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Corrosion Behavior of Metal Matrix Composite: LM25 Reinforcement with Fly Ash

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Abstract— *Fly ash co-product of coal-fired power plant was combined with post-consumer Aluminum (LM 25) to produce a molded composite material. Fly ash content varied from 4 to 12% by weight. Properties of density variance, microstructure changes and mainly focused on corrosion matrix material products were tested.*
The corrosion behavior of LM25 alloy and its composites containing 4, 8, 12 wt. % fly ash and alumina each and 4, 8, 12 wt. % hybrid reinforcement (fly ash + Alumina) was investigated using weight loss method under static condition. The tests were conducted in salty water having 3.5 wt. % NaCl solutions at room temperature for 8 days. The results of the weight-loss corrosion test showed that unreinforced LM25 alloy had a lower corrosion rate than the composites at all the tested values. The corrosion rate of the composites increased with increasing fly ash content.

1. INTRODUCTION

Metal matrix composites (MMCs) are the combination of metal matrix &reinforcement or filler material which gives excellent mechanical properties and they are classified according to reinforcement type or its content. MMCs have ability to achieve any combination of stiffness, strength and density.

The principal matrix materials for MMCs are Aluminium and its alloys. The major advantage of aluminium matrix composites over other material such as steel are, increased specific strength and stiffness, lower thermal coefficient of expansion, wear resistance, lower density, and good corrosion resistance.

Our experimental work is related to corrosion behavior of MMcs-LM25, corrosion is chemical reaction of metal with atmosphere which effects on properties of material. We know, aluminum is very reactive metal but it is passive metal. This contradictory behavior of aluminum helps to react with oxygen or water and forms coherent surface oxide which forces further reaction of Aluminium with environment.

Nowadays, MMCs are main constituent material to encourage engineering application while consideration of design and weight.

Aluminium based metal matrix composites are cheapest one production than other common metallic matrix material (copper, titanium, magnesium). They are easily processed with similar techniques used for production of metals and alloys. Currently, AMCs are reinforced using waste products derived from industrial process like red mud, fly ash. Aluminium metal matrix become very popular and among top choice material for wide range of engineering application with good combination of material properties with reduced cost and use of waste materials as reinforcement materials.

Corrosion behavior of AMCs in particular has been acknowledged too difficult to predict because of wide variation and contradicting results of metal matrix material. A measured result of corrosion behavior of AMCs in different environment is very helpful in assessment of establishing parts and its performance or suitability of number of environment.

In this work we studied corrosion wear of aluminum alloy-fly ash matrix. The interest of studying the corrosion behavior is motivated by adequate mechanical properties of Al alloy based fly ash composites which give comparatively improved strength, corrosion resistance properties over single metal matrix alloy.

The output from this research will be helpful in understanding the corrosion behavior of this AMCs. It also helps to build database of aluminium (LM-25)-fly ash composite properties.

2. LITERATURE REVIEW

P. K. Rohatgi, N. Gupta, and Somon Alaraj [1] have studied the coefficient of thermal expansion of pure Al containing 65 vol% of hollow fly ash particles and suggested that addition of fly ash in aluminum results the lower the coefficient of thermal expansion.

M. Ramachandra K. Radhakrishna [3] has worked on the Effect of reinforcement of fly ash on erosive wear and corrosive behavior of aluminium matrix composite. Al (12 wt% Si) as matrix material and up to 15 wt% of fly ash particulate composite was fabricated using the stir casting method and came forward into conclusions as corrosion resistance of reinforced composite has decreased with increase in fly ash content.

Sudarshan, M.K.Surappa [2] have putting together A356 Al–fly ash particle composites .They studied mechanical properties fly ash with narrow size range (53–106µm) show better properties compared with the wider size range (0.5–400µm) particles. And fracture surface of composites show mixed mode (ductile and brittle) fracture.

S. Sarkar, S.sen and S. C. Mishra and coworkers has studied on Aluminum – fly ash composite produced by impeller mixing[4] and came into a brief idea that

Up to 17wt% fly ash reinforcement can be reinforced by liquid metallurgy route.

3. EXPERIMENTAL WORK

3.1 Materials

LM-25: This alloy conforms to British Standard 1490 LM-25.

Table 1: Chemical composition of LM-25

copper	0.1% max
magnesium	0.2-0.6
silicon	0.5%
iron	0.3% max
manganese	0.1% max
nickel	0.1% max
zinc	0.1% max
lead	0.1% max
aluminium	remainder

Physical Properties:
* Modulus of elasticity- 71*E3 N/mm^2
* Resistance to corrosive attack by sea water and marine atmosphere is high.
*Tensile stress- 130-150 N/mm^2

Fly ash: Our major reinforcement fly ash is one of the residues generated in the combustion of coal. It is an industrial byproduct recovered from the flue gas of coal burning electric power plants. According to burning process of coal, constituents of fly ash vary considerably. Main contents of fly ash are silica (both amorphous and crystalline). Fly ash also contains A_2O_3, Fe2O3 and in minor proportion Mg, Ca, Na, K etc.

Fly ash particles are spherical in shape and range from less than 1µm to 100µm. the specific gravity of fly ash vary in range of 0.6-2.8 gm/cc. As material in light weight fly ash actively used in production of MMCs.

3.2 Casting

The aluminium fly ash metal matrix composite was prepared by stir casting route (see fig.2). For this we took 3 kg of commercially pure aluminium and desired amount of fly ash particles.

The fly ash particle was preheated to 250^{0}C for three hour to remove moisture. Commercially pure aluminium was melted in a resistance furnace. The melt temperature was raised up to 725^{0}C and it was degassed by purging hexachloroethane tablets.

Then the melt was stirred with the help of a mild steel turbine stirrer. The stirring was maintained between 5 to 7 min at an impeller speed of 75 rpm .The melt temperature was maintained 725^{0}C during addition of fly ash particles.

The dispersion of fly ash particles were achieved by the vortex method. The melt with reinforced particulates were poured into the preheated permanent metalic mold. The pouring temperature was maintained at 725^{0}C.The melt was then allow to solidify the moulds. The composites were made with a different amount of fly-ash (i.e.4, 8, 12, wt %), Magnesium and silicon were added to increase the wettability of fly ash particles (see fig.1)

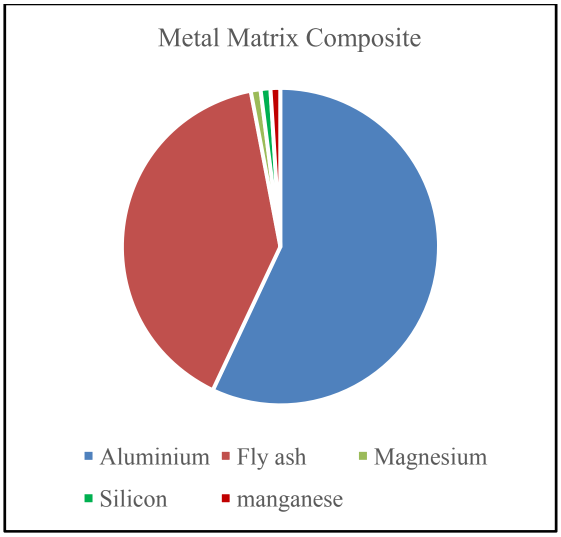

Fig. 1: composition of casting

After production of casting we are making main experiment work i.e. related our corrosion testing.

According % weight of fly ash composites divided in categories. We making 10-15 specimens from each categories for testing with 5*5*5 mm cross section area and 5*5mm*5cm cross section area from the castings which are produced with above procedure

Fig. 2: stir casting setup

3.3 Corrosion

The corrosion behavior of the composites produced was investigated acidic environment i.e.3.5% NaCl solution at room temperature (30◦C). Standard immersion corrosion test was used to investigate the weight loss and corrosion rates of each material. Test specimens of each material were polished using several grades of emery paper ranging from 240 to 600 grit, rinsed in distilled water and dried. They were then weighed using an electronic weighing balance). The sample weights were measured in grams to 3decimal places. After weighing, the specimens were immersed in 3.5 wt. % NaCl solution of 3.5pH or in fresh water. The pH values used for the salt solution were 4, 7 and 9. These pH values were selected to simulate mildly acidic, neutral, and alkaline conditions in which structural applications made of LM-25 and its composites may be exposed .We are investigating corrosion rate in dynamic testing apparatus as shown in Fig. 2.

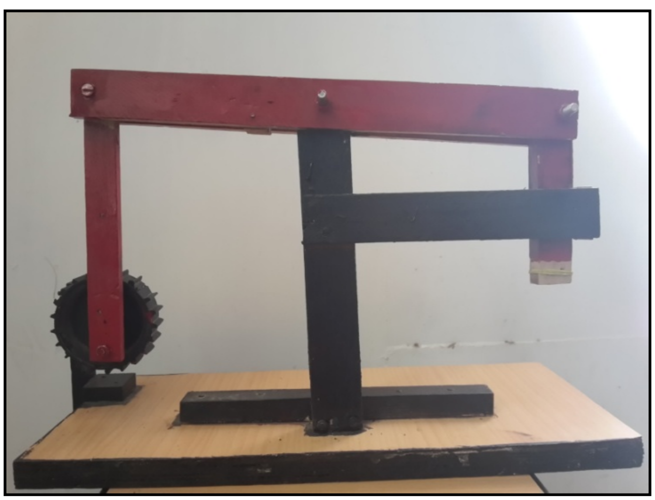

Fig. 2: testing apparatus

In this test ,first we calculate weight of specimen which used in setup then this specimen kept on apparatus after that setup was started continuously with help of electricty for four hours and taking observations or readings for four, eight hours .in this specimen continuously up-down motion in Nacl solution which having 3.5pH,after sometime we observe the solution quantity.

We take second test for corrosion i.e. Immersion Corrosion Test.In this test specimens having cross section area 5*5*5mm deeped in Nacl solution statically. To account for metal loss resulting from cleaning of the specimens, the weight loss of uncorroded control specimens was obtained using the weight measuring procedure. The weight loss for the control specimens was used to correct for metal loss of the alloy and composites resulting from the cleaning procedure (ASTM G1: 7.1.1). Weight loss data were obtained by subtracting weights obtained after each exposure to the electrolyte from the initial weights before the exposure. The corrosion rate of each specimen in mm/year was determined using the expression as follows,

mm/year = 87.6W /DAt

Where *W* is weight loss in mg, *D* is density in g/cm^3, *A* is surface area in cm^2, and *t* is time in hours.

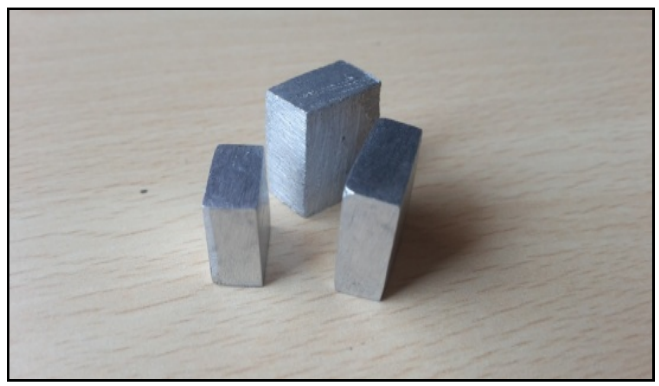

Fig. 3: Specimens for corrosion testing

4. RESULT & DISCUSSION

Table 2: Observations for time- 4 hours

Composition	Density gm/cc	Weight of specimen gm		Weight loss (W) gm	Corrosion in mm/year
		Before	after		
4%wt. fly ash	2.72	4.826	4.820	0.006	19.2325
8% wt. fly ash	2.69	4.830	4.822	0.008	26.0520
12% wt. fly ash	2.65	4.825	4.814	0.011	36.3622

Table 3: Observations for time- 8 hours

Composition	Density gm/cc	Weight of specimen gm		Weight loss (W) gm	Corrosion in mm/year
		before	after		
4%wt. fly ash	2.72	4.826	4.817	0.009	14.49
8% wt. fly ash	2.69	4.830	4.819	0.011	17.91
12% wt. fly ash	2.65	4.825	4.811	0.014	23.13

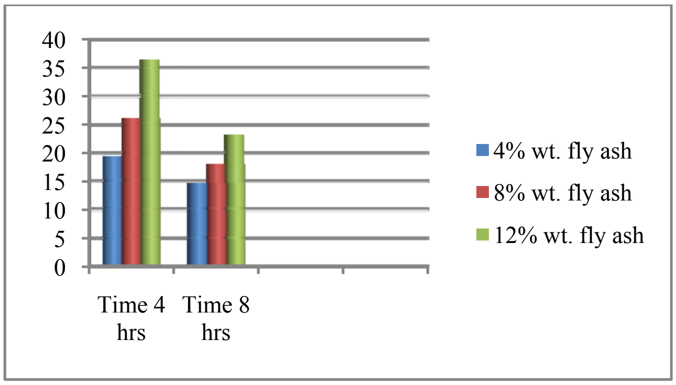

Fig. 4: Time vs. corrosion rate

. The variation of normalized weight loss with exposure time for LM25 composite is, For 4 hours test, it can be seen that composite lost during the exposure period. The weight lost by composite increased gradually as the immersion time increased. The weight lost by composite was gradual in initial hours of immersion after which its weight loss increased sharply at end of test as shown in table no.2

For 8 hours test as shown in table no.3, although corrosion rate increases among 4, 8, 12 wt% of composite, it may be noted that rate of corrosion decreases as compared earlier test. This results compared in Fig. 4

5. CONCLUSION

1. As fly ash weight percent increases corrosion resistance decreases i.e. corrosion rate increases
2. As time period for immersion test increases, it is observed that corrosion rate decreases.

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