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Corrosion Behaviour of Aluminium Alloy-Flyash Composites used in ESP

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The effect of corrosion on aluminium alloy (LM6) containing ceramic fly ash based microspheres is investigated in this work. Stir casting route has been employed to disperse 10 % ceramic microspheres as reinforcement in the alloy matrix. Further, the alloy system was subjected to grain refinement, modification as well as combined action of grain refinement and modification. Three sets of LM6 alloy castings were produced in each case, to check for reproducibility. The corrosion resistance was evaluated by immersing the samples in 3% NaCl solution. The pH and electrical conductivity were measured to assess the damage due to corrosion. It was observed that the corrosion resistance decreased in the composite samples subjected to grain refinement, modification, combined action of grain refinement and modification compared to untreated alloy composite. Scanning Electron Microscopy [SEM] has been used to substantiate the corrosion data. On the other hand, mechanical properties namely hardness and ultimate tensile strength improved greatly in the modified samples compared to grain refined and grain refined and modified samples.

Keywords: *Metal matrix composites, Ceramic microspheres, LM6 and Corrosion.*

1.0 INTRODUCTION

It is well known that Al-Si alloys, by virtue of its excellent conductivity, high strength to weight ratio, excellent castability, good corrosion resistance, low coefficient of thermal expansion, ease of fabrication find extensive use in the Power Sector applications especially in Electro Static Precipitators [ESP], baffle plates, dampers, and other applications [1, 2]. The ESP plates are generally rapped or sprayed with water to collect the ceramic microspheres accumulated on it, thereby exposing the plates to corrosion. However, Al-Si alloys have to be grain refined and modified to realize its full potential [2–6]. It is also reported that eutectic modifiers are widely used to enhance the mechanical properties [7]. The particulates such as SiC, TiB_2 and fly ash have been used to reinforce Al alloys to improve their mechanical properties [8–14]. The mechanical properties of Al-Si alloy-cenospheres composites subjected to melt treatments have shown improvement compared to the base alloy [15].

The current investigation focuses on the effect of corrosion on Al-Si composites with fly ash based microspheres as reinforcement. The pH, electrochemical measurements and Scanning Electron Microscopy [SEM] have been used to measure the rate of corrosion and to examine the corrosion in the composites, respectively. The investigations have been carried out to study the influence of grain refinement, modification and combined grain refinement and modification of

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Al-Si alloy-fly-ash based composites, as this type of work has been less reported.

2.0 MATERIALS

2.1 Matrix

The standard eutectic Al-Si alloy, LM6 containing 11.8% Si as per BS: 1490 was used as the matrix.

2.2 Reinforcement

The reinforcement material used is ceramic microspheres as shown in Figure 1.

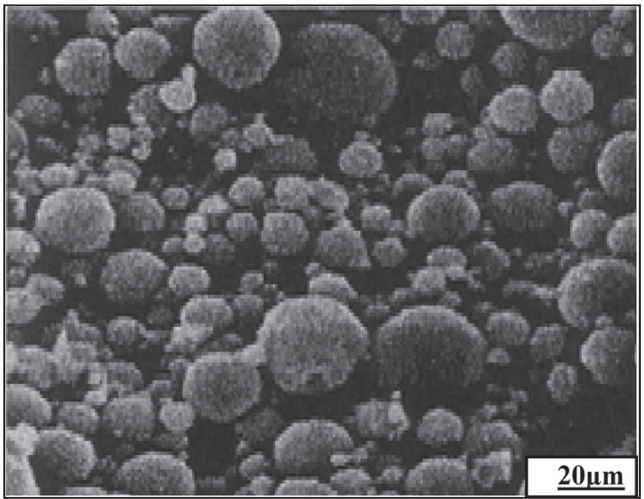

FIG. 1 TYPICAL PHOTOMICROGRAPH OF CERAMIC MICROSPHERES.

They are hollow, fine grained powdery particulate materials that are carried off in the flue gas and usually collected by means of electrostatic precipitators. The size varies from 50–250 µm. Since the particles solidify in suspension, ceramic microspheres are generally spherical in shape and are more consistent in quality, shape and size compared to normal fly-ash. Hence, ceramic microspheres of fly-ash have been used as reinforcement in this investigation.

3.0 METHODS

3.1 Preparation of composites

The melting, pouring, addition of ceramic microspheres and preparation of composites were carried out by the authors as indicated in our earlier papers [14, 15]. The composites were subjected to melt treatments like grain refinement, modification and combined grain refinement and modification as described in our earlier works [16]. From our earlier studies, it was seen that the best results with respect to mechanical properties was obtained for Al-Si alloy-ceramic microspheres composites with 10% addition of reinforcement.

In the present investigation, composites with 10% reinforcement addition were chosen and the test castings were subjected to grain refinement, modification and combined grain refinement and modification.

3.2 Corrosion experiments

Samples for corrosion testing were cleaned in deionized water. The dried samples were immersed in 3% NaCl solution contained in a distillation flask to simulate sea water conditions. The tests were conducted for varying periods of time up to 576 hours under water cooled reflex condenser to keep the concentration of the solution constant. The pH of the 3% NaCl solution was measured using Systronics Digital pH Meter 335 before and after the experiment. Electric conductivity of the solution (Specific Conductance) was measured using Systronics Conductivity Meter 304 before and after the experiment. The effects of corrosion on the composites were studied using Scanning Electron Microscopy. The Corrosion rates were measured using pH variation method and electrochemical method.

It is reported that the excellent corrosion resistance of Al-Si alloys is due to its ability to form a natural oxide film on the surface [17]. The reaction is as follows:

$$Al + 3(OH)^- = Al(OH)_3 + 3e^- \quad .... (1)$$

The dissolution of these oxide films which leads to corrosion of Al is due to the adsorption of chloride ions that react with Al cations leading to the formation of a hydroxychloride salt. This salt goes into solution, leaving the bare Al to corrode according to the following reaction:

$$Al^{3+} + 4Cl^{-} = Al\ Cl_4^{-} \quad .... (2)$$

4.0 RESULTS AND DISCUSSION

The corrosion behavior of composites subjected to various melt treatments are discussed below. The various samples have been designated and shown in the Table 1.

TABLE 1 SAMPLE SPECIFICATION AND DESIGNATION	
Sample Details	**Sample designation**
LM6 + 10% Ceramic microspheres	A
LM6 + 10% Ceramic microspheres with grain refinement	B
LM6 + 10% Ceramic microspheres with modification	C
LM6 + 10% Ceramic microspheres with grain refinement and modification	D

Table 2 shows the improvement in the mechanical properties of the composites compared to the base alloy [15].

TABLE 2 IMPROVEMENT IN THE MECHANICAL PROPERTIES		
Designation	**% Increase in hardness**	**% Increase in UTS**
A	24	32
B	30	84.6
C	36	92
D	24	39

4.1 Corrosion

Table 3 shows the corrosion behavior of composites subjected to various melt treatments.

TABLE 3 OBSERVATIONS ON CORROSION DUE TO pH AND ELECTRIC CONDUCTIVITY OF COMPOSITES SUBJECTED TO VARIOUS MELT TREATMENTS						
Sample desig-nation	Variation in pH of the solution			Variation in electrical conductivity of the solution in mS		
	Min	Max	% change	Min	Max	% change
A	5.9	8.26	40	53	60	13
B	5.9	9.28	57	53	75	42
C	5.9	8.82	49	53	65	23
D	5.9	9.14	55	53	70	32

The following are the observations made from the Table 3.

- The pH of the 3% NaCl solution changes from acidic to alkaline range. For instance, the pH of the composite A changes from 5.9 at the beginning of the test to 8.26 at the end of the test.
- Similarly, the pH of composites B, C and D change from 5.9–9.28, 8.82 and 9.14 respectively. This increase in pH is perhaps due to the formation of Al $(OH)_3$. This is in agreement with the results reported by earlier investigators [17–18].
- The electrical conductivity of the solution also increases, again pointing to detectable corrosion. For instance, the electrical conductivity increases from 53 milli Siemens [mS] at the beginning of the test to 60 mS at the end of the test for composite A.
- Similarly, the electrical conductivity of composites B, C and D increase from 53 mS at the beginning of the test to 75 mS, 65 mS and 70 mS respectively.

4.2 SEM Examination

Scanning Electron Microscopy [SEM] was carried out in order to confirm the above inferences. Figures 2–5 display the SEM micrographs of composites A, B, C and D respectively.

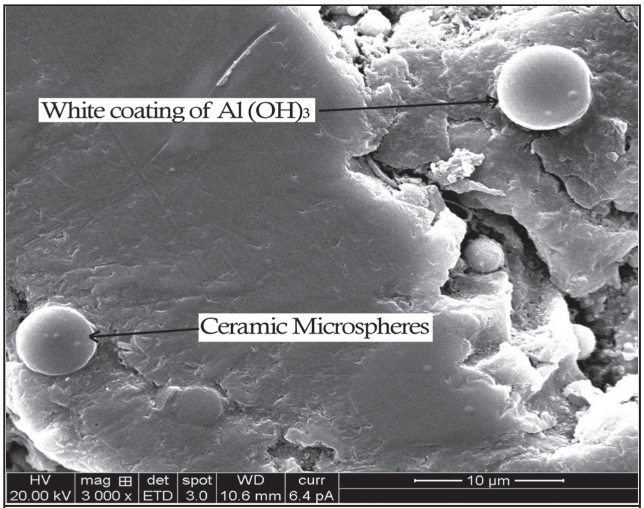

FIG. 2 SEM OF LM6-10% CERAMIC MICROSPHERES COMPOSITE SUBJECTED TO CORROSION.

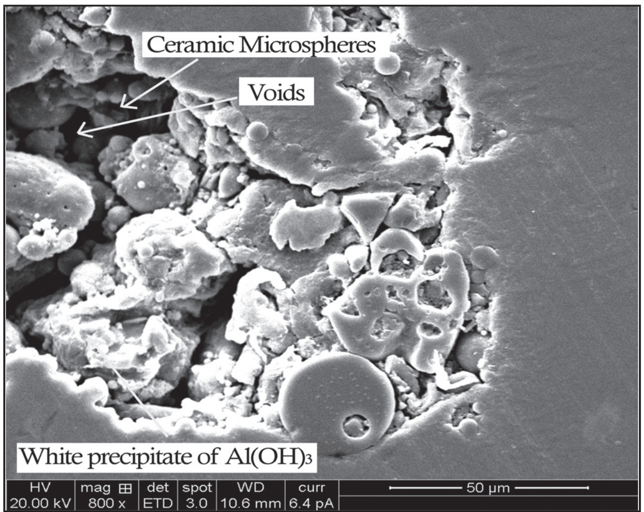

FIG. 3 SEM OF LM6-10% CERAMIC MICROSPHERES COMPOSITE SUBJECTED TO CORROSION (GRAIN REFINED).

FIG. 4 SEM OF LM6-10% CERAMIC MICROSPHERES COMPOSITES SUBJECTED TO CORROSION (MODIFIED).

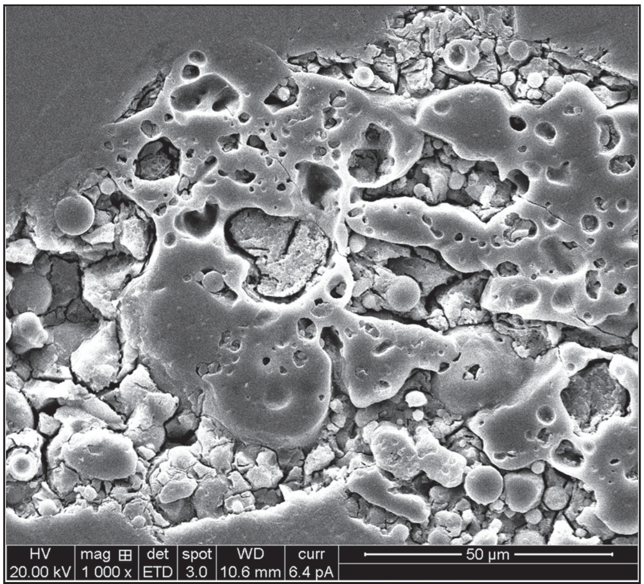

FIG. 5 SEM OF LM6-10% CERAMIC MICROSPHERES COMPOSITES SUBJECTED TO CORROSION (GRAIN REFINED AND MODIFIED).

It is observed from the SEM micrographs that the ceramic microsphere particles are coated by the white precipitate of $Al(OH)_3$, according to equation (1). Subsequent reaction takes place due to the presence of chloride ions in salt water used during the corrosion experiments conducted on such samples as per equation (2), leaving the bare Al to corrode. Corrosion has occurred around the ceramic microsphere particles. The particles are eventually knocked off resulting in voids. This may be the cause for severe corrosion in the composites.

The following points may be observed from the SEM pictures.

- The modified composite namely C, shown in Figure 4 has the least corrosion effect compared to B (Figure 3) and D (Figure 5).

5.0 CONCLUSIONS

- The corrosion behavior is affected for the composites which are subjected to grain refinement/modification/combined grain refinement and modification in terms of pH variation and electrical conductivity.
- The best mechanical properties have been achieved in composite C compared to B and D

- The composite C shows the least variation of 23% in electrical conductivity compared to 42% in B and 32% in D.
- The percentage change in electrical conductivity of the solution due to corrosion is only 13% in composite A compared to 23% in C. On the other hand, the mechanical properties namely hardness and UTS show an improvement of 12% and 60% in composite C compared to A.
- It may be inferred that LM6 composites subjected to modification process [C] is preferred for applications involving the use of electrostatic precipitator plates, baffle plates, dampers etc., as one has to consider a trade-off between the corrosion and mechanical properties of the composites

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