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Study on Corrosion Behavior of Friction Stir Welded AA 6061 Hybrid Metal Matrix Composite Plates

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Abstract- **Cast Aluminium 6061 alloy is most widely used in Advanced engineering fields like marine engineering, automobile and aircraft industry due to corrosion resistance, lightweight, high specific strength and flexural stiffness, however to extend their applications limit, an appropriate joining process is needed for developing a robust structure. In the present investigation, Hybrid Aluminium metal matrix composites (MMCs) is prepared by varying the weight percentage of reinforcement of fine greenish Silicon carbide particulates and short chopped E-glass fiber along with Aluminium 6061 alloy by stir casting technique using graphite crucible furnace, The process yields sound castings which is then followed by joining of plates carried out by Friction stir welding (FSW) process using cylindrical tapered tool with varying welding parameters like rotational speed and traverse feed, and the impetus given on the effects of torque, normal force, traverse force that acts on the plates during welding. The studies majorly focusses on the corrosion behavior of joint obtained by Friction Stir Welding process and compare the same with base material in respect to its corrosion rate.**

Keywords: Corrosion, Friction stir welding, Metal matrix composites, Stir casting.

I. INTRODUCTION

Since the early 1960, there is demand for new and better engineering materials with advancement of modern technology interest in the areas of aerospace, auto-motive, bridges, fabrication industries, buildings, and had forced a rapid development of metal matrix composites. And there is a High demands on material for better overall performance has led to extensive research work and development efforts in the composites fields. To reach the present needs. Among the composites research field, the aluminum related metal matrix composite materials are widely used. Aluminium metal matrix composite (AMMCs) belongs to the group of light weight high performance aluminium centric material systems. And they have high elastic modulus and high specific strength both at ambient and elevated temperatures [1-2].

Prashanth Sharma et al., [3] in their work have shown that the reinforcement in AMMCs could be in the form of continuous/discontinuous fibers and different particulate materials, On that grounds, it is decided in the present work to fabricate metal matrix Composite (MMC) materials reinforced with short E-glass fibers (2-3 mm length and 10μ dia.) and fine particulate Silicon carbide powder (fine greenish 25 μ) to enhance the mechanical Properties of metals. Most of the research work has been concerned with aluminium matrix and SiC reinforcement requiring the light weight along with combinations of high strength and high stiffness. In addition, the reinforcement of E-glass fibers provides impressive strength and better thermal expansion coefficient and corrosion resistance property.

In this work stir casting is adopted to get sound castings and homogeneous distribution of fibers and particulates in matrix [4 – 6].

Further the cast plates are welded by advanced solid joining technique called Friction Stir Welding (FSW), Because of several advantages like clean, fast, environment friendly, absence of residual stresses, better control over process, absence of filler material, absence of inert gas which ensures that unique advanced type of welding is adopted in present work to achieve property enhancement [7-11].

The process of friction stir welding was invented by W.Thomas and his colleagues at The Welding Institute (TWI), UK, in 1991 [12]. Friction stir welding (FSW) was invented to provide controlled micro structural modification in metallic materials.FSW uses a rotating cylindrical tool having a shoulder and a pin (tip) which is pressed against the work material to be processed and moved along the welding direction. The local heating due to friction and forging action of the tool deform and process the work material at high temperature. Since the material flows at high temperatures, the process offers the possibility of redistributing the particles in AMCs [13-16].

The potential applications of FSW in Aerospace, marine, automobiles and land transport domains are as mentioned below: Engine and chassis cradles, Wheel rims, Truck bodies, Tail lifts for Lorries, Mobile cranes, Fuel tanks [17].

II. EXPERIMENTAL

The present work deals with the fabrication and corrosion characterisation of a hybrid composite with the following constituents.
*Aluminium 6061 matrix
Aluminium silicon magnesium alloys – commonly known as AA 6061 series alloys.

Table 2.1 chemical composition of Al 6061

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
0.4 - 0.8	0 - 0.7	0.15 - 0.4	0 - 0.15	0.8 - 1.2	0.04 - 0.35	0 - 0.25	0 - 0.15	Bal

*Silicon carbide particulates.
*E-glass fiber reinforcement.
The composites of above materials varied in the following proportions:

90% Aluminium 6061 +3% E-glass +7% SiC particulates

The experimental procedure adopted in the present research work consists of three phases mentioned as below:

Phase: 1 Fabrication

Cast Aluminium 6061 ingots for a particular composition were placed inside a graphite crucible and melted in a coke fire open furnace, the temperature of a furnace was made to reach 800o C. Aluminium melts at around 660o C the superheat was given to ensure liquid state of aluminium 6061 during mixing and pouring. Molten aluminium 6061 is taken in a ladle and it is poured in to a mould set up contains mould cavity of require shape of plates and produce null percentage of reinforcement in aluminium 6061 specimen followed by varying percentage of sic and E-glass. But preparation of hybrid composite is contains following steps preheat the furnace, placing ingots and heated upto 800 o c separately weigh the 7% and 3% weight fraction of fine greenish silicon carbide particulates preheated up to700o C (preheat leads proper wettabality and prevent sudden cooling of the melt which causes the brittleness) and short chopped E-glass fiber preheated to 500 0C respectively. Before this preheated ingredients added to the mixture, some of the molten state aluminum 6061 is taken out of the furnace, Poured after adding preheated reinforcement in furnace. Immediately the mixture of crucible was stirred with the help of electric stirrer at the speed of 500 rpm 10 minutes to get homogeneous distribution of reinforce in matrix maintain pouring temperature before poured into the cope and drag box setup, allowed to solidifies up to 1 hour after takeout the cast specimen

Fig. 2.1 SiC particulates

Fig. 2.2 Short E-glass fibers

Fig. 2.3 Preheating

Fig 2.4 Electric stirring

Fig 2.5 Mould preparation

Fig 2.6 Pouring

Phase 2: Machining

The cast specimen had to be machined for to get standard weld specimen. The dimensions are in accordance with the ASTM standards. The specimens dimension is 100mm*50mm*6mm.

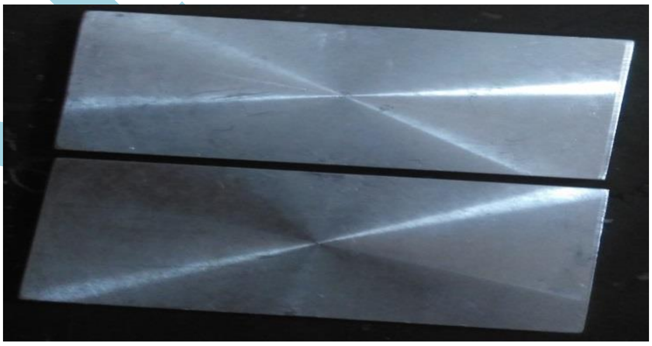


Fig. 2.7 Speciment for Friction Stir Welding

Phase: 3 Friction stir welding

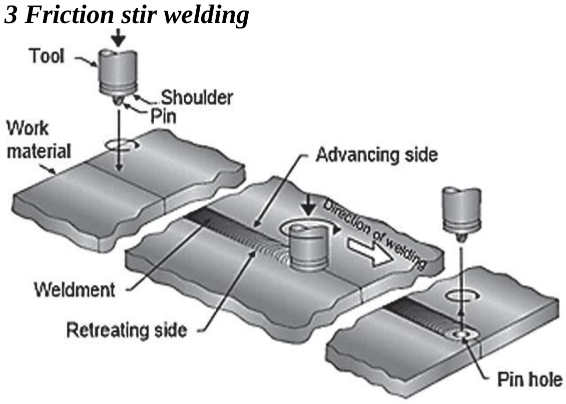


Fig. 2.8 Illustration of Friction stir welding process

In this phase, the plates of standard size 100mm*50mm*6 mm are brought to butt join using Friction stir welding. The welding is carried out using an indigenously built Friction Stir Welding machine, with the shoulder pin of the tool plunging in between plates. Friction stir welding parameters are set considering the tool rotational speed as 600 rpm, tool traverse feed rate as 40 mm per min, number of pass as 1, tilt angle as zero.

The Tool considered in current research is having a shoulder diameter of 25 mm and a tapered pin of 5 mm length, Initially the two plates of aluminium are fixed firmly on the backing plate of versatile FSW machine in the vertical position and a compressive load is applied on the plates in order to prevent the formation of gap between two work plates, the bolt and nuts are tightened by using an allen key firmly to further enhance the compressive load acting on the plates. The machine is switched on and the hydraulic system is actuated, the spindle is operated and the parameters are fed to the FSW machine making use of a data interface setup and the welding is done on plates, the weld length is input in the data interface as 70 mm and tool penetration as 5.2 mm. After FSW, standard specimens of size 20mm*10mm*2mm are cut at weld zone using wire EDM process.

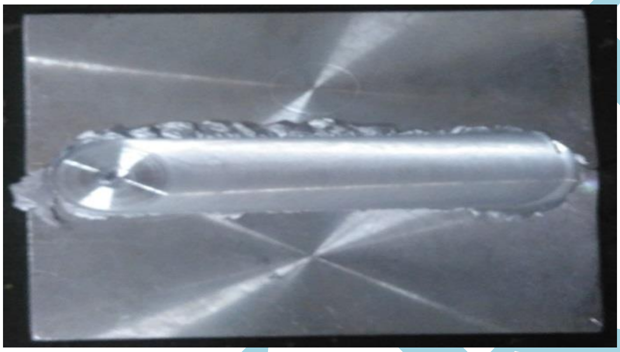


Fig.3.1. Friction stir weld plate

Table 3.1.Specifications Tool used in FSW process

Tool material	HcHCr
Tool pin length	5 mm
pin top diameter	4.5 mm
Pin bottom diameter	6 mm
Tool shoulder diameter	25 mm
Hardness	58-60 HRC

HcHCr: High carbon and High Chromium steel

Table 3.2. Process parameters in FSW process

Spindle speed	600 rpm
Traverse speed	40 mm per min.
Plunger depth	5.2 mm
Preheating time	10 sec.
Tool tilt	0

III. CORROSION TEST

Further to the FSW process, corrosion test is done to evaluate the corrosion behavior of Hybrid Aluminium composite 6061 for different compositions along with the base material and the results are compared taking into considerations all the variables for the samples considered.

Methodology carried out by H M Zakaria [18] serves as basis for the corrosion tests done in present work.

Following Test specimens of dimensions 20 mm * 10 mm * 2 mm are Prepared

[1] As cast Al 6061 specimen

[2] As cast Al 6061 + 3% E-glass +7% SiC

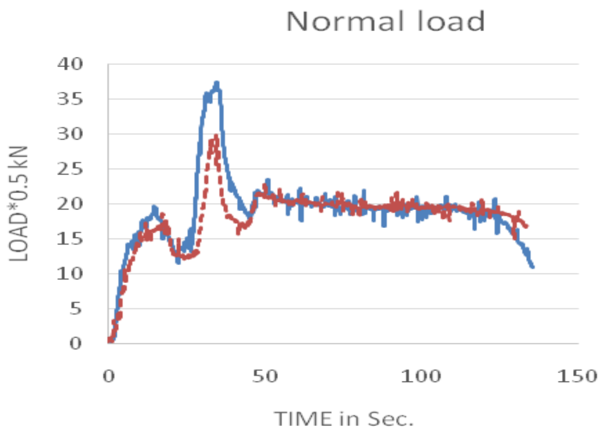
[3] Friction stir welded Al 6061 specimens.

[4] Friction stir welded Al 6061 + 3% E-glass +7% SiC specimens.

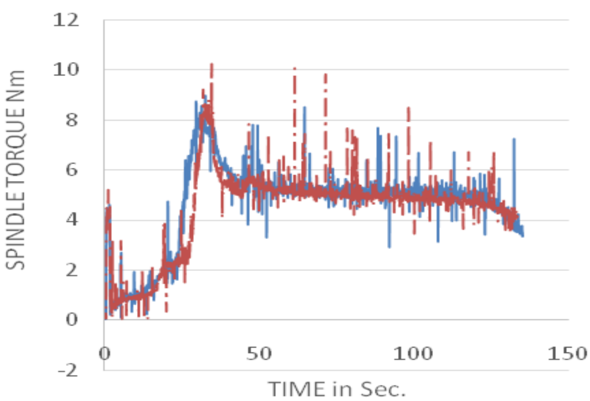
Corrosion characterization is done through potentiodynamic method which involves AC-impedance studies on specimens using 0.1 N HCl solution.

IV. RESULTS AND DISCUSSIONS OF FSW PROCESS OF AA 6061 ALUMINIUM ALLOY

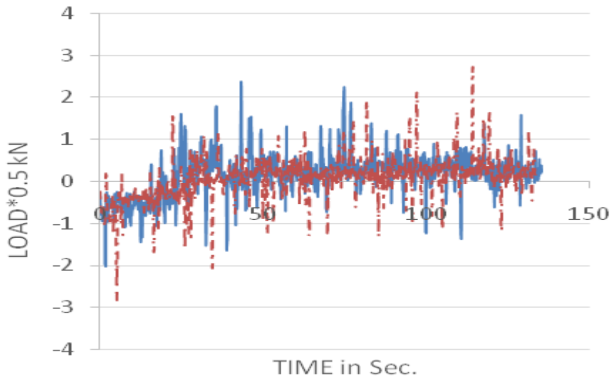
1. Graphical representation and comparison for Al 6061+3% E-glass+7%Sic and Al 6061.



Graph no: 1 Normal load vs time



Graph no: 2 Spindle torque vs time



Graph no: 3 Traverse load vs time

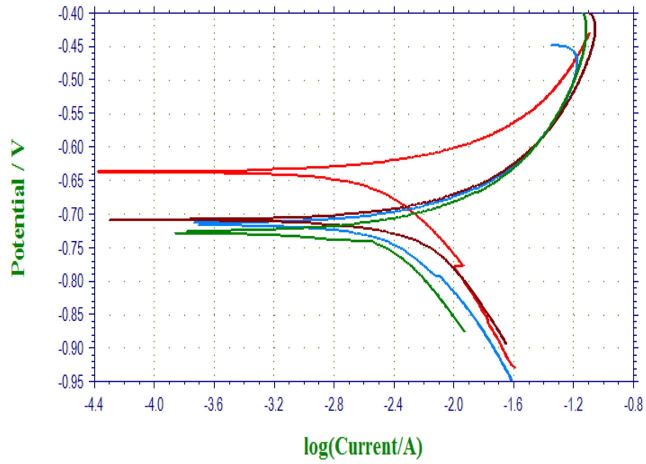
The graphs are plotted for Normal load vs time in seconds, Spindle torque vs time in seconds, Transverse load vs time in seconds for Aluminium 6061 specimens as well as Aluminium 6061/3% E Glass/7% SiC specimens, It is distinct form the graph of normal load versus time, that the normal load varies between 0 k N to 20 k N (Peak value) for an initial duration of 50 seconds (i.e., the time interval for plunging) to further become constant at 10 k N for remaining duration of time to finally drop down at the end of the process.

From the graph of spindle torque vs time, clear inferences can be drawn from the fact that the spindle torque varies from zero to a peak value of 10 N-m during the initial interval of 50 seconds inherently described as the time taken for plunging, and then remain constant until the end to further drop down at the completion stage of the process.
The graph of transverse load vs time is indicative of the fact that the transverse load varies from (-3*0.5 k N = - 1.5 k N to +3*0.5 k N = 1.5 k N) throughout the time duration consumed for friction stir welding the component. i.e., Negative sign indicates that the transverse load component is considered in negative X – axis

V.CORROSION TEST RESULTS

table

Particulars	Test specimens	Corrosion current(μA/cm^{-2})	Corrosion rate (MPY)
Without weld	Al 6061 + 0% reinforcement	$3.547x10^{-4}$	$2.913x10^{-2}$
With weld	Al 6061+ 0% reinforcement	$3.911x10^{-4}$	$3.113x10^{-2}$
Without weld	Al 6061+3% E-glass +7% SiC	$3.034x10^{-4}$	$2.854x10^{-2}$
With weld	Al 6061+3% E-glass +7% SiC	$3.127x10^{-4}$	$2.646x10^{-2}$



Graph no: 4 representation of corrosion rate for specimens

The corrosion test results clearly give inferences in its very fact that the corrosion rate decreases with the addition of reinforcements and further upon the reinforcements are having an incremental effect on the corrosion resistance characteristics of the specimens.
In addition to this fact, another attribute is that; the corrosion rate increases for weld specimens of Aluminium 6061 alloy, whereas the corrosion rate for the weld specimens of Aluminium 6061 alloy/3% E Glass/7% SiC drastically reduces, this is majorly due to the addition of reinforcements to the metal matrix.

VI.CONCLUSION

In the current work, the addition of E-glass and SiC to Al 6061 will enhance the properties much to the concept of reinforcing the base metal; the FSW hybrid plates can withstand the maximum normal load and traverse load and relatively higher spindle torque when compared to friction stir welded base material plates with 0% reinforcement.

The hybrid reinforced composite plates exhibit excellent corrosion resistance property, the corrosion rate for Al 6061 + 0% reinforcement (without weld) specimen is 2.913x10-2 miles/year and for Al 6061 + 0% reinforcement (with weld) specimen is 3.113x10-2 miles/year.

The corrosion rate for 6061+ 3% E-glass+7% SiC (without weld) specimen is 2.854x10-2 miles/year and for Al 6061+3% E-glass +7% SiC (with weld) specimen is 2.646x10-2 miles/year.

Thus by investigating the corrosion rate for both hybrid composite plates and base metal plates, it is found that the corrosion rate for hybrid composite plates is less when compared to AA 6061 alloy.

The critical inferences of results of research work concludes that the Hybrid aluminium 6061 metal matrix composites have a better corrosion resistance property than the base metal.

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