Evaluation of Micro-Structural and Mechanical Properties of Aluminium-(2%) Silicon Alloy of FSW, TIG and MIG Welded Material

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***Abstract*— Even though many investigation has been carried out on Aluminum alloys welded by FWS, TIG and MIG process, data need to be generate for further refinement of the process parameter is feasible to reduce defect and enhance the Weld Quality. The welding parameters such as arc voltage, welding current and speed are taken into account. So, in the present study, an attempt has been made to show how the Solid state Welding process (FWS) is efficient process of welding Aluminum alloys in Engineering applications compared to conventional welding process (TIG and MIG).**

In this paper, attempts are made to compare the welding process through its structural and Mechanical testing such as tensile test and hardness test. The research data will be helpful in defining the Applications for different engineering fields such as Automobile, Marine, nuclear, Aerospace etc..,

Keywords—Aluminium alloy, Silicon alloy, TIG, MIG, FSW

I. INTRODUCTION

Aluminium-silicon alloys are heavily used in the aluminum alloy casting industry, where silicon is the single most important additive to aluminum to improve its casting properties. Since cast aluminum is widely used in the automobile industry, this use of silicon is thus the single largest industrial use of "metallurgical grade" pure silicon (as this purified silicon is added to pure aluminum, whereas ferrosilicon is never purified before being added to steel). Various additives are usually used to modify industrial alloys. At the same time, the structure and mechanical properties of hyper-Eutecticum modified cast alloys has been studied mainly for Si content up to 19 at.%. It is only known that increasing the Si content results in an increase of the strength of hypoeutectic alloys and a decrease of the strength of hypereutectic alloys. Important factors are the structure of the melt, the crystallization rate, and the temperature gradient at the liquid–solid interface.

After the discovery of the electric arc in 1800 by Humphry Davy, arc welding developed slowly. C. L. Coffin had the idea of welding in an inert gas atmosphere in 1890, but even in the early 20th century, welding non-ferrous materials such as aluminium and magnesium remained difficult because these metals react rapidly with the air and result in porous, dross-filled, welds. Processes using flux-covered electrodes did not satisfactorily protect the weld area from contamination. To solve the problem, bottled inert gases were used in the beginning of the 1930s. A few years later, a direct current, gas-shielded welding process emerged in the aircraft industry for welding magnesium. During the 1950s, as the process continued to gain popularity, some users turned to carbon dioxide as an alternative to the more expensive welding atmospheres consisting of argon and helium. However, this proved unacceptable for welding aluminium and magnesium because it reduced weld quality, so it is rarely used with GTAW today. The use of any shielding gas containing an oxygen compound, such as carbon dioxide, will quickly contaminate the tungsten electrode and should not be used with the TIG process. To improve welding quality of aluminum plate pre and post welding precautions must be taken during welding process. TIG welding is a high quality welding process used to weld the aluminum. The TIG welding process is so good that it is widely used in the high-tech industry applications such as, nuclear industry, aircraft, food industry, maintenance and repair work and some manufacturing areas [1, 2]. From literature study, it is found that welding of aluminum is a big challenge by conventional arc welding process. Again repeatability of welding depends on its control on welding speed and other processing parameters. The tungsten and the welding zone are protected from the surrounding air by a gas shield (inert gas). The electric arc can produce temperatures of up to 19,400º C and this heat can be much focused local heat.

II. LITERATURE REVIEW

TIG welding is a welding process that uses a power source, a shielding gas and a TIG hand piece. The power is fed out of the power source, down the TIG hand piece and is delivered to a tungsten electrode which is fitted into the hand piece. An electric arc is then created between the tungsten electrode and the work piece. The tungsten and the welding zone are protected from the surrounding air by a gas shield (inert gas). The electric arc can produce temperatures of up to 19,400oC and this heat can be much focused local heat. The weld pool can be used to join the base metal with or without filler material [1, 2]. Sukhomay Pal, Santosh K. Malviya, Surjya K. Pal and Arun K. Samantaray [3] studied optimization of quality characteristics parameters in a pulsed metal inert gas welding process using grey-based Taguchi method. K.Y. Benyounis and A.G. Olabi [4] the optimization methods used in this study are appropriate for modeling, control and optimizing the different welding process. A. Kumar and S. Sundarrajan [5] Taguchi method was applied to optimize the pulsed TIG welding process parameters of AA 5456 Aluminum alloy welds for increasing the mechanical properties. P. Srinivasa Rao, O. P. Gupta, S. S. N. Murty and A. B. Koteswara Rao [6] studied the effect of process parameters and mathematical model for the prediction of bead geometry in pulsed GMA welding. Ching-Been Yang & Chyn-Shu Deng and Hsiu-Lu Chiang [7] proposes a progressive Taguchi neural network model, which combines the Taguchi method with the artificial neural network to construct a prediction model for a CO_2 laser cutting experiment.

Her-Yueh Huang [8] They presents the effect of each welding parameter on the weld bead geometry, and then sets out to determine the optimal process parameters using the Taguchi method to determine the parameters. S.C. Juang and Y.S. Tarng [11] studied the process parameter selection for optimizing the weld pool geometry in the tungsten inert gas welding of stainless steel.

III. EXPERIMENTAL PROCEDURE

In the present study, investigation has been carried out on Aluminum alloys welded by FWS, TIG and MIG process. In this process, plates (110mm*60mm*6mm) of commercial aluminum and 2% Silicon Alloy were used for base material. Taking the mixtures of Aluminum and 2% Silicon alloy an Ingot, sample is made by the Stir casting process. The term stirring is the process of continuous stirring of molten Aluminum and 2% Silicon alloy melt for some time and immediately pouring the molten metal into the sand mould then cooled and allowed to solidify. In stir casting, the particles tend to agglomerates, which can only be dissolved by vigorous stirring at high temperature.

Fig. 1. Ingot sample of Aluminum and Silicon alloy

Then converting ingot in to rectangular plate of required dimensions used for the welding process.

Fig. 2. Fig: Rectangular plate of Aluminum Silicon alloy

A. *MIG, TIG & FSW Welding*

- MIG, TIG *Welding*

An arc is maintained between the end of the bare wire electrode and the work piece. The wire is fed at constant speed selected to give the require current, and the arc length is controlled by the power source. The process can be operated at high currents (130-140amps).The electrode can be solid or flux code.

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perfectly clamped in a FSW machine bed on a backup plate tool is punched into the joint in the downward direction with feed rate in clockwise direction. Higher tool rotation rates generates higher temperature because of higher friction heating and result in more intense stirring and mixing of material.

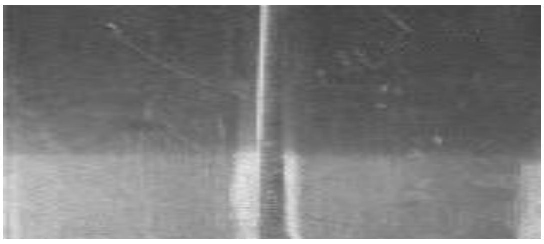


Fig. 5. Friction Stir welding specimen (FSW)

- Test specimen preparation for testing

Test sample for the welding were made in the form of plate ,length of 110 mm , width 60 mm , thickness of 6 mm were casted and machine. The samples where cleaned by using acetone to remove surface oxides.

TABLE I. TABLE STYLES PARAMETERS USED FOR WELDING SPECIMENS (FSW)

Sl. No	Speed (RPM)	Load (tons)	System Pressure(kg/cm^2)
1	650	2.65	30
2	650	2.48	30
3	650	2.56	30

1) *Tensile test:*

Test is performed as per the ASTM E8 standards. A tensile test measures the resistant of material to a static or slowly applied force. The stress obtained at the maximum force is the tensile strength. Elongation describes the extent to which the specimen stretched before fracture.

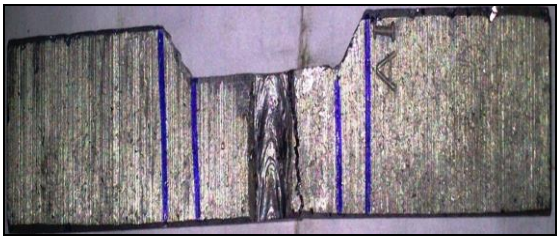


Fig. 6. Tensile specimen

2) Hardness:

Hardness test was carried out by using Vicker's hardness testing machine .The surface preparation of the specimen was done and diamond indenter was used to make a dent on the prepared surface and the dimension of the dent measured . Hardness measurements were taken at different points for an applied load 50 gms using Vickers hardness testing method.

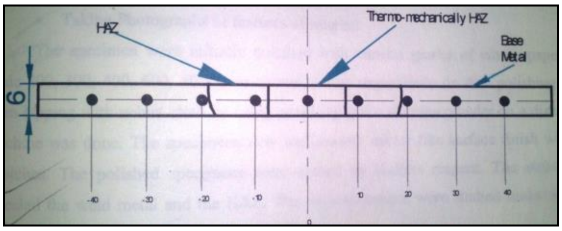


Fig. 7. Hardness specimen of FSW Welded specimen

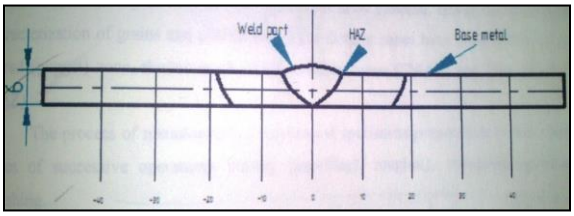


Fig. 8. Hardness specimen of MIG welding

3) Microstructure for Aluminum- 2% Silicon

- Microstructure of Base metal

Microstructure for the Base metal weld consists of randomly dispersed particles of Silicon in a matrix of a aluminum solid solution. Some coring (micro-segregation) is seen in the matrix.

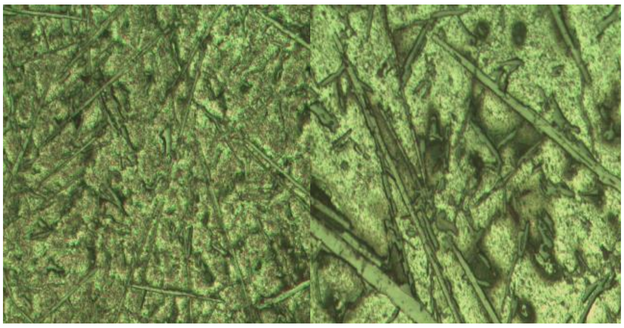


Fig. 9. Microstructure of a Base metal weld

- Microstructure of TIG Welded specimen

Microstructure of the TIG welded specimen of parent metal shows randomly dispersed particles of Si in a mixture of aluminum solid solution. Some coring is also seen. The HAZ shows a mixture of fine dendrites along with finer particles of Silicon. The weld shows fine dendrites aluminum solid solution. Fusion is good, no defect were seen.

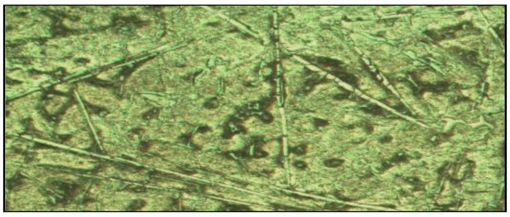


Fig. 10. Microstructure of parent

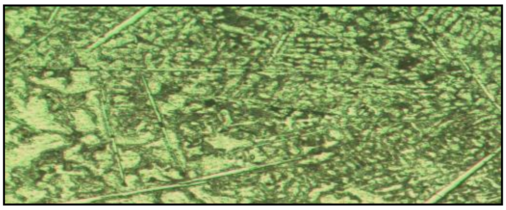


Fig. 11. Microstructure of HAZ

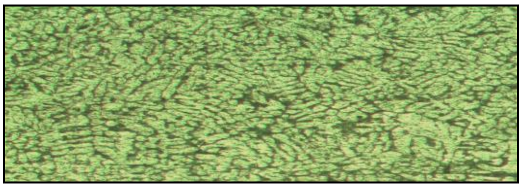


Fig. 12. Microstructure of welded zone

- Microstructure of MIG Welded specimen:

Microstructure of the MIG welded specimen of parent metal shows randomly dispersed particles of Si in a mixture of aluminum solid solution. Some coring is also seen. The HAZ shows a mixture of fine dendrites along with finer particles of Silicon. Some eutectic mixture is also seen. The weld shows fine dendrites aluminum solid solution. Fusion is good. No defects were seen.

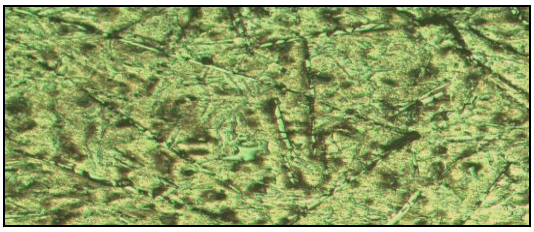


Fig. 13. Microstructure of parent

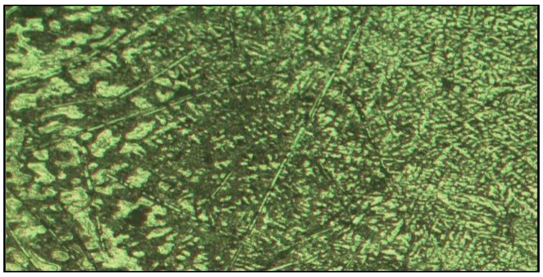


Fig. 14. Microstructure of HAZ

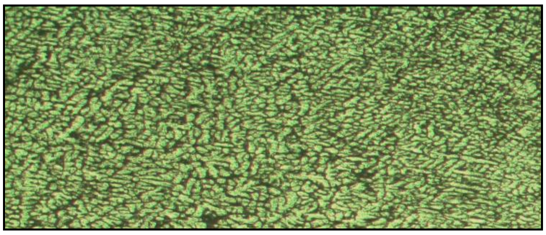
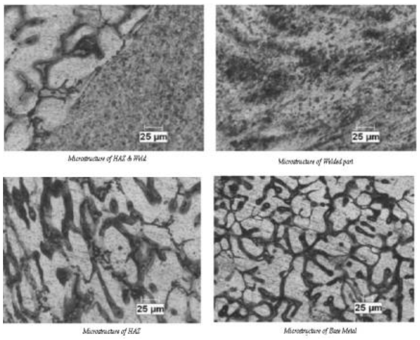


Fig. 15. Microstructure of weld region

- Microstructure of Friction stir welded specimen (FSW):



IV. RESULTS AND DISCUSSIONS:

After a weld has been done, the specimens were tested in a universal testing machine in the order to determine yield strength. The tensile test result of FSW weld specimens was compared to the tensile test results of a MIG, TIG weld specimen. Tensile test were carried out for three different samples to obtain the Stress-Strain of the weld metal zone.

A. Tensile test results

Following table and figure shows the tensile test reading and results of different specimens.

TABLE II. YIELD STRENGTH FOR TIG, MIG AND FSW SPECIMENS

Welding process	Specimen	Tensile strength (N/mm2)
Base	1	75
	2	78
	3	80.83
TIG	1	9.25
	2	10
	3	12
MIG	1	3.83
	2	4.56
	3	6
FSW	1	47.48
	2	92.63
	3	49.4

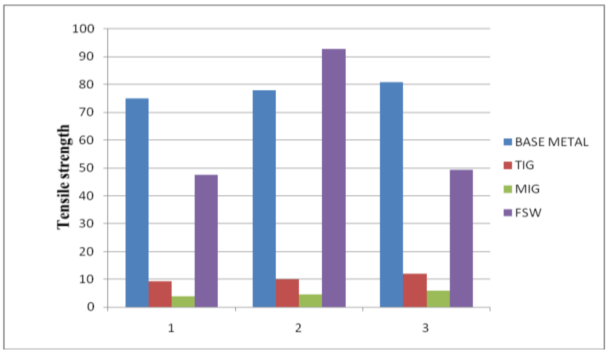


Fig. 17. Tensile Strength for different specimens Graph

B. Micro-hardness test

Micro-hardness test was conduct to measure the hardness at different zones namely weld zone, HAZ and base metal zone.

Micro-hardness values along the cross section (transverse to weld direction) of samples was measured by using Vickers micro hardness testing machine. Surface Hardness of the Base metal specimen is 84 HV1. The results obtained for TIG, MIG and FSW is shown.

TABLE III. MICRO-HARDNESS MEASUREMENTS FOR TIG WELD

Location	Hardness , HV1
Weld	72
HAZ	63
Base	88

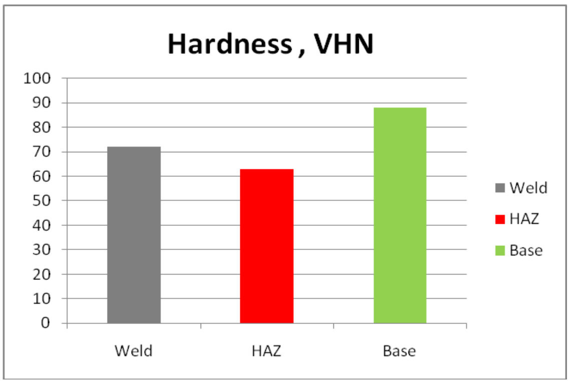


Fig. 18. Hardness values in different areas

TABLE IV. MICRO-HARDNESS MEASUREMENT FOR MIG WELD

Location	Hardness , HV1
Weld	82
HAZ	97
Base	88

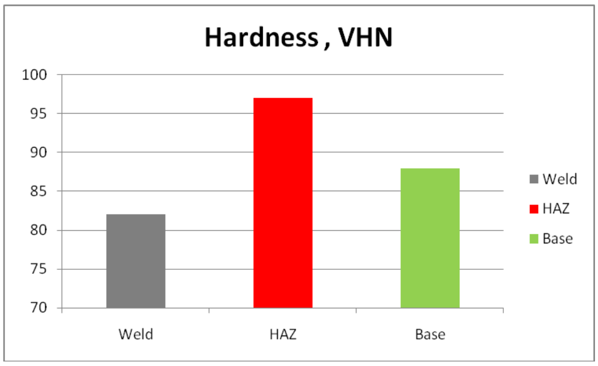


Fig. 19. Hardness values in different areas

TABLE V. MICRO-HARDNESS MEASUREMENT FOR FSW WELD

Location	Hardness , HV1
Weld	69.4
HAZ	71.2
Base	76.4

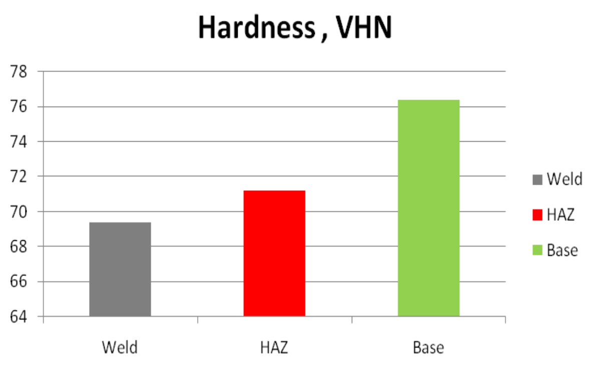


Fig. 20. Hardness values in different areas

V. CONCLUSIONS:

After all the experiments and discussions we have come to a point that the welded imperfection significantly reduce the tensile strength and Hardness of welded joints. Further from the above investigation we arrived at following results.

- Of the three processes, FSW welding joint exhibited higher tensile strength values in comparison with TIG and MIG joints.
- TIG & MIG joints shows less strength because of incomplete penetration compared to FSW joints.
- Hardness of welding joint was found to be low in the FSW compare to TIG and MIG weld specimens
- In FSW joints the grains are fine columnar at weld zone. Microstructure of the parent metal shows dendrites of aluminium silicon solid solution.

VI. ACKNOWLEDGMENT

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