured and it is shown in the Table 5. The hardness of the base metal is same as to the standard value and there is also variation in the hardness of weld zone due to varying welding parameter combination. The Microhardness testing is conducted and the hardness of the various portion such as base metal, weld metal and heat affected zone (HAZ) are found out for samples A, sample B, sample C, sample D.

Macrostructure

A macrostructure study is conducted with the welded specimens of various combination of welding parameter ranges. In sample A, weld dilution is uniform in the first pass of the weld and low weld dilution in the second and third pass. A hint of porosity is observed in the sample A. In sample B the weld dilution is high for first, second and third pass of the weld and also the bead width is high.

Weld penetration is also high for sample B and there is more weld deposition in the weld area. In sample C the weld dilution is moderate for the first, second and third pass of the weld and the bead width is also moderate for the first, second and third weld passes. In sample D the bead width is low for the first pass of the weld and then the bead width is high for second and third pass comparing to the first pass of the weld and there is also low penetration of weld.

Microstructure

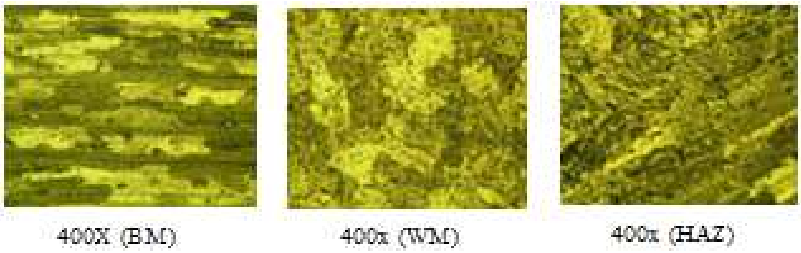

Figure 1: Microstructure of BM, WM and HAZ (Sample A)

Microstructure of weld metal of sample A is shown in the Figure 1 with magnification 400X. Considering the Figure 1 we can see the white portion which is aluminium and black portion is magnesium. Precipitates are formed in the weld metal it can be seen clearly in the 400X magnified figure. The Figure 1 also shows heat affected zone (HAZ) of sample A, in which we can see that HAZ is minimum and there is good bonding. In sample B the weld metal in which grains are uniformly distributed and low precipitates are formed. In the heat affected zone precipitate formed is found from the microstructure study. The microstructure of weld metal of sample C is studied and the precipitate is formed and it is very less compared to sample A and similar to sample B. In the heat affected zone (HAZ) of sample C fine grains are formed. The grain size is almost equal and the heat affected zone (HAZ) formed is very less compared to sample A and Sample B. The microstructure of weld metal (sample D) is studied and it is found that precipitate is formed and it is similar to that of sample A and more. In the heat affected zone also precipitates are formed so elongation is less and hardness is more so brittleness of material increases and the tensile strength of material decreases.

Fractography Analysis

In this study the specimen after tensile testing is used for the determination of whether the welded material shows brittle or ductile nature. For this purpose SEM analysis is done for the samples A, B, C and D. Sample A shows the indication of ductile fracture due to the formation of dimples i.e.; the bright portion and the other portions are not so bright. In sample B and C, there is also dimple formation which shows a ductile nature. In sample D there is very less dimples are formed, so this sample shows the sign of less ductile nature and more brittle nature.

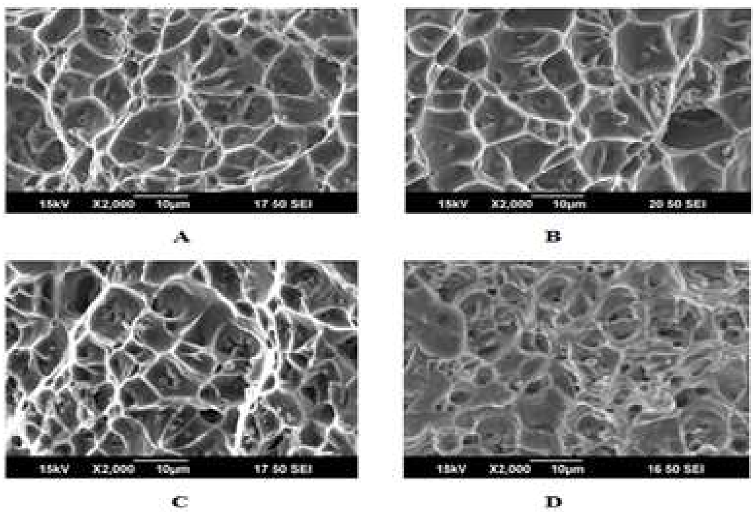

Figure 2

Influence of Welding Parameters on the Response Variables

The study deals with two welding parameters, welding current and shielding gas flow rate. In this section the influence of the two welding parameters on the response variables are considered. The response variables are Ultimate tensile strength, Percentage elongation and Microhardness. MINITAB software is used to find out the influence of welding parameters on the response variables. The trends in which the mechanical properties are influenced when the factors are varied on their levels are shown on main effects as well as interaction plots. Each point on the plots presents the average of two replicated experimental data on the relevant level. From this study we can find out which parameter has significant effect on the response variables.

Ultimate Tensile Strength

The tensile testing of the welded specimen is conducted on a Hounsfield tensometer. Specimen for tensile testing were taken at the middle of all the joints and machined to ASTM E8M standards. By conducting the test it is found that the specimens are failed at the heat affected zone (HAZ).

The main effect plot for ultimate tensile strength is shown in Figure 3. From the main effect plot it is found that as the welding current increases the tensile strength decreases, but when the shielding gas flow rate increases it is found that the tensile strength increases. So it is clear that as the welding current increases the tensile strength decreases and the tensile strength increases with increase in the shielding gas flow rate. The interaction plot is shown in the Figure 4. Interaction plot indicates that ultimate tensile strength increases with increase in the shielding gas flow rate while welding current is kept constant. The same increasing trend is shown at both the levels of welding current, however ultimate tensile strength was maximum when welding current is at 200 A.

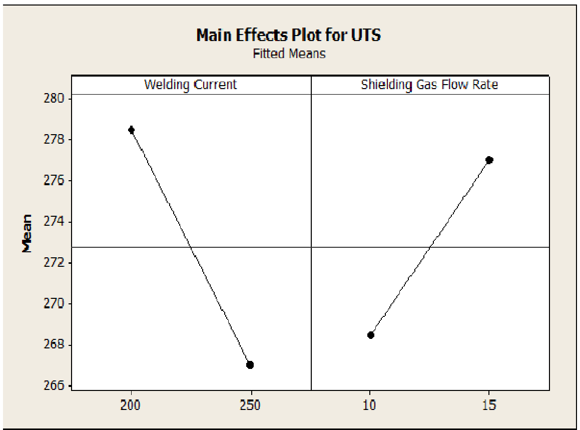

Figure 3: Main Effects Plot for UTS

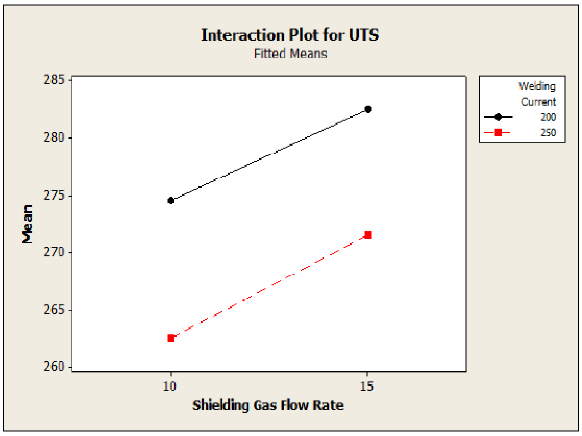

Figure 4: Interaction Plot for UTS

Table 6: Analysis of Variance for UTS

Analysis of Variance for UTS (Coded Units)					
Source	**DF**	**SS**	**MS**	**F**	**P**
Welding Current	1	264.5	264.5	25.19	0.007
Shielding Gas Flow Rate	1	144.5	144.5	13.76	0.021
Shielding Gas Flow Rate X Welding Current	1	0.5	0.5	0.05	0.838
Error	4	42	10.5		
Total	**7**	**451.5**			

Analysis of variance (ANOVA) is conducted and the values were tabulated in the Table 6. The p- value for welding current, shielding gas flow rate and the interaction between welding current and shielding gas flow rate was calculated and found to be 0.007, 0.021 and 0.838 respectively for α=0.05. The obtained p-value is compared with the α=0.05. If the α- value is more, then the hypothesis is rejected. From this study it is found that welding current and shielding gas flow rate has individual effects on ultimate tensile strength and these factors are significant. The interaction between the two factors has no significance.

Percentage Elongation

Specimen for tensile testing were taken at the middle of all the joints and machined to ASTM E8Mstandards. By conducting the test it is found that the all the tensile testing specimens are failed at the heat affected zone(HAZ). Minitab software is used to find the effects of parameters on percentage elongation and there significance was analyzed. From this it is found that with an increase in welding current the percentage of elongation decreases and in the case of shielding gas flow rate, the percentage of elongation decreases when shielding gas flow rate increases. Figure 5 shows the main effect plot for percentage elongation. The interaction plot is shown in the Figure 6. From this plot it is found that the interaction between the two factors welding current and shielding gas flow rate has high significance. So it is clear that the interaction between the two factors influences the percentage elongation. But the individual effects of two factors have less significance.

Analysis of variance (ANOVA) for percentage elongation is conducted and the results are shown in the Table 7. The p – value for welding current, shielding gas flow rate and the interaction between the two parameters welding current and shielding gas flow rate are 0.662, 0.662 and 0.047 respectively for α= 0.05. Hence from the p – value it can be concluded that the individual effects of welding current and shielding gas flow rate has no significance, but the interaction between the two factors welding current and shielding gas flow rate has significance on the contribution for the percentage elongation.

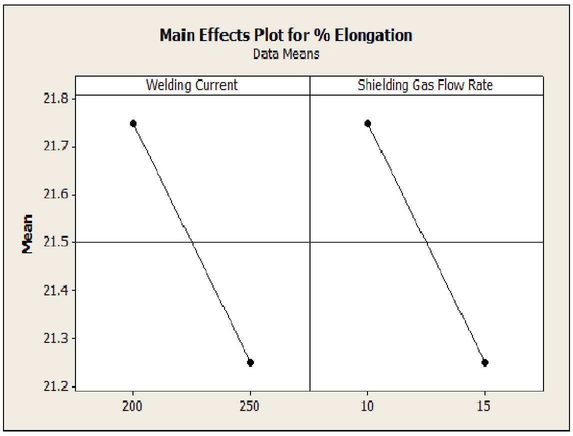

Figure 5: Main Effects Plot for % Elongation

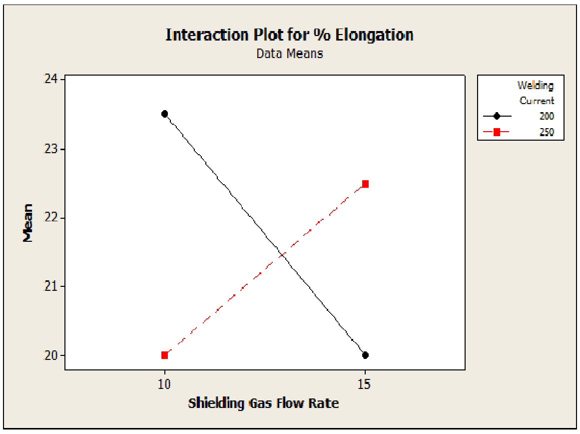

Figure 6: Interaction Plot for Percentage Elongation

Table 7: Analysis of Variance for Percentage Elongation

Analysis of Variance for % Elongation (Coded Units)					
Source	DF	SS	MS	F	P
Welding Current	1	0.5	0.5	0.22	0.662
Shielding Gas Flow Rate	1	0.5	0.5	0.22	0.662

Table 7: Contd.,

Shielding Gas Flow Rate X Welding Current	1	18	18	8	0.047
Error	4	9	2.25		
Total	**7**	**28**			

Microhardness

Microhardness measurements were made on the polished samples. Vickers micro hardness was measured using "Zwick 3212" micro hardness tester using 300gm indenting load and a dwell time of 30s. For all the specimens minimum hardness was reported at weld zone. Among the specimens, the specimen welded at condition c (Welding current - 250A, Shielding gas flow rate – 10 l/min) had maximum hardness value 80.7 HV at the weld zone. Minitab software is used to analyze the significance of the effect of welding parameters on Microhardness. The main effect plot for hardness is shown in the Figure 7. From the main effect plot it is found that as the welding current increases the Microhardness also increases and when the shielding gas flow rate increases the Microhardness decreases.

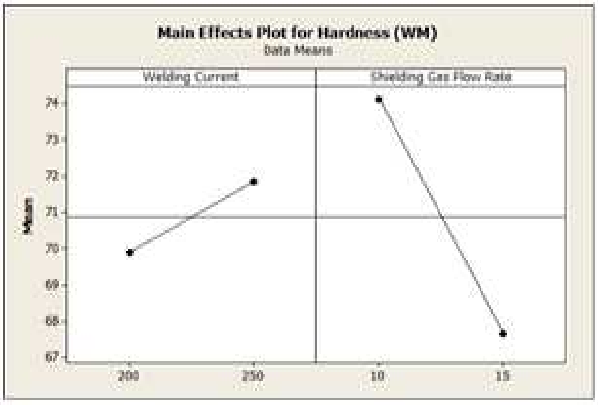

Figure 7: Main Effects Plot for Hardness

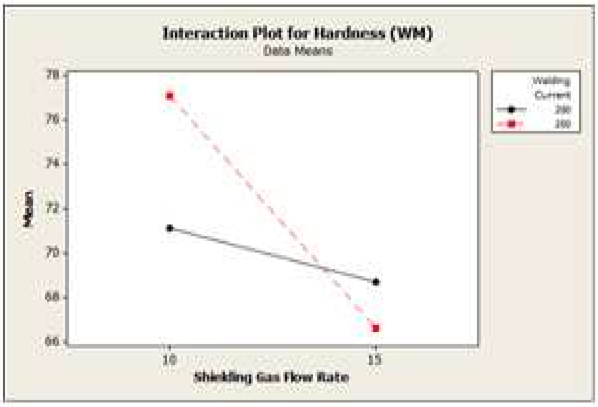

Figure 8: Interaction Plot for Hardness

Table 8: Analysis of Variance for Hardness

Analysis of Variance for Hardness (VHN)					
Source	**DF**	**SS**	**MS**	**F**	**P**
Welding Current	1	7.605	7.605	0.77	0.429
Shielding Gas Flow Rate	1	83.21	83.205	8.44	0.044
Shielding Gas Flow Rate X Welding Current	1	32.81	32.805	3.33	0.142
Error	4	39.44	9.86		
Total	**7**	**163.1**			

The Figure 8 shows the interaction plot for hardness. In this welding current is kept constant, and we can see that Microhardness decreases with increase in shielding gas flow rate. In the figure there is an interaction can be seen, but this interaction has least significance. The analysis of variance (ANOVA) for Microhardness was conducted and the results are shown in the Table 8. The p – value for welding current, shielding gas flow rate and the two way interaction between welding current and the shielding gas flow rate are 0.429, 0.044 and 0.142 respectively for $\alpha = 0.05$. From the p – value it can be concluded that shielding gas flow rate is the significant factor. Welding current and the interaction between welding current and shielding gas flow rate has least significance.

CONCLUSIONS

The study on the influence of Gas Tungsten Arc welding parameters such as welding current and shielding gas flow rate on the mechanical properties such as ultimate tensile strength (UTS), percentage elongation and hardness of Al 5083 welded joints are conducted and the conclusions obtained are shown below.

The shielding gas flow rate has individual effect in contribution for hardness and ultimate tensile strength. Welding current also has individual effect on contribution for ultimate tensile strength. Shielding gas flow rate and welding current has a two way interaction effect on contribution for percentage elongation. The interaction between shielding gas flow rate and welding current has least significance in the case of ultimate tensile strength, but in the case of hardness it shows an interaction but it is not significant. From this study it is found that shielding gas flow rate has more effect on mechanical properties such as hardness and ultimate tensile strength and welding current has effect on ultimate tensile strength. The macrostructure study is conducted and it is found that the welded joint has good quality. The microstructure study reveals that there is precipitate formation on the welded area and the heat affected zone and it is in a small rate, so we can say that there will be no much variation on the mechanical properties. The fractography study is conducted and it is found that the welded joints showductile nature.

For the future study we can conduct the same experiment on an automatic TIG welding machine with the selection of welding parameters such as welding speed, welding torch angle, shielding gas flow rate and welding current so that we can obtain a quality weld and an EDX analysis to be done to find out the composition of the precipitates formed in the weld area and we can understand which all composition of the precipitate will enhances the mechanical property of the welded joint.

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