

To Determine Effects of Gas Metal Arc Welding (GMAW) Parameters on Mechanical Properties of Aluminium Alloys

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ABSTRACT: The ever growing use of Aluminium alloys in transportation, like in railways, shipbuilding and aeronautics, calls for more efficient and reliable welding techniques and accurate welding parameters to obtain strong joints. The objective of this work is to determine effect of Gas Metal Arc Welding parameters on Mechanical properties of 6mm thick Aluminium alloy 6061 plates. The welding parameters under consideration were the Welding Current, Voltage and Gas Flow Rate. The Mechanical properties compared with welding parameters were Tensile Strength, Hardness, Microstructure and Micro hardness. As Aluminium alloys exhibit large micro structural changes after welding it is essential to observe about the effect of welding parameters on the mechanical properties of weldments as too high welding current will result in high heat input and weakening of weld profile so a balance is need to be struck between welding parameters and mechanical properties.

KEYWORDS: Gas Metal Arc Welding, Aluminium Alloys, Mechanical Properties, Weldments

I. INTRODUCTION

Aluminium alloys have been more and more extensively utilised in structural applications and transportation industry for their light weight and attractive mechanical properties achieved by thermal treatments. [1] Alloy 6061 is one of the most widely used alloys in the 6000 series. This standard structure alloy, one of the most versatile of the heat-treatable alloys, is popular for medium to high-strength requirements and has good toughness characteristics [2] and used in marine frames and in pipeline and aircraft applications. [3] A number of researchers have studied effect of welding process parameters on mechanical properties of weldments. In the Al-Mg-Si alloys, that are widely used in welded structures, the strengthening mechanism is associated to a well known sequence of precipitation in four distinct stages, during aging after solution heat treatment and quenching, as validated by numerous experimental works [4,5,6]. For instance, in a study, an experiment to find out the effects of MIG welding on the corrosion and mechanical properties of AA 6061 T6 was done; It was found that hardness of the welded specimens was increased as we moved away from the weld centre even at HAZ. In a study, effects of welding current, welding speed and voltage were observed on tensile strength and hardness of AA 6101 plates using MIG welding technique and it was concluded that tensile strength of specimen are comparable to those of base metal and mean effect of all three of welding parameters on ultimate strength is negative. [7] The spray mode of metal transfer using Argon as shielding gas and direct current electrode positive (DCEP) power has been found suitable to weld aluminium; DCEP gives good penetration and a cathodic cleaning action of the work action. [8]

In another study, experimentation on two age hardenable Al alloys weldments was done namely 6061-T6 and 6082-T6 to know about their fatigue behaviour using MIG and FSW techniques. Main conclusion drawn from the experiment was Yield and rupture stress of MIG welded specimens are lower than for base material in case of MIG welding. [9] In case of welding of aluminium alloys using spray arc transfer method welding current ranges from 50A to 600A. The width and depth of weld metal as well as heat affected zone (HAZ) increases with increase in current. [10] Using Argon as shielding gas minimum current used for spray arc method with wire electrode of diameter of 1.6 mm is 180 A

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and with wire diameter of 1.2 mm is 135 A. [11] experimentation was performed to know about the Micro structural changes accompanying repair welding in 5xxx aluminium alloys and their effect on the mechanical properties. The material used in the experiments was the AA5083-H112, which is a non heat treatable alloy. Microstructure was compared before and after annealing processes and mechanical properties under consideration were ultimate tensile strength and tensile strength. The main conclusion drawn included heating of the parent metal (AA5083) close to the melting point caused softening and a 10% hardness drop when compared to the as received parent metal. [12] Welding current is proportional to electrode diameter for a particular electrode material. With increase in electrode extension, a slight decrease in current occurs at which spray transfer develops. [13] For welding of aluminium arc voltage varies between 17 V to 40 V. [14] A filler metal with melting temperature below that of base metal greatly reduces the tendency for intergranular cracking in HAZ. Such a filler metal minimizes the stresses imposed by solidification shrinkage of the weld metal until any low melting phase in the HAZ has solidified and developed sufficient strength to resist the stress. [15] Fusion area increases with increase in heat input and increasing heat input increases the restraining forces. [16]

As found out from above literature review that these heat treatable aluminum alloys are susceptible to hot cracking when high heat input or high value of current is employed so it is important to know behavior of weldments at different values of welding parameters. 6XXX Series aluminum alloys are heat treatable or age hardenable having high strength among heat treatable Al alloys. An aluminum alloy of 6XXX series includes Silicon and Magnesium as its main alloying elements having good weldability. The main objective in the present study was to find effects of welding parameters such as welding current, arc voltage and gas flow rate on mechanical properties of AA 6061-T6 plates. The spray arc transfer method was implemented during the welding operation because of its ability to work at higher current ranges and to provide weldments with lesser amounts of spatter. The mechanical properties under consideration for present work were the Tensile Strength, Hardness, Microstructure and Micro hardness. Tensile Strength, Hardness were determined using UTE100, with capacity of 100kN and Vickers hardness tester respectively. After performing these experiments micro structural changes in the weldments were observed using Standard Metallurgical microscope. Optimized values of process parameters can be determined by performing this experiment as value of welding parameters were altered and its corresponding effects on mechanical properties of weldments were investigated

II. MATERIALS AND METHODS

In this experimental work Gas Metal Arc Welding was used to produce weldments as it is one of the simple and easy methods of producing strong joints in welding industry.

Selection of Material: For this study material considered was Aluminum alloys 6061 selected. The alloy was taken in the form of 6 mm thick sheets having dimension of 125 x 150 x 6mm. The chemical composition of material can be shown in tabular form as below.

Element	Mg	Si	Cu	Cr	Fe	Mn	Ti	Zn	Al
Wt %	0.345	0.5 -0.8	0.002	0.019	0.32	0.029	0.010	0.005	Rest

Table 1: Chemical composition of Aluminum alloy

The filler metal chosen for present research was commercially available AA 4043 wire having 1.2 mm diameter. Commercially available Argon was used as shielding gas. Now chamfering was done on that side of plate which was to be joined to obtain single V groove joint which allows greater penetration and smooth weld bead. Root gap was taken as 3 mm for welding of each plate.

Specimen preparation and testings: Specimen were prepared using wirecut EDM machine. Both surfaces of the pieces were sand blasted and polished just before welding using a SUS brush, a grinder and alumina powders of 0.3 μ m diameters to remove dirt and oxides. Each weld was cross-sectioned at mid-length and then polished with the help of alumina powders. And the specimens were etched in Keller's reagent [methanol (25 ml) + hydrochloric acid (25 ml) +

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nitric acid (25 ml) + hydrofluoric acid (3 ml)] for about 30 s to reveal the bead profile. Specimen after the cutting was etched and cleaned thoroughly to reduce any possibility of impurities which may have stuck to welded joints. These impurities in the form of dust particles or any other type of element may lead to inappropriate readings of mechanical testings. So Utmost care has to be taken for preparation of samples in case of such type of aluminium alloys to obtain suitable values.

The welding parameters for experiment were taken as:

Welding Parameters	Run 1	Run 2	Run 3	Sample No.
Welding Current(A)	150	160	170	1
Arc Voltage(V)	20	22	24	2
Gas Flow Rate(L/min)	14	14	14	3

Table 2: Selection of Welding Parameters for first three runs

Now to observe the changes in weldments due to the effect of welding parameters the Gas flow rate in the process was increased from 14L/Min to 18L/Min. The arc voltage and welding current were altered in the same manner as for first three samples. The root gap maintained was also similar as in the above mentioned welding process. Filler wire for this experiment was also same. The effect on Mechanical properties of weldments was analysed for all these 6 samples along with base metal mentioned latter in the article .

Welding Parameters	Run 1	Run 2	Run 3	Sample No.
Welding Current(A)	150	160	170	4
Arc Voltage(V)	20	22	24	5
Gas Flow Rate(L/min)	18	18	18	6

Table 3: Selection of Welding Parameters for next three runs

Now after obtaining 6 welded plates of Aluminum alloy samples were prepared to conduct mechanical testing. To carry out the tensile testing using UTM machine with capacity 100KN and resolution 0.05KN. Tensile testing was done at Industrial Development Facility Centre, Chandigarh, India. The testing conditions were taken as temperature of 25 degree celsius and relative humidity of 40-60%. These specimen were loaded on UTM and a gradually increasing load was applied.

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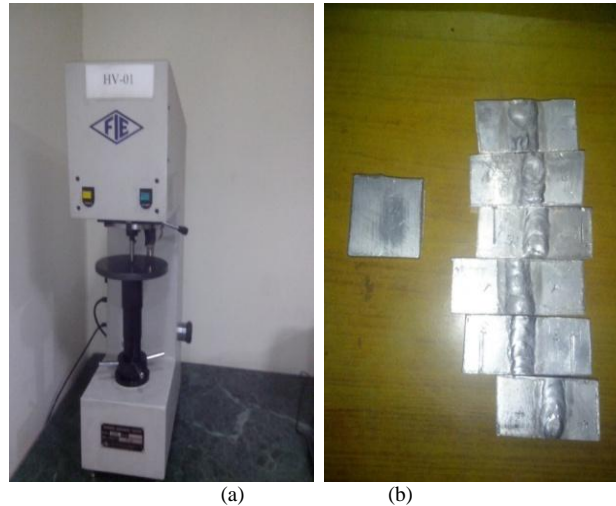


Fig. 1 (a) Vickers Hardness Tester (b) Samples for Hardness Testing

The actual images of finally prepared samples are shown above. Similarly Hardness test was performed using Vicker Hardness tester with same testing conditions as used in Tensile test also shown above in figure 1. After Hardness testing microstructural changes were observed using Standard Metallurgical Microscope. Microhardness of all the samples along with base metal was also tested at Indiana Test, Calibration and Certification Services, Mohali, India.

III. RESULTS AND DISCUSSIONS

The Tensile Specimen were prepared according to the ASTM E8M-04 standard for testing. The results for 6 samples welded at different combinations of current, voltage and gas flow rate are given as below.

Sr.No.	Sample Nomenclature	T.S. (Mpa)	%EL
1	Sample 1,DUMBLE	118	4.8
2	Sample 2,DUMBLE	144	4.4
3	Sample 3,DUMBLE	136	5.8
4	Sample 4,DUMBLE	97	2.9
5	Sample 5,DUMBLE	143	7.5
6	Sample 6,DUMBLE	84	2.1
7	BASE METAL,DUMBLE	129	24.27

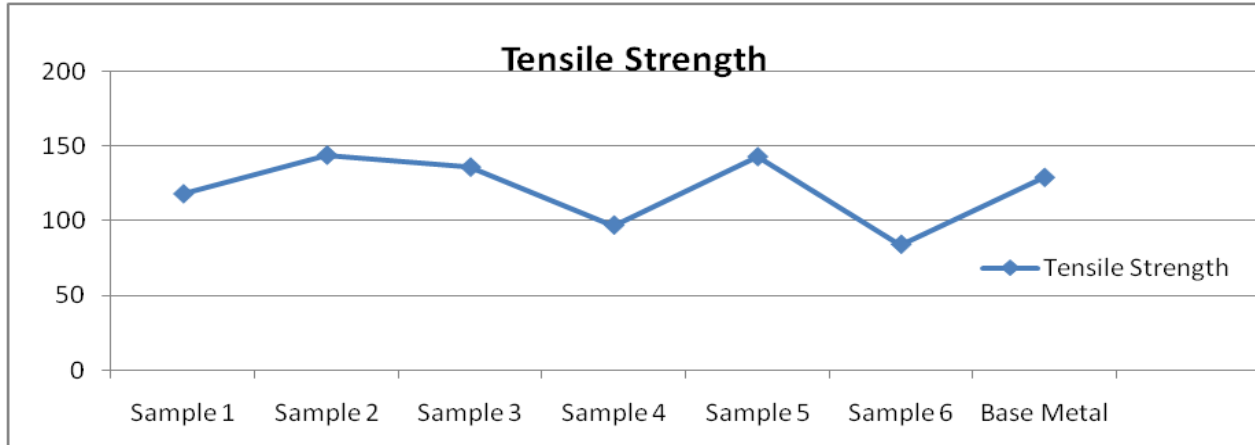
Table 4: Results of Tensile test

For Tensile testing DUMBLE shaped specimen were prepared using Wire-cut EDM Machine taking appropriate measures under consideration. The results demonstrated above showed typical properties of aluminium alloys and their uniqueness. The variation among different samples and base metal can be shown below as.

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Graphical Representation of variation in Tensile Strength

Discussion for Tensile Strength : The pattern observed from the graph showed that with increase in welding current and voltage there is slight decrease in tensile strength of samples. This property is found out while analysing the different samples due to the fact that as we add up the welding current value the heat input per unit length of weld also increases correspondingly which lowers the cooling rate of work pieces which allows the grains of fusion zone to have ample time to grow thus resulting in microstructural coarsening accounting for lower yield strength but this property does not follow the same pattern from sample 1 to sample 6. When we analyse sample 2 having current value of 160 A and voltage 22 V with Gas flow Rate of 14 L/min the Tensile Strength obtained was 144 Mpa showing that there is optimal welding parameter range that has to be applied while doing GMA welding of Aluminium alloys. In present study the range of tensile strength vary from 84 Mpa to 144 Mpa for corresponding samples showing a vast impact of welding parameters on mechanical properties of aluminium alloys and also the deep study that is to be done in this area of welding.

The Hardness Test was performed using Vickers Hardness tester with which yielded following results :

Sr No.	Sample Nomenclature	HV HAZ(L.H.)	HV On WELD	HV HAZ(R.H.)
1	SAMPLE 1	42	47-49	44
2	SAMPLE 2	42	50-51	41
3	SAMPLE 3	45	52-52	44
4	SAMPLE 4	46	51-53	46
5	SAMPLE 5	43	48-49	44
6	SAMPLE 6	43	53-55	42
7	BASE METAL	34-36	34-36	34-36

Table 5: Results of Hardness Test

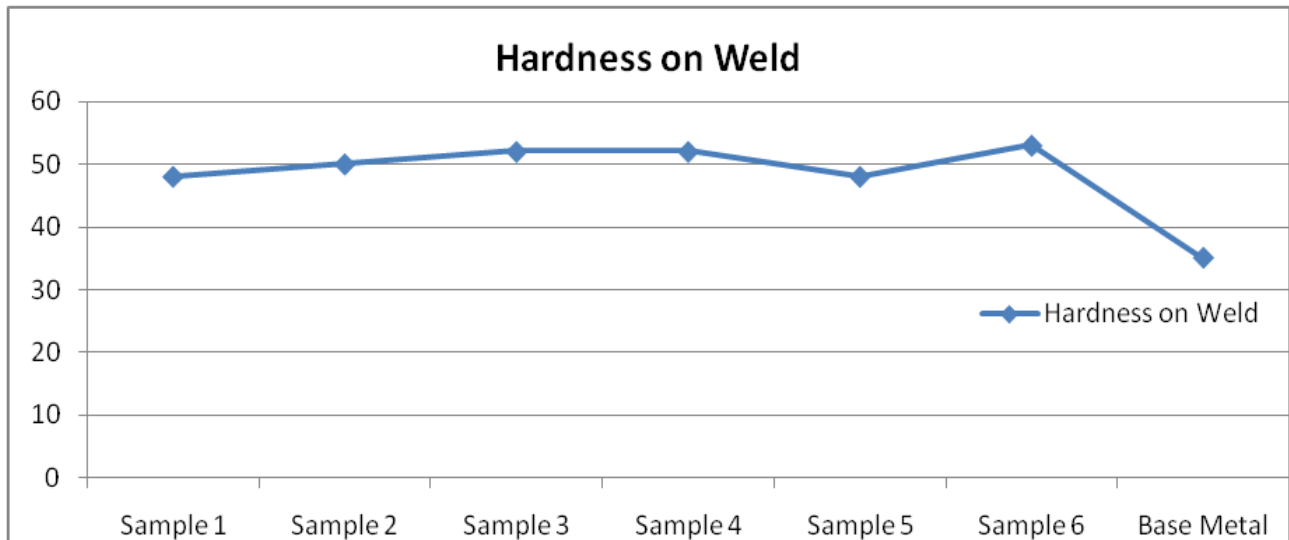
As Hardness Test was performed using Standard Vickers Hardness tester the readings were taken on Weld Bead, on Left Hand side and Right Hand side of weld bead to obtain mean values. The testing conditions were taken as

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temperature of 25 degree celsius and relative humidity of 40-60%. The variation in hardness on weld in all samples can be understood on the basis of graph shown below as :



Graphical Representation of variation in Hardness

Discussion for Hardness : However in case of the hardness value increased than the base metal due to the effect of fine grain structure and uniform distribution of alloy silicides. As hardness increases there will be adverse effect on ductility of the material so the samples having combination of moderate hardness and high tensile strength will be the appropriate samples i.e. sample 2 and sample 5 having both of these properties. Hardness properties of aluminium alloys don't show the conventional pattern like in other materials i.e. steels, ferrous materials, glass or plastics. The pattern showed by this type of alloy is due to the effect of a number of constituents playing their part during the joining process and corresponding effects are also exhibited by the welded joints. This property also affects the characteristics of other mechanical testings. 6XXX Series aluminum alloys are heat treatable or age hardenable having high strength among heat treatable Al alloys. Aluminum alloys in 6XXX series include Silicon and Magnesium as their main alloying elements having good weldability so hardness is an important property to be calculated for further analysis of these alloys.

The microstructure of all the samples along with Base Metal was observed using Standard Metallurgical Microscope to analyse changes in structure of the material after the welding process. The Metallurgical microscope was well equipped to take photographs of highest quality.

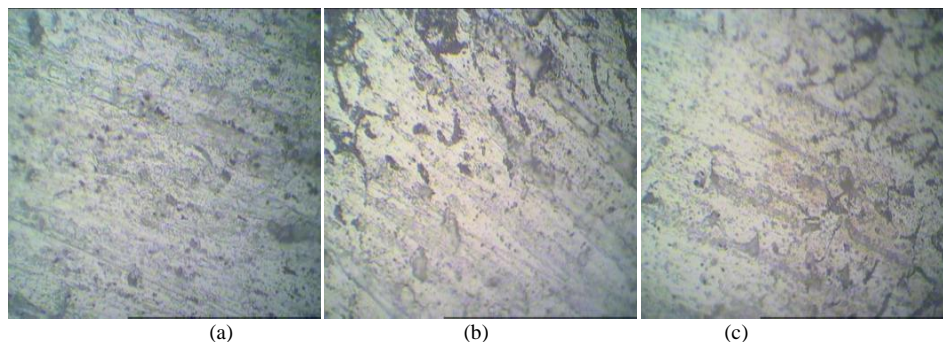


Fig. 2 (a) Microstructure of Base Metal (b) Microstructure of Sample 1 (c) Microstructure Sample 2

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The microstructure of all the samples along with Base Metal was observed using Standard Metallurgical Microscope to analyse changes in structure of the material after the welding process. The samples were cleaned and washed with dilute Hydrochloric acid. The microstructure observed in base metal and sample 1 and 2 are shown above.

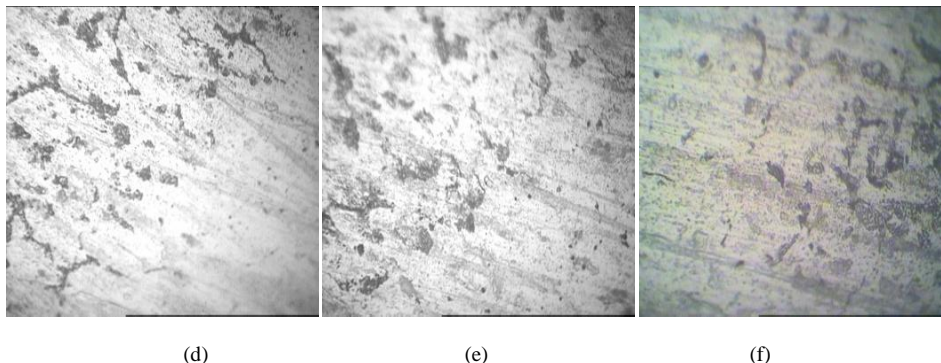
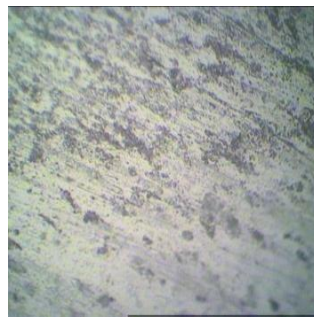


Fig. 3 (a) Microstructure of Sample 3 (b) Microstructure of Sample 4 (c) Microstructure Sample 5

As Aluminium alloys have high thermal conductivity so Heat Affected Zone (HAZ) is very less in case of weldments for this experiment. Weld metal showed fine nuggets of self cooled structure of Al-Si alloy. The microstructure of sample 3, sample 4 and sample 5 are shown above.



(f)
Fig.4 (f) Microstructure of Sample 6

Discussion for Micro Structure : As Magnesium and Silicon are prime constituents in this type of Aluminium Alloy the Base metal showed uniformly distributed Lumps of Alloy Silicides with fine grains. The microstructure is characterized by epitaxial growth with columnar-dendritic grains competitively growing toward the heat source. The microstructure changes in aluminium alloys plays an important role in overall analysis of these types of alloys. Microstructural demonstration allows one to analyse relationship between various constituents of alloys.

The micro hardness was tested for all samples along with the base metal using small diamond indenters. The apical angle taken under consideration was 136° .

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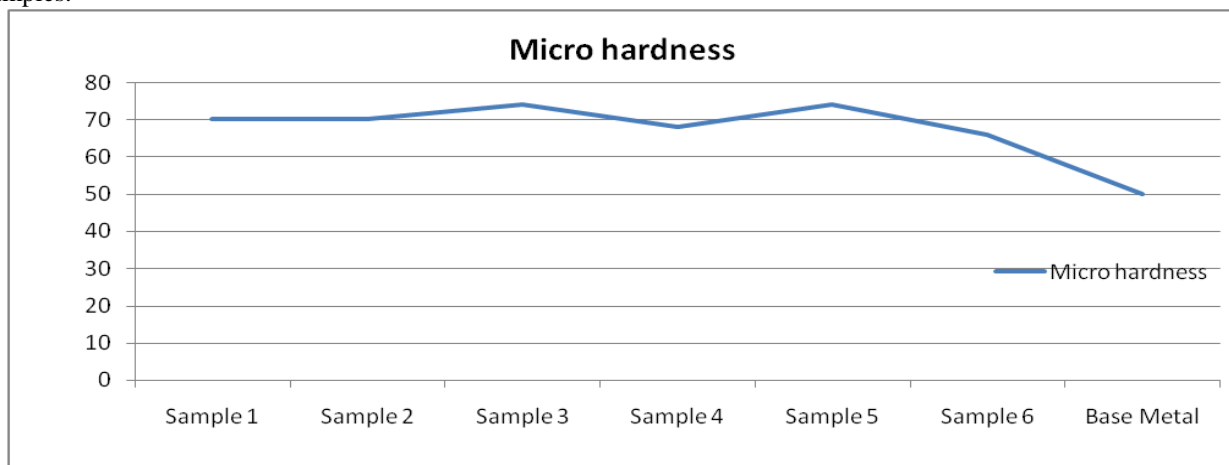
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Sample Nomenclature	Reading 1	Reading 2	Reading 3
Sample 1	72	72	68
Sample 2	71	74	74
Sample 3	68	71	74
Sample 4	72	68	64
Sample 5	72	72	77
Sample 6	70	72	74
Base Metal	47	50	50

Table 6: Results of Microhardness Test

Microhardness of all the samples along with base metal was tested with HV0.1 hardness conditions. Samples were properly cleaned before testing. The above table shows the results gained from the microhardness examination of all samples.



Graphical Representation of variation in Microhardness

Discussion for Microhardness : Again in microhardness we have seen that more values of hardness has been obtained at specific values of welding parameters as in case of sample 2 and sample 5 where Welding parameters are 160 A and 22V value due to fact that fine grain structure improves remove the possibility of cracks and enhance hardness.

IV. CONCLUSION

The conclusions drawn from these experiments are that defect free welds can be obtained on 6 mm thick aluminium alloy plates using Gas Metal Arc Welding process with current range of 150-170 A and at Gas Flow rate of 14-18L/Min. Some of welding samples as in case of sample 4 and sample 6 failed in the region of welding when conducting the Tensile tests due to inappropriate values of welding. The Hardnes was increased due to the fine grain structure of silicides. Sample 2 and Sample 5 were found to be best samples among others having welding parameters of 160 A and Gas flow rate of 14L/min and 18L/min respectively showing mechanical properties are dependent on specific values of welding parameters.

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