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Comparative Study of Different Welding Joining Processes on Aluminum Plate

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Abstract*:* *We observed that when we weld on Aluminum plate with various welding processes some defects are found in the weld. Some weld defects are less corrosion resistance, less strength, porosity, lack of fusion, black spot, change in mechanical properties, change in microstructure and environmental harmful gases produced. Welding is process of permanent joining of two materials with or without using filler material between two metal plates. Welding use a non-consumable or consumable tool to generate heat in the abutting surface. To change in welding parameter such as temperature, pressure, voltage, current, tip angle, welding speed, rotational speed, tool geometry play major role in deciding joint properties. So our attempt for this project is to comparative study of considering three welding processes such as Friction stir welding, manual metal arc welding and Metal inert gas welding Aluminum plate and observes changes in mechanical properties and microstructure of Aluminum plate. Also to find best welding process to overcome defects in different welding processes to join Aluminum.*

Keywords: Tungsten inert gas welding, Metal inert gas welding, Friction stir welding, Aluminum 6082, Tool pin EN8 series, Process parameter & mechanical Testing, Microstructural Analysis of TIG, MIG & FSW

I. INTRODUCTION

Welding is a process of permanent joining two materials (usually metals) through localised coalescence resulting from a suitable combination of temperature, pressure and metallurgical condition. Depending upon the combination of temperature and pressure from a high temperature with no pressure to a high pressure with low temperature, a wide range of welding processes has been develop.

Friction stir welding (FSW) is a relatively new joining process that is presently attracting considerable interest. The FSW process was developed at TWI in 1991. Friction stir welding uses a non-consumable, rotating tool that is cylindrical in shape with a cylindrical pin of smaller diameter extending from the tool shoulder Important process parameters include the tool rpm and travel speed, as well as the tool dimensions and the downward force on the tool

Hardness is very important mechanical property of material but during welding high heating and rapid cooling influence the hardness of the weld as well as the Heat affected zone (HAZ) Also the optimum hardness of weld and heat affected zone (HAZ) at minimal heat input rate for 60 and 70' bevel angle weldments have been investigated.

II. LITERATURE REVIEW

Ahmed Abotaleb & Marwan Khraisheh et al(2024) described in his paper Parametric investigation of friction stir welding of aluminum alloy using finite element analysis about The findings provide valuable insights into the influence of process parameters on key aspects such as temperature distribution, material flow, and strain rate. A 3D transient thermomechanical model was developed to examine these effects in detail, with particular emphasis on material softening at elevated temperatures and high strain rates during FSW. The analysis highlights the impact of various FSW parameters axial force, rotational speed, welding speed, shoulder diameter, and pin diameter Results indicate that lower workpiece temperatures lead to finer grain structures, reduced stress evolution, and increased hardness[1]

Piotr Noga &Tomasz Skrzekut et al(2023) analysed the applied joining technologies of the 6082 aluminum alloy allowed us to obtain homogeneous joints without inconsistencies and with comparable mechanical properties. The joint

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obtained in relation to the starting material, while the FSW joint was 61%.. However, in the case of the fracture of the FSW joint and the base material, the fractures were plastic, which translated into a higher elongation obtained in the tensile test. The microstructural analysis of the FSW joint showed that structure-renewal processes dominated in the weld area. There is a change in the morphology and dissolution of the particles due to high temperature and the influence of the tool [2]

Vanita S. Thete et al. (2015) describe in this paper that, the taper cylindrical with three flutes all made of High speed steel for the friction stir welding (FSW) aluminum alloy H30-H30 and the tensile test of the welded joint were tested by universal testing method. The detailed mathematical model is simulated by Minitab17. In this investigation, an effective approach based on Taguchi method, has been developed to determine the optimum conditions leading to higher tensile strength. Experiments were conducted by varying rotational speed, transverse speedconstant welding depth, using L9 orthogonal array of Taguchi method. The present work aims at optimizing process parameters to achieve high tensile strength. The optimum value of process parameters such as rotational speed, traverse speed and welding depth are found to be 1400rpm (level 2), 20 mm/min (level2) and 5mm (constant) respectively [3]

Dan Birson et al. (2014), The investigation focused on the modeling by finite elements of heat transfer and Von Misses stress field and simulation of the tensile test when applying friction stir welding (FSW) and classical Tungsten Inert Gas (TIG) welding at the aluminum alloy AA 6082-T6 butt joints performing. Both the numerical and experimental results revealed big differences between the behavior of the base materials welded by FSW and TIG. It is important to study the heat transfer mode during the welding process, because it has a huge influence on the mechanical properties changes of the welded joint Taking into account the great number of advantages, Friction Stir Welding (FSW) could be a welding ecological alternative to the classical fusion welding procedures. Higher process temperature reached in the fusion welding process, with negative consequences on the metallurgical and mechanical behavior of the aluminum alloy, makes FSW procedure more attractive from this point of view. Besides, because no filler wire is required then more reduced weight is achieved and due to the lower heat input required then less distortion occurs in the joint [4]

Samir S. Kulkarni et al. (2014), In this paper one of the method is Metal inert gas (MIG) welding, in which argon, helium Co2 are used as shielding gas. MIG welding is versatile and having less loss of alloying elements and can be operated as semi- automatic and fully automatic welding Parameters of welding such as welding current, arc voltage, welding speed and output parameter are hardness, tensile strength, impact energy, and microstructure. We considered aluminum alloys which widely used in marine, aerospace, pipe industries etc. Aluminum alloys are light in weight comparably less density with better mechanical properties with mild steel from the above literature survey we find that there are much investigation is done on effect of welding parameters on mechanical properties by using MIG welding and others on aluminum alloys. But we found that there is only few research is done on mechanical properties by varying various parameters of MIG welding such as gap between metal and torch, welding speed angle of torch feed wire diameter and Gas flow rate on aluminum alloys[5]

III. PROBLEM DEFINATION AND METHODOLOGY

3.1 Problem Definition

To investigate best welding joining process among FSW, TIG, MIG for Aluminum alloy. We observed that when we weld Aluminum alloy with convectional welding process then defect in weld this defect like porosity, lack of fusion and burn, less strength, less corrosion resistance, black spot, environmental harmful gases etc. So, now days we required non-convectional welding process which overcome this defect and have environment friendly property

3.2 Objective

- To find tensile strength as per ASTM 370 standard on Al Alloy plate using Tungsten inert gas welding (TIG), Metal inner gas welding (MIG) and Friction stir welding (FSW).
- To find impact strength as per ASTM standard E23-07a on Al Alloy plate using Tungsten inert gas welding (TIG), Metal inner gas welding (MIG) and Friction stir welding (FSW).
- To investigate microstructure behaviour of welding process.

3.3 Methodology

1. Selection of welding process, TIG, MIG, & FSW joining processes.
2.Selection of base plate & tool pin, fabrication of pin profile
3.Tensile property evaluation on UTM, Microscopic analysis

3.4 Result validation

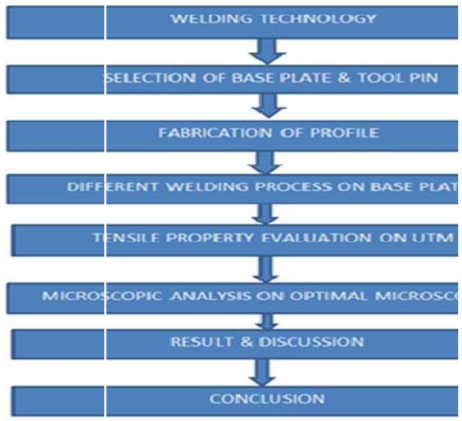

Fig-3.3.1.Flow chart for methodology for completion

IV. MATERIAL SELECTION AND PROPERTIES

4.1 Base plate material

Alloy 6082 T6, Melting point of aluminium alloy is about 550ºC, Light weight density is about of 1/3 that of steel or copper alloys. Certain aluminium has better strength to weight ratio than that of high strength steel. It has good malleability and formability, high corrosion resistance and high electrical and thermal conductivity. Apure form of Al is used as photographic reflectors.Non tarnishing characteristics on toxic, nonmagnetic, and non- sparking Electrical conductivity of the electric conductor grade is about 62% that of copper.It is relatively soft and weak and its Strength can be increased by cold working, alloying and heat treatment, High machinability and workability

Table 4.1 chemical composition of Aluminium plate

Aluminum	Al	Mg	Mn	Cu	Si	Cr
6082 T6	95.2 To 98.3	0.60 To 1.20	0.40 To 1.0	Max 0.10	0.7 To 1.3	Max 0.25

4.2 Tool pin material for FSW

H-13 Tool steel is used, It is a hot worked tool steel with good tensile and wear resistance properties, General purpose hot worked tool steel used in a wide range of applications like Aluminum extrusion dies, backers and bolsters, stems and mandrels, die casting dies and forging inserts. Hardening should be done in controlled atmosphere, vacuum or fluidized bed furnaces, Preheat slowly to 450/800°C then raise to 1000/1030°C, holding for sufficient, time to attain uniformity throughout the tool, and it will later air cooled,

Tempering should be carried out immediately after air quenching. Heat to 550/650°C, holding for one to three hours. Tools benefit from multi tempering and a minimum of two tempers is recommended

Table 4.2 chemical composition of EN 8 series steel

Steel	Cr	Mn	Mo	C	Si	p
H-13	4.75 TO 5.50	0.20 to 0.5	1.1 to 1.75	0.3 to 0.45	0.8 to 1.2	0.05 Max

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4.3. Specimen Profile for tensile testing

Dimension for tensile test specimen are Length-150mm, width-25mm, Thickness -5 mm. Ultimate tensile strength & Yield strength are observed on tensile test

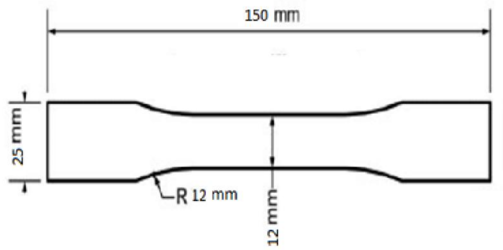

Fig.4.3.1-tensile test specimen

4.4. Specimen Profile for Impact testing

The impact test sspecimens were prepared to the welded joints as per the guidelines of American Society of Testing of Materials (ASTM E23-07a), Standard specimens (50 x 10 x 5) mm with a notch of 2 mm depth, 45 and 0.25 mm root radius was prepared to evaluate the impact toughness of the weld metal.
Dimension for impact test specimen are Length-55 mm, width 10mm, & Thickness 5mm. The specimen profile is used to perform tensile test and impact test are taken from ASTMA370: 2012 standards and American Society of Testing of Materials (ASTM E23-07a).

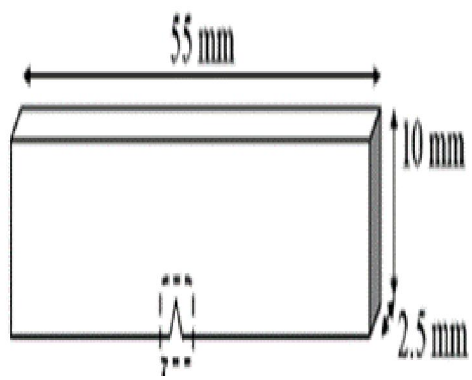

Fig.4.4.1-Impact test specimen

V. EXPERIMENTAL TESTING

5.1 Process parameter for FSW welding

Various Process parameter for Friction stir welding We had taken into consideration while welding on aluminium 6082 T6 plate are as follow

Table 5.1-process parameter for FSW welding

Sr. No	Process Parameter	Reading
1	Total rotational speed	700 rpm
2	Welding speed	1.5 in/min
3	Tool pin spindle	Square & taper
4	Machine used	Milling
5	Tilt angle	2 degree.
	Tool pin Dimension	

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6	a) Shoulder diameter	16 mm
	b) length of pin	4.7mm
	c) Lower pin tip	$2*2=4mm^2$
	d) Taper angle	100

5.2 MECHANICAL TENSILE TESTING

Specimen for tensile testing were taken at middle of all the joints in the transverse direction from the welded joints and machined to ASTMA370: 2012 standards tensile test was carried out in 25 KN, servo controlled Tensile Testing Machine (Make: FSA99/03, India, Model: TKG 25 KN), at SHANMUKHA LABORATORIES in MIDC Ambad, Nasik Ultimate tensile strength, yield strength are the output parameters of tensile strength

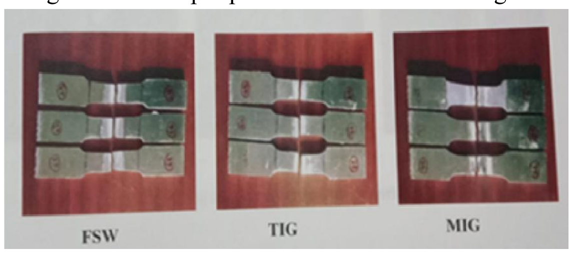

Fig.5.2.1-Tensile specimen after testing

5.3 MECHANICAL IMPACT TESTING

The impact test specimens were prepared to the welded joints as per the guidelines of American Society of Testing of Materials (ASTM E23-07a), Standard specimens (50 x 10 x 5) mm with a notch of 2 mm depth, 45 and 0.25 mm root radius was prepared to evaluate the impact toughness of the weld metal.
The specimen prepared for impact test before testing and after testing is carried out on charpy impact tester of standard specifications. The specimen standardization is done according to machine specification and mechanical properties of material. It is observed from fig. that all the specimens are break at the welded zone, because it has comparatively less strength. The values obtained are in terms of joules. And according to that we can concluded that FSW is best welding process which gives very good mechanical properties.

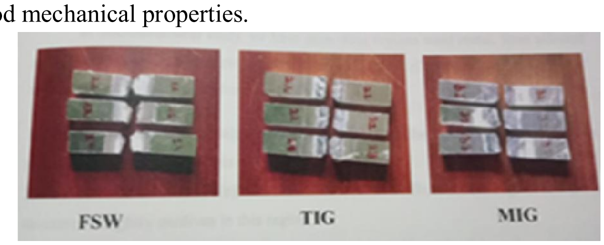

Fig.5.3.1-Impact specimen after testing

5.4 MICROSTRUCTURE TESTING

The microstructure test specimens were prepared to the welded joints as per the guidelines of American Society of Testing of Materials (ASTM E23-07a). Standard specimens (50 x 10 x 5) mm was prepared to evaluate the microstructure testing of the weld metal.

5.4.1 Microstructure of Friction stir welding

In microstructural study we have seen three regions weld metal, Heat affected zone. Base metal in every sample. The grain structure of material and structure of welding is very much differ from each other. Weld metal (left hand side): Grain structure is not uniform in this region and grain structure is slightly fine in this region.Heat affected zone

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(middle): Grain structure is not uniform in this region and grain structure is slightly medium in this region.Base metal (right hand side): Grain structure is uniform in this region and grain structure is slightly course in this region.

Fig 5.4.1Microstructure of FSW

5.4.2 Microstructure of Tungsten Inert Gas welding

In microstructural study we have seen three regions weld metal, Heat affected zone, Base metal in every sample. The grain structure of material and structure of welding is very much differ from each other**.**Weld metal (left hand side): Grain structure is not uniform in this region and grain structure is slightly course in this region**.**Heat affected zone (middle): Grain structure is not uniform in this region and grain structure is slightly medium in this region. Base metal (right hand side): Grain structure is uniform in this region and grain structure is slightly fine in this region

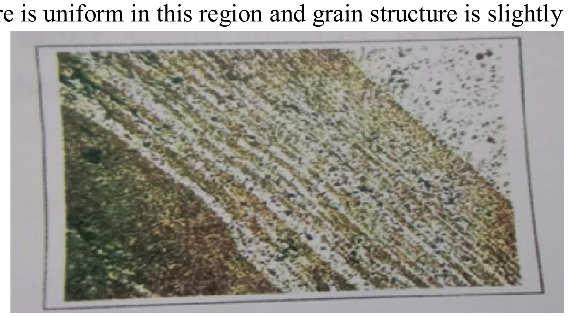

Fig 5.4.2 Microstructure of TIG

5.4.3 Microstructure of Metal Inert Gas welding

In microstructural study we have seen three regions weld metal, Heat affected zone, Base metal in every sample. The grain structure of material and structure of welding is very much differing from each other**.**Weld metal (left hand side): Grain structure is not uniform in this region and grain structure is slightly medium in this region**.**Heat affected zone (middle): Grain structure is not uniform in this region and grain structure is slightly course in this region. Base metal (right hand side): Grain structure is uniform in this region and grain structure is slightly fine in this region.

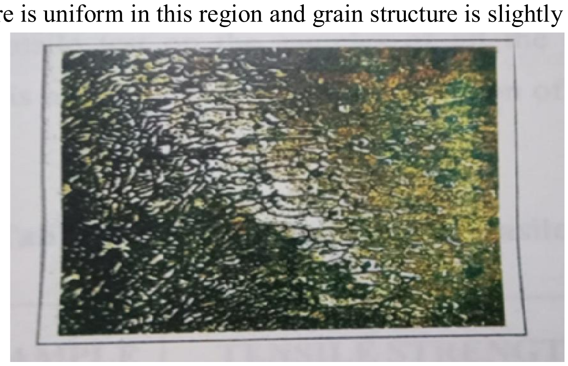

Fig 5.4.3 Microstructure of MIG

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VI. EXPERIMENTAL RESULTS AND DISCUSSIONS

6.1 Tensile testing Result

After doing tensile test on the samples of all the three welding processes following result table is obtained, which shows the variation of tensile strength in all the three welding processes.

Table 6.1 Result obtained for tensile test

Type of process	Sample number	Tensile strength (Mpa)	% Elongation
FSW	11	241.17	9.10
	12	153.26	6.08
	13	137.79	5.10
TIG	21	43.80	1.68
	22	19.96	1.94
	23	47.20	2.96
MIG	31	177.46	5.42
	32	160.16	3.26
	33	137.28	1.73
Base Metal	BM	282.70	13.76

From the above result table 6.1 we can say that tensile strength & % of elongation is highest of FSW, followed by TIG and MIG. FSW gives highest tensile strength among all three selected welding processes. This also gives high mechanical properties as compared to TIG and MIG. Tensile strength of FSW is about 74.8% that of the base metal. Tensile strength of TIG is about 15% that of the base metal. Tensile strength of MIG is about 62.8% that of the base metal. From above observation we can say that FSW have highest tensile strength among all welding processes.

6. 2 Impact testing Result

After doing impact test on the samples of all the three welding processes, following result table is obtain which shows the variation of impact strength in all the three welding process rom above result table we can say that impact strength of FSW is highest, followed by TIG & MIG. FSW have highest impact strength among all the three welding processes. Which also gives high mechanical properties as compared to TIG and MIG.

We can say that FSW gas highest impact strength, which is higher than base metal. This also gives high mechanical properties as compared to TIG and MIG. Impact strength of FSW is about 105.6% that of the base metal. Impact strength of TIG is about 21.1% that of the base metal. Impact strength of MIG is about 43.9% that of the base metal. From above observation we can say that FSW have highest Impact strength among all welding processes

Table 6.2 Result obtained for Impact test

Type of process	Sample number	Joules	Average
FSW	11	9.5	9.5
	12	10.0	
	13	8.0	
TIG	21	1.5	1.5
	22	1.5	
	23	1.5	
MIG	31	3.0	3.67
	32	4.0	
	33	4.0	
Base Metal	BM	9.0	9.0

6.3 Conclusion & Future Scope

6.3.1 Conclusion

The applied joining technologies of the 6082 T6 aluminum alloy allowed us to obtain homogeneous joints without inconsistencies and with comparable mechanical properties.

FSW have highest tensile strength& Impact strength among all welding processes.

The microstructural analysis of the FSW joint show that structure renewal process dominated in weld area

6.3.2 Future scope

We have studied that when we weld Aluminum alloy by using convectional welding process, we have found out various defect like porosity, lack of fusion and burn, less strength, less corrosion resistance, black spot, environmental harmful gases etc. So, now days we required non-convectional welding process which overcome this defect and have environment friendly property. In this project we have find out best welding process in which we had overcome the defects found in conventional welding process.

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