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Corrosion, wear properties of boron carbide and graphite reinforced AL2024 hybrid metal matrix composites

[1] Nagendra Reddy H R, [2] M.S.Bhagyashekar, [3] H. V. Panchakshari, [4] Pramod.K,
[1][2][3][4]R.R. Institute of Technology, Chikabanavara, Bangalore-560090

Abstract: -- With the increase in demand for less denser and high stiffer components, aluminium matrix composite find its place in the area of aerospace structure and in automobiles. The purpose of this work is to study the corrosion and wear properties by development of hybrid metal matrix composite constitutes boron carbide and graphite particulate reinforced to aluminium (AL2024) alloy matrix which is in continuous phase. Using stir casting fabrication technique, keeping boron carbide constant and varying the weight % of graphite and vice versa according to ASTM standards. The wear characteristics and corrosion test for different compositions have been tested using pin on disc apparatus and weight loss method.

Keywords: Composites, Hybrid Metal Matrix Composites, Aluminum 2024, Boron carbide, Graphite, Corrosion, Wear

1. INTRODUCTION

Use of Metal Matrix Composites in the fields of aerospace, automotive and other engineering applications is gaining momentum nowadays due to their high strength to weight ratio, stiffness, and hardness and wear and corrosion resistance as well as thermal conductivity. Combining the low density metals with reinforcing particles result in enhanced performance components which can be used as substitutes for existing monolithic materials. Composite may be defined as any multiphase materials that exhibit significant proportions of properties of both the constituent materials. A hybrid metal matrix composite has more than one reinforcement material. These are developed mainly for performance optimization. Aluminium hybrid metal matrix composites have gained momentum due to their structural applications in aircraft, automotive, construction, packaging, electronics and military industries. Specimens were fabricated using stir casting technique in coal fire furnace. strips were melted which acts as matrix to which boron carbide and graphite were added as reinforcement particles with continuous stirring. During this process the weight % of boron carbide and graphite were varied thus obtaining samples with different compositions of reinforcements in aluminium matrix. Specimens were fabricated, cured and machined to standard dimension. The wear and corrosion characteristics of boron carbide and graphite reinforced with hybrid metal matrix composite were studied with different composition of reinforcements. The objective of this work was to study the wear and corrosion characteristics of boron carbide and graphite reinforced with hybrid metal matrix composite with different composition of reinforcements. The testing was carried out using weight loss method for corrosion test and computerised pin-on-disc apparatus for wear test.

2. MATERIALS AND METHODOLOGY

2.1 MATERIALS USED

Aluminium 2024 Alloy Matrix

Fig 1: Aluminium 2024 Alloy

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The chemical composition of AL2024 is given in the below table

Table 1. Chemical composition of AL2024

Elements	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Zr
contents	0.05	0.12	4.38	0.49	1.49	0.01	-	0.02	0.06	-

- ***Boron Carbide***

boron carbide particles confers high specific strength, elastic modulus, good wear resistance and thermal stability

Fig 2: Boron carbide

- ***Graphite***

Graphite is well known as a solid lubricant and its presence in aluminium alloy matrices makes the alloy, self-lubricating..

Fig 3: Graphite

3. SPECIMENS PREPARATION

Pre heat and melt the Aluminium 2024 alloy upto its melting point 6600o C in the coke fire furnace. Coal is used as a fuel for heating up the furnace. Reinforcements such as Graphite and Boron Carbide were preheated at a specified temperature 15 min in order to remove moisture or any other gases present within reinforcement. Pre heated materials are added and mixed up with the molten Aluminium manually and heating up for proper distribution in the Aluminium Matrix. The melting of the aluminium is carried out in the crucible in the coal-fired furnace Pouring of preheated reinforcements at the semisolid stage of the matrix enhance the wettability of the reinforcement, reduces the particle settling at the bottom of the crucible. Reinforcements are poured manually with the help of conical hopper. Stirring up the molten aluminium with reinforcements at a constant rate enhances the uniform distribution throughout the matrix phase which is necessary to join the reinforcements with matrix material.

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Fig 4: Stir Casting

While pouring the slurry into the mould, the flow of the slurry is kept uniform to avoid trapping of gas. Then it is quick quenched with the help of air to reduce the settling time of the particles in the matrix. After stirring molten slurry, it is poured into the desired mould with preferred dimensions which would be facilitated for conducting various tests on it. In this project work Aluminium based metal matrix composite were produced in the laboratory by using stir casting method.

Table 2. Composition of reinforcements in the prepared samples

Sl.no	**Types of rein forcement**		**Reinforcement (%)**		
1	B_4C	0	2	2	2
	Gr	0	2	4	6
2	B_4C	0	2	4	6
	Gr	0	2	2	2

3.1 CHARACTERIZATION OF SPECIMENS

Table 3. Characterization of specimen

Test	**Geometry**	**Dimensions (mm)**	**ASTM Standard**
Wear	Cylindrical	10x30	G-99
Corrosion (weight loss method)	Cylindrical	20x20	G-90

4. EXPERIMENTAL WORK

The following tests were conducted

4.1 CORROSION TEST

4.1.1 WEIGHT LOSS METHOD

For the determination of corrosion rate using weight loss analysis, the specimen is machined into cylindrical shapes of 20mm diameter and 20mm length. The machined samples is weighed and then cleaned in acetone to remove any possible dirt in the samples. The samples are then weighed in an electronic balance. These are then introduced into different solutions and kept aside for chemical reaction to take place for a time period of 24 hours. The solutions used here are 3.5% NaCl solution and 0.1% N HCL solutions. The sample is then removed from the solution. The samples are then cleaned of all the corrosion product and is reweighed. From this the weight loss of the samples before and after introducing it into the solution is calculated this is then converted to corrosion rate.

Fig5: Weight Loss Test

4.2 WEAR TESTING OF THE SPECIMEN

A pin-on-disc test apparatus was used to investigate the dry sliding wear characteristics of the AL 2024 hybrid metal matrix composite. The wear specimen is machined in to cylindrical shape of 10mm diameter and 30mm length as per ASTM standards. It is then polished and the wear test were conducted at different loads and sliding speeds. The frictional traction experienced by the pin during sliding is measured continuously by PC based data logging system.

The test was carried out for about 10 minutes with a rotating speed of the disc as 300rpm.The test parameters like rate of wear, frictional force, pin temperature was displayed on the computerised pin-on-disc wear testing machine. Based on the values so obtained graphs were plotted considering the various parameters. The graphs so obtained were analysed and the relations between the various parameter were discussed based on this result conclusions were made considering the variations in wear rate for different compositions of reinforcements in the matrix.

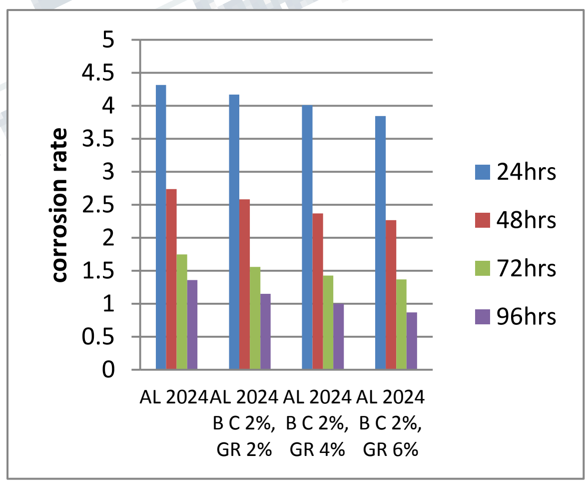
5. RESULTS

5.1 WEIGHT LOSS METHOD TEST RESULT

The following graph shows the variation in corrosion rate with time for different composition of reinforcements in the matrix for the prepared samples.

Table 4. Corrosion rate for varying % of boron carbide in 0.1 N HCl solution

% of reinforcement Exposure Time in Hours	AL2024	AL 2024 GR 2%, BC2%	AL 2024 GR 2%, BC4%	AL 2024 GR 2%, BC6%
24hrs	4.3133	4.202	4.003	3.986
48hrs	2.7356	4.023	3.967	3.865
72hrs	1.7456	3.925	3.536	3.465
96hrs	1.3569	3.865	3.656	3.423



Graph 1. Corrosion rate for varying % of boron carbide in 0.1 N HCl solution

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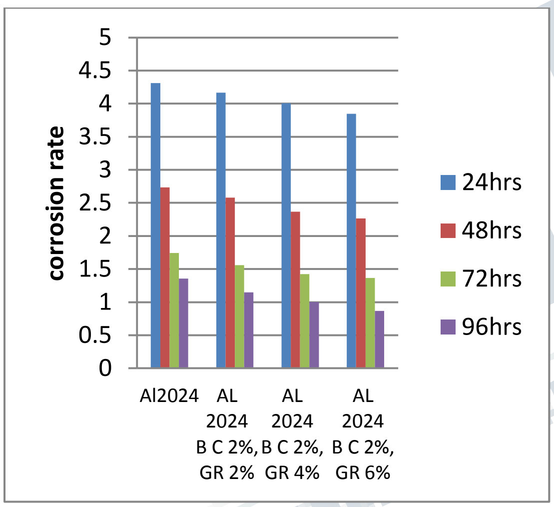
Vol 2, Issue 5, May 2017

Table 5. Corrosion rate for varying % of graphite in 0.1 N HCl solution

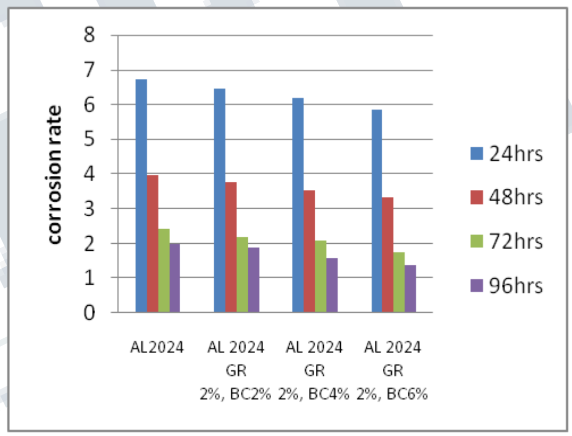
% of reinforcement Exposure Time in Hours	AL2024	AL 2024 B C 2%, GR 2%	AL 2024 B C 2%, GR 4%	AL 2024 B C 2%, GR 6%
24hrs	4.3133	4.1661	4.0067	3.8445
48hrs	2.7356	2.5809	2.3679	2.2657
72hrs	1.7456	1.5579	1.4232	1.3666
96hrs	1.3569	1.1477	1.0009	0.8667



Graph 2. Corrosion rate for varying % of graphite in 0.1 N HCl solution

Table 6. Corrosion rate varying % of boron carbide in 3.5% NACl solution

% of reinforcement Exposure Time in Hours	AL2024	AL2024 GR 2%, BC2%	AL2024 GR 2%, BC4%	AL2024 GR 2%, BC6%
24hrs	6.7111	6.4656	6.1724	5.8320
48hrs	3.9712	3.7522	3.5334	3.3412
72hrs	2.4309	2.200	2.0981	1.7622
96hrs	1.9803	1.8678	1.5711	1.3697



Graph 3. Corrosion rate varying % of boron carbide in 3.5% NACl solution

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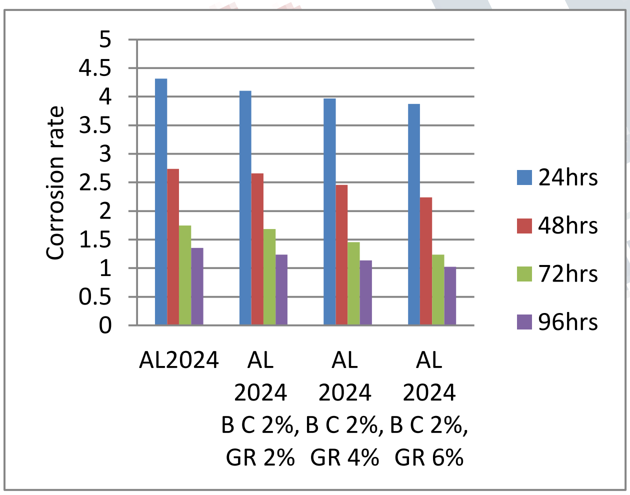
Table 7. shows the corrosion rate for varying % of graphite in 3.5% NACl solution

% of reinforcement Exposure Time in Hours	AL2024	AL2024 B C 2%, GR 2%	AL2024 B C 2%, GR 4%	AL2024 B C 2%, GR 6%
24hrs	4.3133	4.102	3.965	3.875
48hrs	2.7356	2.656	2.456	2.236
72hrs	1.7456	1.685	1.458	1.236
96hrs	1.3569	1.236	1.136	1.026



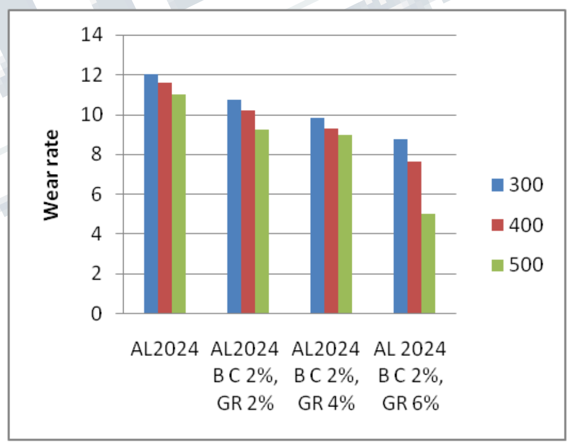
Graph 4. Corrosion rate for varying % of graphite in 3.5% NACl solution

5.2 WEAR TEST

The following graph shows the variation in wear rate with time for different composition of reinforcements in the matrix for the prepared samples.

Table 8. Wear rate for varying % of graphite with 2% fixed B4C

% of reinforcement speed in rpm	AL2024	AL2024 B C 2%, GR 2%	AL2024 B C 2%, GR 4%	AL 2024 B C 2%, GR 6%
300	12	10.75	9.84	8.75
400	11.60	10.20	9.32	7.65
500	11	9.23	8.98	6.90



Graph 5. Wear rate for varying % of graphite with 2% fixed B4C

6. DISCUSSION

It is observed from the graph that the rate of corrosion of the composite in HCL medium is not yielded appreciable results. Also it is observed from the graph that the rate of corrosion of the composite in NACL medium is found to decrease considerably with the increase in the percentage of reinforcement. From the graph it is observed that with the increase in exposure duration the rate of corrosion decreases due to formation of protective layer. From the graph it is observed that the rate of wear decrease with the increase in the percentage of reinforcement.

7. CONCLUSION

From the weight loss test it was concluded that the corrosion rate decreases with increase in the percentage of reinforcements.. From the Wear test using pin-on-disc apparatus, the rate of wear decreases with increase in percentage for reinforcements.

it can be concluded that corrosion rate and rate of wear decreased with increase in percentage of reinforcements and the characteristics varies with the composition. Boron carbide and graphite reinforced with AL 2024 HMMC is well suitable for Automobile industry, Aerospace application etc.

7. ACKNOLEDGEMENT

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7. REFFERENCE

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