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Influence of Gas Tungsten Arc Welding Parameters in Aluminium 5083 Alloy

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Abstract*— *The present work deals with the identification of the best combination of welding parameters, in TIG welding of Aluminium alloy 5083. In this study two level full factorial experimental design is considered which consists of two factors and two levels. Inorder to avoid experimental errors two replications are performed for each experimental combination. The working ranges of welding parameters for conducting experiments are initially obtained by trial and from literature survey. After the experiment, various tests like Tensile test; Microhardness, Macrostructure and Microstructure study are conducted to the welded specimens. The analysis of the test results is conducted and the combination of welding parameter ranges that gives best result is found. This combination can be considered as good working ranges for TIG welding of Aluminium alloy 5083.

Index Terms **— TIG Welding, Aluminium 5083 Alloy, Welding current, Shielding gas flow rate, Design of experiment.**

I. 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 5083 is commonly used in:

- Shipbuilding
- Railroad cars
- Coachwork
- Pressure vessels
- Vehicle bodies
- Tip truck bodies
- Mine skips and cages

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 defense 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. 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. 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. Reverse polarity may be of interest in welding aluminum alloys because of the cathodic cleaning action of negative pole in the work-piece, that is the removal of the refractory aluminum oxide layer.

However alternating current is better adapted to welding of aluminum and magnesium alloys, because it allows balancing electrode heating and work-piece cleaning effects. The mechanical properties of Aluminium alloy 5083 is shown in the Table I.

Table I: Mechanical properties of Aluminium alloy 5083

Property	Value
Hardness, Vickers	96
Ultimate Tensile Strength	317 Mpa
Tensile Yield Strength	228 Mpa
Elongation at Break	16%
Modulus of Elasticity	703 Gpa
Fatigue Strength	159 Mpa

II. 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 effects of temperature and shielding gas mixture on fatigue life of 5083 aluminium alloy. This study was to evaluate fatigue life of the 5083 alloy according to the mixing shield gas ratio and temperature change. Tungsten Inert Gas welding is one of the widely used techniques for joining ferrous and nonferrous metals. TIG welding process offers several advantages like joining of unlike metals, low heat effected zone, absence of slag etc compared to MIG welding. The accuracy and quality of welded joints largely depends upon type of power supply (DCSP or DCRP or ACHF), welding speed, type of inert gas used for shielding. This paper deals with the investigation of effect of welding speed on the tensile strength of the welded joint.

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. 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. When welding thick aluminium sections with pure argon as the shielding gas, porosity, lack of penetration and fusion defects can occur. 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. This paper deals with the detailed study of shielding gas used for aluminium welding. 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.

III. 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. An experimental design matrix is obtained by using Minitab software.

Table II: 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

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. 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 III: Experimental Design Matrix

SI. 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

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 factors and their levels are shown in the Table II and also the experimental design matrix is also shown in the Table III. The aluminium alloys are welded by using TIG and MIG welding process. The filler materials used for welding are aluminium alloy 5183 and 5356. 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 600 and butt joint is obtained. The composition of base metal and filler material is shown in the Table IV.

Table IV: 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

IV. RESULTS AND DISCUSSION

The results of various tests are obtained and it is shown below. The Fig. 1 shows the welded samples.

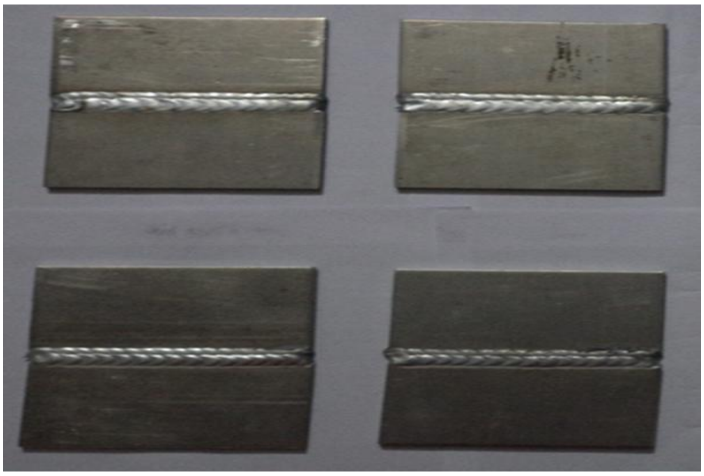


Fig 1: Welded Specimen

A. *Tensile Test*

Tensile testing is conducted to determine the ultimate tensile strength and percentage elongation. The tensile sample is prepared as per ASTM standard and it is shown in Fig. 2. The tensile test is conducted for all combination of the welding parameter ranges. The results of the tensile test are shown in the Table V. 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 to find out the best welding parameter ranges in the TIG welding of aluminium alloy 5083.

Table V: Tensile Testing Results

SI. No.	Welding Current (A)	Shielding Gas Flow Rate (l/min)	UTS (MPa)	% Elongation
1(A)	250	15	268	21
2(B)	200	10	274	22
3(C)	200	15	281	20
4(D)	250	10	258	20

Fig 2: Tensile Specimen

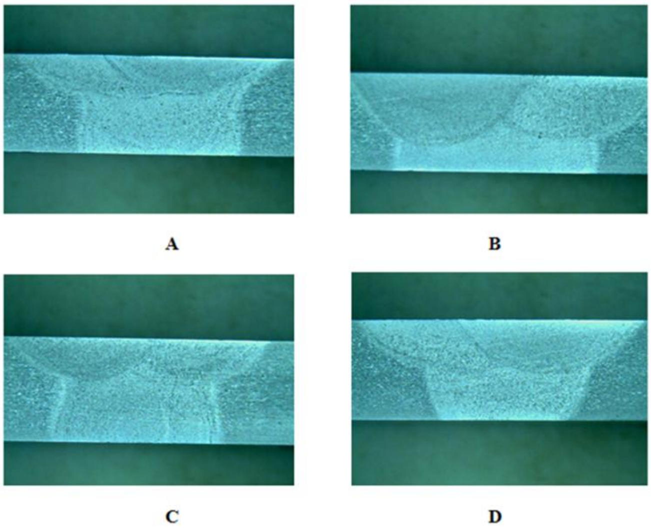
B. Microhardness

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 VI. 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. Then the four combinations are found out by considering the UTS as the reference for the Microhardness results. 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. The results of the hardness test are used to compare the samples for microstructure study and macrostructure study. From the results obtained it is found that sample C is better with hardness 68.7 HVN for base metal, 75 HVN for heat affected zone, 73.5 HVN for weld meal.

Table VI: Microhardness Test Result

SI. No	Welding Current (A)	Shielding Gas Flow Rate (l/min)	Hardness (HVN)		
			Base Metal (BM)	Heat Affected Zone (HAZ)	Weld Metal (WM)
1(A)	250	15	68.7	73.2	67.6
2(B)	200	10	68.7	71.8	68.7
3(C)	200	15	68.7	75	73.5
4(D)	250	10	68.7	73.5	80.7

C. Macrostructure



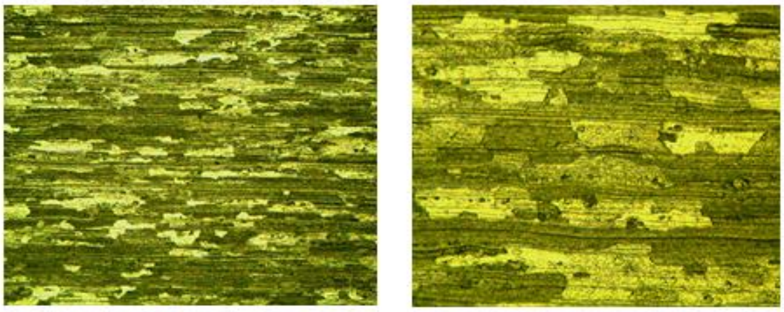
A
B
C
D

Fig 3: Macrostructure of Welded Specimen

A macrostructure study is conducted with the welded specimens of various combination ranges of welding parameters. The macrostructure is shown in the Fig. 3. Considering 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. Comparing sample A, B, C and D it is found that sample C is better.

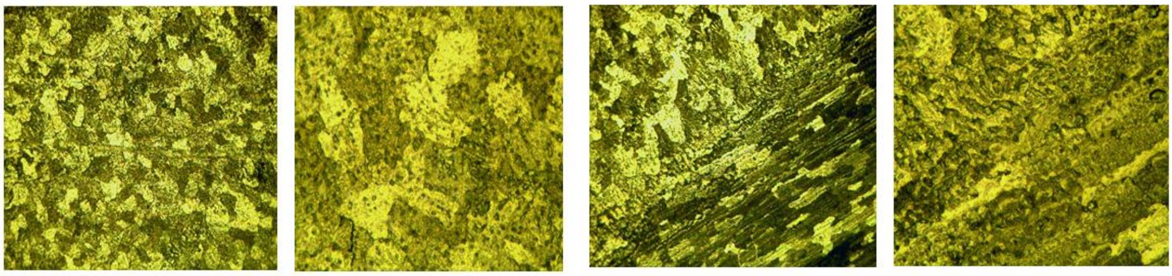
D. Microstructure

Microstructural characterization studies were conducted on metallographically polished and chemically etched samples to investigate morphological characteristics of grains and secondary phases. The microstructure of base metal is shown in the Fig. 4.



(a) BASE METAL (100X) (b) BASE METAL (400X)

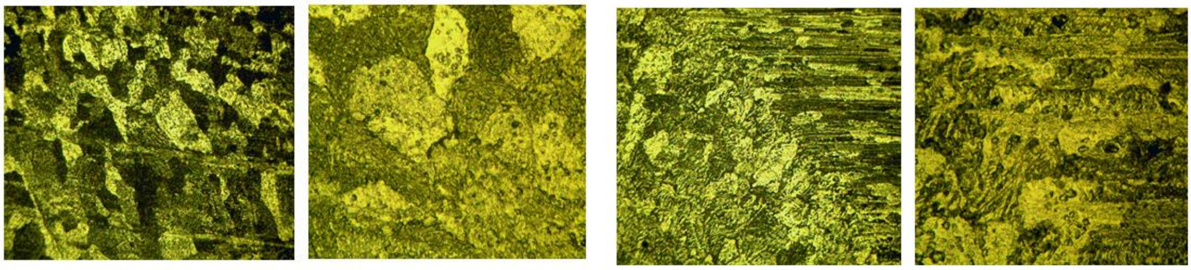
Fig 4: Microstructure of Base Metal



WELD METAL (100X) WELD METAL (400X) HEAT AFFECTED ZONE (100X) HEAT AFFECTED ZONE (400X)

Fig 5: Microstructure of Weld Metal and Heat Affected Zone (Sample A)

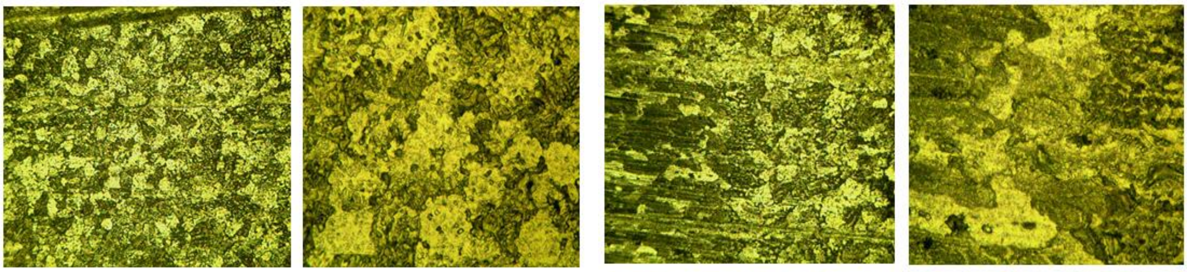
Microstructure of weld metal of sample A is shown in the Fig. 5 with magnification 100X and 400X. Considering the Fig. 5 we can see the white portion which is aluminium and black portion is magnesium. Precipitates are formed in the weld metal it can be seen clearly in the 400X magnified figure. The figure 5 also shows heat affected zone (HAZ) of sample A, in which we can see that HAZ is minimum and there is good bonding.



WELD METAL (100X) WELD METAL (400X) HEAT AFFECTED ZONE (100X) HEAT AFFECTED ZONE (400X)

Fig 6: Microstructure of Weld Metal and Heat Affected Zone (Sample B)

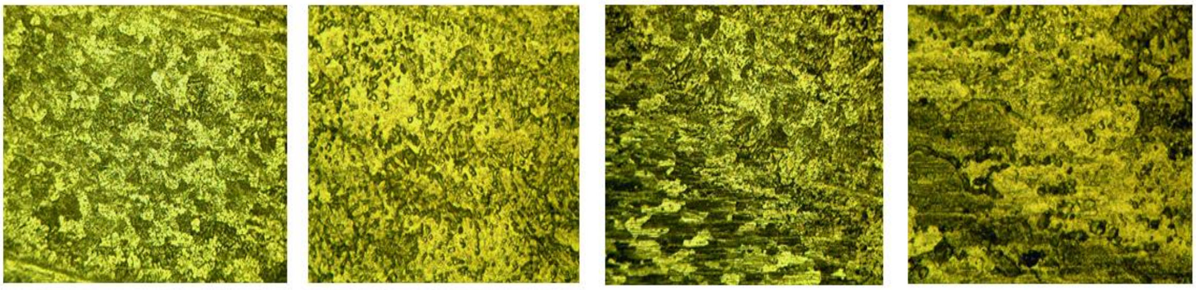
Consider Fig. 6, sample B shows the weld metal in which grains are uniformly distributed and low precipitates are formed. The heat affected zone is shown in the Fig. 6 with magnification 100X and 400X and the precipitate formed is also found from the microstructure study.



WELD METAL (100X) WELD METAL (400X) HEAT AFFECTED ZONE (100X) HEAT AFFECTED ZONE (400X)

Fig 7: Microstructure of Weld Metal and Heat Affected Zone (Sample C)

In the Fig. 7 the microstructure of weld metal of sample C is shown and the precipitate is formed and it is very less compared to sample A and similar to sample B. The heat affected zone (HAZ) for sample C is also shown in the Fig. 7 and it is found that 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.



WELD METAL (100X) WELD METAL (400X) HEAT AFFECTED ZONE (100X) HEAT AFFECTED ZONE (400X)

Fig 8: Microstructure of Weld Metal Heat Affected Zone (Sample D)

The microstructure of weld metal (sample D) is shown in the Fig. 8. Precipitate is formed and it is similar to that of sample A and more. In the heat affected zone precipitates are formed so elongation is less and hardness is more so brittleness of material increases and the tensile strength of material decreases. Fig. 8 shows the heat affected zone (HAZ) for sample D. Considering the four samples A, B, C, D; we can say that sample C is better than sample A, B, D from the microstructure study.

V. CONCLUSION

The experimental design is done with two parameters and two levels, and the defect free working ranges (levels) of welding parameter for conducting experiment is found out by trial and error and from the literature survey. The welding of the samples is done as per the order of experimental design matrix. Various tests like tensile test, micro hardness test, macrostructure study and microstructure study are conducted for the welded specimens. According to the test results obtained the detailed study of the four samples A, B, C, D is conducted. The macrostructure and microstructure study in conducted with reference to the tensile test results and the micro hardness test. From the study it is found out that sample C is better than sample A, B, D. The test results of sample C includes ultimate tensile strength of 281MPa, hardness of weld metal is 73.5 HVN. The sample C has a working range of welding current 200A and shielding gas flow rate 15 l/min. So the welding of Aluminium alloy 5083 performed in the experimental combination of welding current 200A and shielding gas flow rate 15 l/min is found to give a better result.

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