Study on Corrosion Behaviour of Aluminium Alloy 6061 Reinforced With MWCNT And Boron Fiber Composite Material

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Abstract- *This paper aims to study the corrosion resistance of metal matrix composite of an aluminum alloy (Al 6061) reinforced by MWCNT and boron fiber with 10wt% and 20wt%. Composite materials were prepared by stir casting using vortex technique. Corrosion behavior of aluminum matrix composite in Hcl solution was examined using potentiostatically measurements.. It was found that adding of boron fiber particles to the aluminum alloy matrix increases the corrosion resistance. Selection of material depends on many factors, including its corrosion behavior. Although we are primarily concerned with the corrosion resistance of materials, the final choice frequently depends on the factors other than corrosion resistance.*

Keywords- Aluminum matrix composite, stir casting, corrosion, weight loss method, electrochemical polarization, microstructure.

I. INTRODUCTION

A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties; when combined it produces a material with characteristics different from the individual. It consists of matrix and reinforcement; matrix is the bulk of material holding the reinforcement together in position. Al composites are used essentially. In structural applications such as helicopter parts (parts of the body, support for rotor plates, drive shafts), rotor vanes in compressors and in aero-engines . The presence of pits on the composite and base alloy surfaces was seen clearly. However the pit formation is less on the composite surface than on the matrix alloy surface. The surface damage produced in the composites was smaller and there is no surface damage as the addition Boron fiber particulates weight percentage.

II. MATERIALS AND METHODS

A. Selection of Materials.

Matrix

The matrix material to be used was chosen as Al6061 which is a precipitation hardened aluminium alloy, containing iron, silicon and chromium as its major alloying elements as indicated in Table I. It has good mechanical properties and exhibits good weldability, good formability and high corrosion.

TABLE I. CHEMICAL COMPOSITION OF ALUMINIUM

Constituents	Percentage
Manganese (Mn)	0.108%
Iron (Fe)	0.125%
Copper (Cu)	0.392%
Magnesium (Mg)	0.970%
Silicon (Si)	0.620%
Chromium (Cr)	0.079%
Others (Total)	0.04%
Aluminium (Al)	97.7%

TABLE II. PHYSICAL PROPERTIES OF Al6061

Properties	Value	Unit
Density	2.7	g/cm^3
Melting point	582-652	°C
Brinell Hardness	45	
Ultimate Tensile Strength	130	MPa
Yield Strength	276	MPa
Modulus of Elasticity	68.9	MPa
Thermal conductivity	167	W/m-K
Coefficient of Thermal Expansion	23.6×10^{-6}	m/°C

Reinforcement

The materials selected to be reinforced into the metallic matrix is Alumina. Aluminium oxide is a chemical compound of aluminium and oxygen with the chemical formula Al_2O_3. Alumina is significant in its use to produce aluminium metal, as an abrasive owing to its hardness, and as a refractory material owing to its high melting point. It is reinforced in the Al6061 matrix to increase strength, hardness, stiffness, wear resistance and impact strength.

TABLE III PROPERTIES OF ALUMINA

Properties	Alumina (Al_2O_3)	Units
Density	3.98	g/cm^3
Melting point	2300	°C
Vickers Hardness	1560	
Fracture toughness	4.9	MPa√m
Elastic Modulus	300	GPa
Tensile Strength	210	MPa
Thermal conductivity	21	W/mK
Coefficient of thermal Expansion	9	m/°C

A. Fabrication process

Stir casting is the most popular commercial method of producing aluminium based composites. In this method, pre heated ceramic particulates are incorporated into the vortex of the molten matrix created by a rotating impeller. In principle, it allows a conventional metal processing route to be used, and hence minimizes the final production cost of the product.

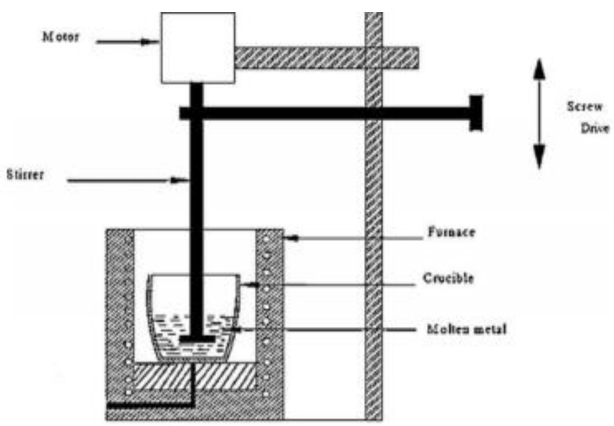


FIG1. STIR CASTING DIAGRAM

The stir casting process starts with the preheating of graphite crucible in a gas-fired furnace for 20 minutes.

The Alumina was initially preheated separately at a temperature of 250°C to remove moisture and to help even distribution within Al6061 alloy. y is stirred at a constant speed of 450 rpm to create vortex. The preheated Alumina is then charged into the melt at constant pour rate and stirring of the slurry was performed manually for 5-10 minutes. Magnesium about 1% of weight is added to ensure good wettability for all proportions of the reinforcements.

N. Venkat Kishore et. al., studied on Al (LM25) reinforced with the boron carbide (B4C) metal matrix produced. The fabricated composites were tested to find wear behavior in wear testing machine.

Keshav Singh et. al., carried out investigations on fabrication and characterization of Aluminium(LM25) metal matrixes in forced with boron carbide(B4C). In this study the fabricated MMC showed very good tensile strength.

V.M. Ravindranath et. al., carried out investigations on Aluminum is reinforced with 8% Boron carbide and 3% Graphite particulates. Hybrid Aluminium metal matrix were produced by stir casting method. Wear test is conducted by pin-on-disc wear testing machine at room temperature on hybrid composite and base alloy.

Michael et. al., carried out investigations on different combination of reinforcements used in the production of hybrid Aluminium metal matrix composites and studied the mechanical, corrosion and tribological characteristics.

K.PunithGowdaet.al., conducted investigation on 5wt% of tungsten carbide(WC) which was reinforced with aluminum by liquid metallurgy process. The Al/WC metal matrix composites were subjected to ASTM standard tests.

III. IMMERSION CORROSION TEST

CORROSION TEST

The corrosion behavior of the composites is studied by weight loss method using mass loss and corrosion rate measurements in both acidic and basic environments. The corrosion test will be carried out by immersion of the test specimens up to 1N HCl solutions which will be prepared following standard procedures. The specimens for the test are cut to size 20×20 mm and then mechanically polished with emery papers from 150 down to 600 grit sizes to produce a smooth surface. The samples are de-greased with acetone, rinsed in distilled water, and then dried in air before immersion in still solutions at room temperature (25°C). The solution-to-specimen surface area ratio will be about 150 ml cm-2 , and the corrosion setups are exposed to atmospheric air for the duration of the immersion test. The weight loss readings will be monitored for a period of 24 hours.

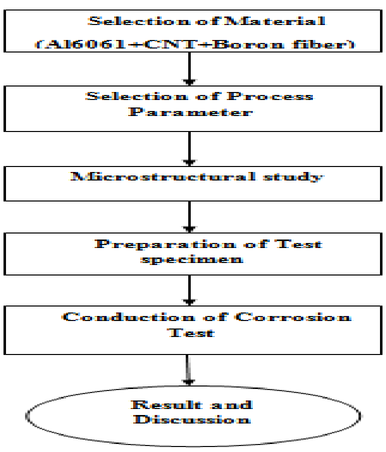
$$\text{Corrosion Rate (CR)} = \frac{\text{Weight loss (g)} * K}{\text{Alloy Density (g/cm}^3) * \text{Exposed Area (A)} * \text{Exposure Time (hr)}}$$

The constant can be varied to calculate the corrosion rate in various units:

Desired Corrosion Rate Unit (CR)	Area Unit (A)	K-Factor
mils/year (mpy)	in^2	5.34×10^5
mils/year (mpy)	cm^2	3.45×10^6
millimeters/year (mmy)	cm^2	8.75×10^4

$$\text{Metal Loss (ML)} = \frac{\text{Weight loss (g)} * K}{\text{Alloy Density (g/cm}^3) * \text{Exposed Area (A)}}$$

Desired Metal Loss (ML)	Area Unit (A)	K-Factor
mils	in^2	61.02
mils	cm^2	393.7
millimeters	cm^2	10.0



In order to achieve the above stated objective following methodology is to be adopted in the present work. It includes:

1. Selection of material

In this stage Aluminum Alloy 6061 with specific applications has to be selected to get ultra-fined grain structure using Stir casting technique.

2. Selection of process parameters

With reference to the literature survey, proper and effective process parameters to be selected. These process parameters will have major influence on final grain structure, in turn changing mechanical and tribological properties.

3. Microstructural study

Microstructure study is to be conducted for the prepared specimens. It involves grain size measurement, Scanning Electron Microscope ,Optical Microscopy and Transmission Electron Microscopy.

4. Preparation of Test Specimens

After Stir casting process, Al6061reinforced with MWCNT's and Boron fiber is obtained to form hybrid composite material to conduct corrosion test as per ASTM standards.

5. Corrosion Test

The Prepared specimens of various proportions composition materialss are subjected to corrosion test as per ASTM standard and properties are to be study.

6. Discussion of results and conclusions

After getting the results from various tests, results are analyzed to check the improvement in the properties of Aluminum Alloy 6061 and finally conclusions are drawn.

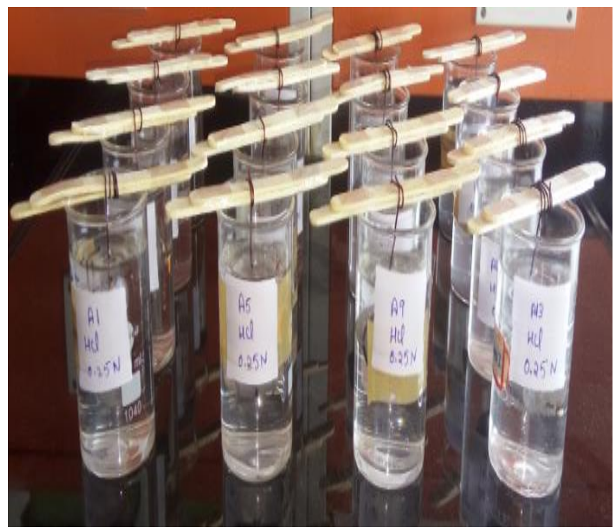


Figure 2: Immersion of Specimen in HCL Solution

Figure 3: Corroded Specimens

STATIC CORROSION

The Variation of corrosion rate with test duration The ables and graphs show that for every composite similarly as for unreinforced Al 6061 alloys, the corrosion rate is found to decrease with the test period of the corrosion tests.

The observation of gradual decrease in corrosion rate indicates attainable passivation of the matrix alloy. Corrosion rate depends on the stability, nature and thickness of the passive layer. After a specific duration, the film may be stable but it contains pores and micro cracks through which solution may come in contact with the specimen surface and hence oxygen drifting might take place through these defects in the passive layer.

IV. EXPERIMENTAL PROCEDURE

Corrosion resistance was also found to improve with increase in Boron fiber concentration. Therefore the resistance of corrosion of the composites increases with the percentage of boron fiber particle in the composite.

1. The resistance of corrosion of the composites increases with the percentage of boron fiber particle in the composite along with MWCNT.
2. The corrosion rate at 0.25%N for A1 specimen reduces from 0.238% to 0.048% from 24 hrs to 96 hrs.
3. The corrosion rate at 0.25%N for A5 specimen reduces from 0.162% to 0.045% from 24 hrs to 96 hrs.
4. The corrosion rate at 0.25%N for A9 specimen reduces from 0.191% to 0.041% from 24 hrs to 96 hrs.
5. The corrosion rate at 0.25%N for A13 specimen reduces from 0.196% to 0.047% from 24 hrs to 96 hrs.

Corrosion rate (mpy) = 534×W/D×A×T Miles Per year
Where, W=W1-W2 weight loss due to corrosion in the static immersion corrosion test in grams.

If W1 = weight of the specimen before the conduction of the test in grams.
W2 = weight of the specimen after the conduction of the test in grams.
D = density of the composite in g/cm3
A = Surface area of the specimen exposed to corrosion in square inch.
A =2 x π x R(R+h) in square inch.
Where, R = cross sectional radius of the specimen.
h = height of the specimen.
T = time in hours for which the corrosion test is conducted.

Calculations:

Area=2 x π x R(R+h) in square inch
Where Diameter of specimen (d)=20mm,r=10mm,length of specimen(h)=20mm
Area=2*3.14*10(10+20) (converting mm to square inch=0.00155sq inch)
Area=2*3.14(300*0.00155 sq inch)

Area=2.9202 square inch

Density of Composite Material:
Density of Al=2.71g/cm^3
Density of CNT=1.8g/cm^3
Density of Boron fiber=2.61g/cm^3
D=2.71+1.8+2.61/3

D=2.37g/cm^3

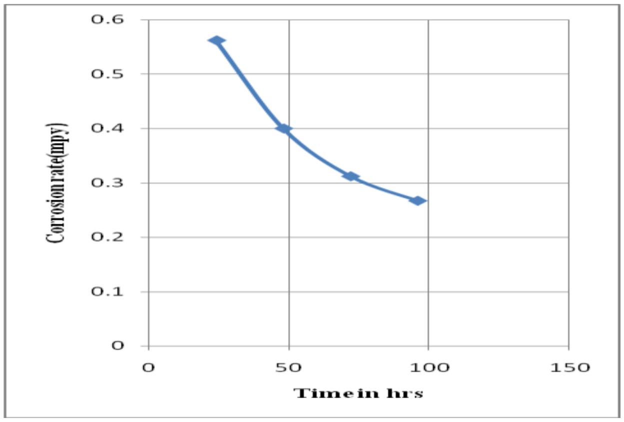
Table 1: Corrosion rate calculations of A1,A5,A9,A13 specimen at 0.25N

NORMALITY	SPECIMEN	WEIGHT LOSS(g)				CORROSION RATE(mpy)
		TIME(hrs)	Initial weight(g)	Final weight(g)	Weight Loss(g)	
0.25	A1	24	19.349	19.133	0.216	0.697
		48	19.349	19.067	0.282	0.459
		72	19.349	19.037	0.312	0.334
		96	19.349	18.992	0.357	0.286
NORMALITY	SPECIMEN	WEIGHT LOSS(g)				CORROSION RATE(mpy)
		TIME(hrs)	Initial weight(g)	Final weight(g)	Weight Loss(g)	
0.25	A5	24	17.292	17.117	0.175	0.562
		48	17.292	17.043	0.249	0.4
		72	17.292	17	0.292	0.312
		96	17.292	16.959	0.333	0.267
NORMALITY	SPECIMEN	WEIGHT LOSS(g)				CORROSION RATE(mpy)
		TIME(hrs)	Initial weight(g)	Final weight(g)	Weight Loss(g)	
0.25	A9	24	19.158	18.972	0.186	0.597
		48	19.158	18.905	0.253	0.406
		72	19.158	18.852	0.306	0.327
		96	19.158	18.802	0.356	0.286
NORMALITY	SPECIMEN	WEIGHT LOSS(g)				CORROSION RATE(mpy)
		TIME(hrs)	Initial weight(g)	Final weight(g)	Weight Loss(g)	
0.25	A13	24	17.604	17.403	0.201	0.646
		48	17.604	17.324	0.28	0.45
		72	17.604	17.293	0.311	0.333
		96	17.604	17.247	0.357	0.286

The Graph represents the Corrosion rate behavior of the Specimen:

As day's increases, Corrosion rate decreases. And as Normality increases, Corrosion rate also increases.
The graph is plotted against Corrosion rate (mpy) v/s Time (hrs)

Normality: 0.25N



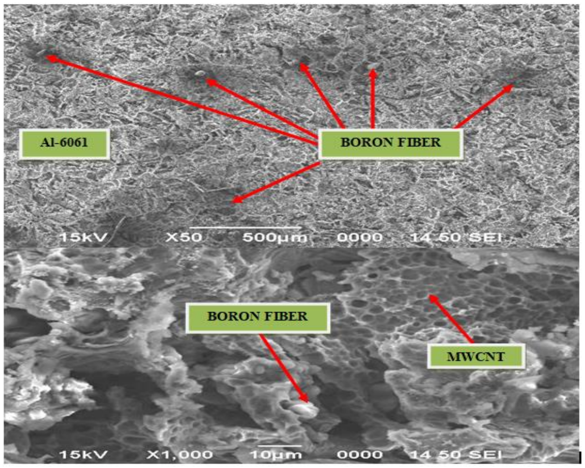


Figure 4. SEM of AM0.25BF1 specimen

V. CONCLUSION

The micro structural changes introduced by the addition of the particles are the most likely reasons for the difference in corrosion resistance among the composites. Firstly, it is reported that the micro structural refinement provides a superior corrosion resistance.

The observed grain refinement in the Al+ CNT and Al+MWCNT+Boron Fiber composites may contributes to the improved corrosion resistance. The second possible reasons for the dramatically reduced corrosion resistance with the addition of Boron fiber reinforcements to the Al matrix could be galvanic coupling between matrix and Al 6061 particles.

All the above features are detrimental and may cause difference in corrosion resistance among the composites although it is not possible to separate them. Therefore, it is not known exactly if only one, two or all the above mentioned mechanisms are effective in reducing the corrosion rate.

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