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Corrosion Characterization of Boron Carbide and Tungsten carbide Aluminium 7075 T6 Hybrid Composites

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Abstract:- Corrosion study of aluminium hybrid metal matrix composites is a major study aimed at evaluating the potential of using the materials for automobile and aerospace components. Aluminium 7075 T6 is a specific class of alloy which is known for its corrosion resistance in extreme environments and is used in automobile and aerospace components. The present work involves the fabrication of aluminium-boron carbide-tungsten carbide composites and study of the corrosion behaviour of these composites. The composites are manufactured by liquid metallurgy technique using stir casting technique, with the composition of the boron carbide particulates varying in the range of 2.5 to 10 wt% at an interval of 2.5% each for every addition. The percentage of tungsten carbide is taken constant at 4% for limiting the scope of our study after successive trials and errors. The composite specimens thus prepared are evaluated for corrosion by different test methods namely, weight loss test, open circuit potential test, potentio-dynamic test. The weight loss technique involved the process of preparation of cylindrical specimens of standard size (20 mm diameter and 20 mm length), and suspending them in hydrochloric acid (HCl) and sodium hydroxide (NaOH) medium for a duration of 120 h (5 days), taking note of the weight loss for every 24 h and corrosion rates are henceforth computed using an empirical relation. There is a reduction in the corrosion rate with the increase in percentage of boron carbide from 24 to 120 h and it almost reached a constant state at the end of 120 h.

Key word: Corrosion, aluminium, metal, matrix composite, weight loss method, HCL, NaOH.

INTRODUCTION

Aluminium metal matrix composites are the major structural materials which have found vast scope for engineering applications; this is majorly due to their superior characteristics and performance capabilities. Aluminium and its combinations have been utilized as a matrix for an assortment of reinforcements: boron carbide, Al_2O_3, SiC and graphite filaments, short fibers and whiskers. Additionally, the melting point of aluminium is sufficiently high to fulfil numerous application necessities, yet sufficiently low to render processing of composites sensible [1, 2]. Fabricated pure aluminum 7075 alloy with reinforced B_4C and WC using a stir casting technique and investigated the tensile strength. Hybrid composite samples presented high tensile resistance compared with the aluminum 7075 alloy-based composites [3, 4]. In these cases, the presence of galvanic cells empowers the consumption procedure on the lattice. Alumina is a protector and alumina particles can be utilized to strengthen aluminum compounds without instigating corrosion [5, 6].

Corrosion characterizations have likewise turned out to be essential because of expanding attention to the need to preserve the world's metal assets [7]. Corrosion investigations of aluminium and aluminium composites have got significant consideration by specialists due to their wide mechanical applications and monetary contemplation [8–12]. Aluminium and aluminium compounds have risen as substitute materials in aerospace and in some synthetic preparing ventures [13]. Metal matrix composites reduce corrosion in addition to bringing in other mechanical properties. Alumina with aluminium alloy 6063 has good corrosion resistance property in NaCl environment [14]. pure aluminium alloy and inferred that cenosphere-aluminium composite has better corrosion resistance [15] heat-treatment process resulted in significant improvement in corrosion resistance of the composites in comparison to the as-cast and solely solution heat-treated temper conditions.[16]

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2 MATERIALS AND METHODS

2.1 AL7075-T6 (Al 7075-T6)

Aluminium 7075 having good fatigue strength. It exhibits excellent machinability under both as cast and heat-treated condition. The temper T6 grade heat treated alloy that is the solution heat-treated and artificially aged until it meets standard mechanical property. The figure shows the ingot of Al 7075 alloy.

Component	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn
Weight %	87.1-91.4	0.18-0.28	1.2-2	0.5	2.1-2.9	0.05	0.4	0.2	5.1-6.1

Table 1 composition of Al 7075 alloy

Figure 1. Aluminium 7075 alloy ingot

2.2. Boron Carbide (B_4C)

Boron Carbide (B_4C) is one of the hardest materials known, ranking third behind diamond and cubic boron nitride. It is the hardest material produced in tonnage quantities. Boron carbide powder is mainly produced by reacting carbon with B2O3 in an electric arc furnace, through carbon thermal reduction or by gas phase reactions. For commercial use B4C powders usually need to be milled and purified to remove metallic impurities. Boron Carbide has Extreme hardness, Good chemical resistance, Good nuclear properties, Low density properties.

Property	Density	Melting Point	Hardness	Young's Modulus
Value	$2.52g/cm^2$	2445(°c)	2900-3580	450-470 GPA

Table 2 Properties of Boron carbide

Figure 2 Boron carbide powders

2.3. Tungsten Carbide (WC)

Tungsten carbide (WC), also referred to as cemented carbide, is a composite material manufactured by a process called powder metallurgy. Tungsten carbide powder, generally ranging in proportion between 70%-97% of the total weight, is mixed with a binder metal, usually cobalt or nickel, compacted in a die and then sintered in a furnace. Tungsten Carbide has high melting point, boiling point at standard atmospheric pressure, thermal conductivity and coefficient of thermal expansion.

3. MATERIAL PROCESSING METHODOLOGY

Property	Density	Melting Point	Modulus elasticity	Shear modulus	Compressive modulus
Value	15.7g/cm^2	2445(°C)	670-707 GPA	262-298 GPA	384 GPA

Table 3 Properties of Tungsten carbide

Figure 3 Tungsten carbide powders

3.1 Stir casting

The aluminium 7075 -T6 is mixed with reinforced materials Boron carbide (B_4C) and tungsten carbide (WC) where wt. % of Boron carbide and wt. % Tungsten carbide are varied for each trail. The stir cast equipment consists three mild steel stirrer blades and main furnace. The figure 4 shows experimental setup of stir casting process.

- Initially the reinforcement are preheated at 400^{o}c temperature in the empty crucible.
- The Al -7075 ingot is preheated at 550 temperature for 1-2hrs after which the mixture is poured into crucible.
- The Al -7075 is melted up to 750c and preheated reinforcement is mechanically mixed with matrix.
- The stirrer speed is maintained 100 to250 rpm for about 10 to 25 mints for uniform distribution of reinforcement. Later the mixture is poured into mould cavity.
- The process parameters selected for stir casting the aluminium composites based on extensive review of literature and thorough evaluation of the capabilities of the equipment, are listed below in Table 4.

Figure 4 Experimental Set-up of Mechanical Stir Casting Process

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3.2 Heat treatment

The Heat treatment is metal working process used to alter the physical and chemical properties of materials. The Al-7075 is heated to T6 temperature grade and age hardening process is carried out at 480˚c for 4hrs. The Al7075 T6 is mixed with reinforcement B_4C and WC in solution form and solution hardening process is carried out for 120˚c for about 24hrs before pouring into mould.

Figure 5 Heat treatment Process

4. WEIGHT LOSS CORROSION TEST

The corrosion behaviour of aluminium AA 5083 alloy-silicon carbide-fly ash composite is studied by immersion test. Static immersion corrosion method is adopted to measure the corrosion loss. Hydrochloric acid and sodium hydroxide of 1 M concentration is used to characterize the corrosion behaviour. For conducting weight loss corrosion test, “250 ml of the prepared solution is taken in a beaker and samples are suspended in the corrosive medium for 120 h in time intervals of 24 h. At least three samples are tested and average value is taken. Corrosion rates are computed using Eq. (1)”.

Corrosion rate =534 W/DAT mpy” ---------------------- (1)

Where, W is the weight loss in g, D is density of the specimen g/cm3, A is the area of the specimen

5. RESULTS AND DISCUSSION

5.1Weight Loss Corrosion Test

The weight loss corrosion test conducted in 1 M NaOH and 1 M HCl has yielded with the following values which are tabulated and plotted to critically evaluate the variation of corrosion rate with the passage of time. It is therefore observed that the weight loss corrosion rates decrease from 24 to 120 h, and also with the further addition of boron carbide reinforcements from 2.5 to 10 wt% in both acidic and alkaline medium.

The Table 4 corresponds to the variation of corrosion rates with varying percentage of boron carbide reinforcements in1 M alkaline solution (NaOH). The corrosion rate varies from 10.884 to 2.9313 mpy for time duration of 24 to 120 h for 2.5 wt% of boron carbide, while the corrosion rate varies for 5 wt% of boron carbide from 10.228 to 3.4932 mpy; it varies for 7.5 wt% of boron carbide from 9.9644 to 3.2212 mpy, and finally, the corrosion rate varies from 8.812 to 2.9313 mpy for 10 wt% of boron carbide (Figure 6).

Table –4 Corrosion rates mpy in 1 M NaOH for varying wt. % of B4C [with 4 wt. % WC]

Duration in hours	**Corrosion rates in mpy for varying wt**% of B4C [with 4 wt. % WC]			
	2.5	**5**	**7.5**	**10**
24	10.884	10.228	9.9644	8.812
48	6.9455	6.6322	6.2214	5.8764
72	5.6953	5.3312	4.9842	4.7653
96	4.6621	4.3242	4.1128	3.8132
120	3.7255	3.4932	3.2212	2.9313

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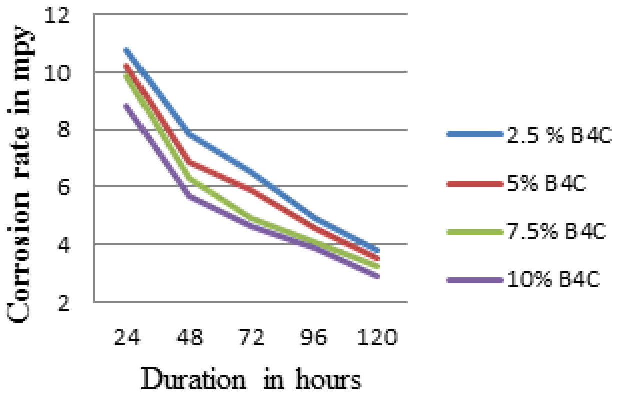

Figure – 6 Corrosion rate mpy in 1 M NaOH for varying wt. % of B4C [4 wt. % WC]

The Table 5 corresponds to the heat treatment specimen corrosion rates with varying percentage of boron carbide reinforcements in1 M alkaline solution (NaOH). The corrosion rate varies from 8.592 to 3.261 mpy for time duration of 24 to 120 h for 2.5 wt% of boron carbide, while the corrosion rate varies for 5 wt% of boron carbide from 8.351 to 2.981 mpy; it varies for 7.5 wt% of boron carbide from 8.099 to 2.726 mpy, and finally, the corrosion rate varies from 7.849 to 2.559 mpy for 10 wt% of boron carbide (Figure 7)

Table – 5 Corrosion rates mpy in 1 M NaOH for varying wt. % of B4C [with 4 wt. % WC] with heat treatment

Duration in hours	Corrosion rates in mpy for varying wt% of B4C [with 4 wt. % WC]with heat treatment			
	2.5	5	7.5	10
24	8.592	8.351	8.099	7.849
48	7.069	6.391	5.869	5.482
72	6.192	5.486	4.799	4.349
96	4.517	3.926	3.685	3.279
120	3.261	2.981	2.726	2.559

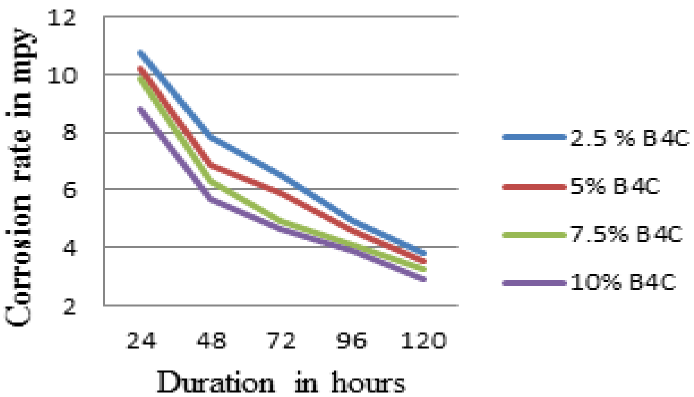

Figure – 7 Corrosion rate mpy in 1 M NaOH for varying wt. % of B4C [4 wt. % WC] with heat treatment

The corrosion rates in mpy is tabulated as in Table 6 for varying percentage of boron carbide in 1 M HCl and plotted as in Figure 2. The results clearly show that the corrosion rates decrease with the duration of time from 24 to 120 h, and furthermore the addition of boron carbide without heat treatment(As Cast) of developed composite. The corrosion rate varies from 9.784 to 3.6255 mpy for time duration of 24 to 120 h for 2.5 wt% of boron carbide, while the corrosion rate varies for 5 wt% of boron carbide from 9.328 to 3.093 mpy; it varies for 7.5 wt% of silicon carbide from 9.1644 to 2.821 mpy, and finally the corrosion rate varies from 8.12 to 2.631 mpy for 10 wt% of silicon carbide. (Figure 8)

Table – 6 Corrosion rates in mpy 1 M HCl for varying wt. % of B4C [with 4 wt. % WC] As cast

Duration in hours	Corrosion rates in mpy for varying wt% of B4C [4 wt. % WC]as cast			
	2.5	5	7.5	10
24	9.784	9.328	9.1644	8.712
48	6.7455	6.5322	6.0214	5.8764
72	6.3953	5.7312	4.8842	4.6653
96	4.5621	4.0242	3.8128	3.5132
120	3.6255	3.0932	2.8212	2.6313

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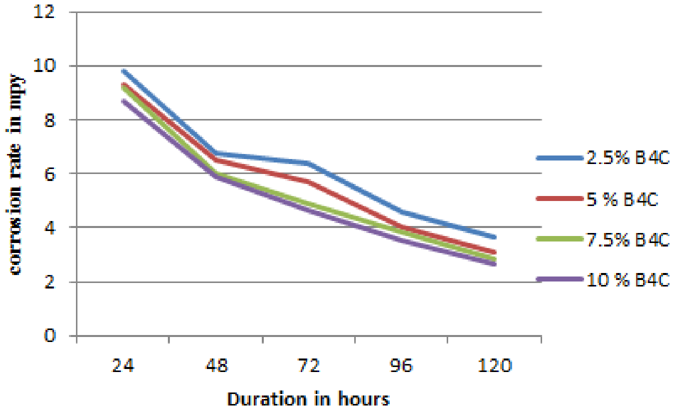

Figure – 8 Corrosion rate in mpy 1 M HCl for varying wt. % of B4C [4 wt. % WC] As cast

The Table 7 corresponds to the heat treatment specimen corrosion rates with varying percentage of boron carbide reinforcements in 1 M HCl. The corrosion rate varies from 7.592 to 3.061 mpy for time duration of 24 to 120 h for 2.5 wt% of boron carbide, while the corrosion rate varies for 5 wt% of boron carbide from 7.531 to 2.781 mpy; it varies for 7.5 wt% of boron carbide from 7.099 to 2.526 mpy, and finally, the corrosion rate varies from 6.849 to 2.259 mpy for 10 wt% of boron carbide (Figure 9)

Table – 7 Corrosion rates in mpy 1 M HCl for varying wt. % of B4C [with 4 wt. % WC] heat treatment

Duration in hours	Corrosion rates in mpy for varying wt% of B4C [4 wt. % WC]with heat treatment			
	2.5	5	7.5	10
24	7.592	7.351	7.099	6.849
48	7.269	6.091	5.529	5.152
72	5.685	5.286	4.599	4.049
96	4.317	3.726	3.485	3.079
120	3.061	2.781	2.526	2.259

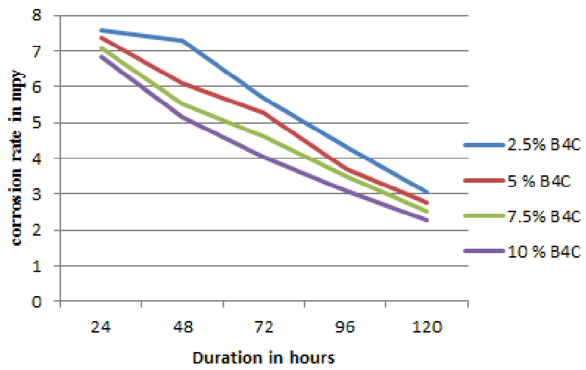

Figure – 9 Corrosion rate in mpy 1 M HCl for varying wt. % of B4C [4 wt. % WC] with heat treatment

CONCLUSION

- Weight loss corrosion test of Aluminium 7375/B4C/WC Composite has shown that the corrosion and corrosion rate decrease as the time progresses. It has also yielded enough inferences about the effect of Silicon carbide reinforcements on the corrosion of the composites, therefore giving a substantial base for the use of boron carbide reinforcement as corrosion inhibitor for aluminium composites.
- The addition of boron carbide to the Aluminium 7075 T6 – WC composite sub system decreases the corrosion current and hence the corrosion rates, this is majorly because the boron carbide reinforcement selected is a ceramic material and doesn’t involve in corrosion due to electrolytic reactions.
- The boron carbide particles act as obstacles for pitting corrosion majorly because they occupy the dendrite arm spacing in the composite and avoid material removal from the surface due to galvanic reactions.

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