DEVELOPMENT OF ALUMINIUM-CERIA COMPOSITE BY USING STIR CASTING

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Abstract:

Development of aluminum alloy based casting composite materials via stir casting is one of the prominent and economical route for development and processing of metal matrix composites. Properties of these materials depend upon many processing parameters and selection of matrix and particulates. Literature reveals that most of the researchers are using aluminum matrix with SiC, ZnO and Al_2O_3 particles for achieving good mechanical and electrochemical properties whereas, insufficient information is available on aluminum matrix composite incorporated with CeO particles. The present research was conducted to investigate the effect of CeO particle on mechanical and electrochemical properties of aluminum composite material using simple foundry melting and casting route.

Key words: Stir casting, aluminium alloy, ceria, particulate composite

1. Introduction:

Modernization in the field of science and technology increases the demand in the developments of advanced engineering materials for various applications. These area demands light weight, high strength, good tribologicaland electrochemical properties. Such demands can only be met by development and processing of aluminium metal matrix composite materials(Gopalakrishnan and Murugan, 2012; Moses et al., 2014; Sajjadi et al., 2012).

Literature review indicates that aluminum can be used in corrosion application as a sacrificial anode in cathodic protection system. The formation of passive layer within a very short time, is the main reason due to which pure aluminum could not achieved industrial attraction. To overcome these difficulties aluminium is alloyed with Cu, Zn, Mg, etc. and different ceramic particulates (like SiC, ZnO and Al_2O_3)are added to it by different researchers (Barbucci et al., 1997; Bharath et al., 2014; Idenyi et al., 2009; Kumar et al., 2013; Shibli et al., 2008).

The main challenge in the development and processing ofengineering materials is to control the microstructure and properties.The processing of particulate metal matrix composite involves two major processes (1) powder metallurgy route (2) liquid cast metal technology. The powder metallurgy process has its own limitation such as processing cost and size of the components. Therefore only the casting method is to be considered as the most optimum and economical route for processing of aluminium composite materials. Stir casting is a casting methodthat includes: melting of metal; addition of ceramic particles in molten metal under controlled mechanical stirring system. Schemetic diagram of stir casting device is shown in Fig. 1(Bauri et al., 2011; Brabazon et al., 2002; Hashim et al., 1999; Jokhio et al., 2011a, 2011b).

The present work was planned to investigatethe effect of CeO particle on mechanical and electrochemical properties of aluminum composite material using simple foundry conventionalcasting. Thedetails of the research work are given in the subsequentsections.

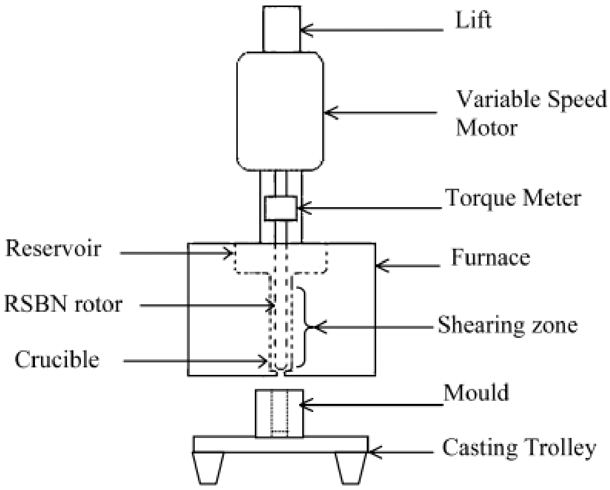


Fig. 1: Schematic diagram of stir casting device

2. Materials and Method:

For present workaluminum ingot, zinc ingot and cerium oxide (ceria)of 1-3mm grains were purchased from market. Composition of aluminum, zinc and ceria is described elsewhere(Aftab, 2012; Aftab et al., 2012).Ceria particles were ground in High-speed shimmy ball mill (Mtixl, SFM-1) for 30 min and 60 min time intervals and the particles produced were labelled as micro-30 and micro-60 respectively. The particle size distribution of micro ceria was determined using HorribaLaser Particle Size Analyser (Model: LA-300). Aluminum-5%Zinc alloy was heated up to 750^{o}C in pit furnace and micro ceria particles (composition shown in Table 1) were added in the molten bath. Temperature was kept constant and bath was mechanically agitated continuously to properly mix the particles.

Table 1. Aluminum-5% Zinc-Ceria Composite Composition

Composition	**AZC-1**	**AZC-2**	**AZC-3**	**AZC-4**	**AZC-5**	**AZC-6**	**AZC-7**
Ceria	NA	0.2% (micro-30)	0.4% (micro-30)	0.6% (micro-30)	0.2% (micro-60)	0.4% (micro-60)	0.6% (micro-60)
Aluminum-5 % Zinc	balance	balance	balance	Balance	Balance	balance	Balance

Aluminum -5% Zinc-Ceria samples were ground initially by using emery paper of 320 to 1000 mesh size and polished using velvet cloth. Keller's etch solution was used to etched the samples. Scanning Electron Microscope (Model: JEOL: JSM-6380L) was utilized to assess the microscopic texture of the samples. The VHN hardness of the composite samples was checked by using Vickers Hardness Tester (Model: Masuzawa Seiki Co. Ltd. MV-1) at 1Kg_f load.

Open circuit potential (OCP) and close circuit potential(CCP) of Auminium-5% Zinc-Ceria composite were investigatedto inspect the electrochemical properties of the composite. In OCP investigation samples were made as anode and immersed in 3% brine solution kept at 30 ± 2^{o}Cfor seven days. After every 24 hr, potential difference of test anodes was determined using copper/copper sulfate (CCS) reference electrode. In CCP investigation Auminum-5% Zinc-Ceria and mild steel samples were made as anode and cathode respectively. Composite anodes were mechanically attached with mild steel cathode and immersed in 3% brine solution for the period of seven days at 30 ± 2^{o}C. After every 24 hr, emf difference of anode and cathode was determined by using copper/copper sulphate (CCS) reference electrode.

3. Results and Discussion:

The particle size distribution of micro ceria particles ground for 30 min and 60 min is shown in Fig. 2. It can be seen that 80% passing is achieved at 10 µm and 1.25 µm particle size in case of 30 min and 60 min grinding time respectively. Sufficient reduction in 80% passing size achieved at additional 30 min grinding indicates that ceria is highly fragile due to which it has better grindability.

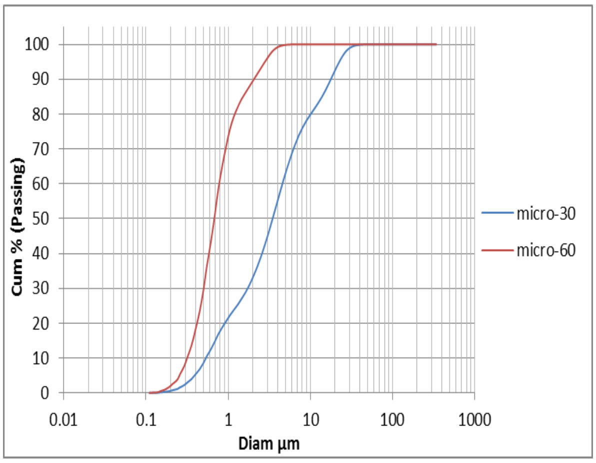
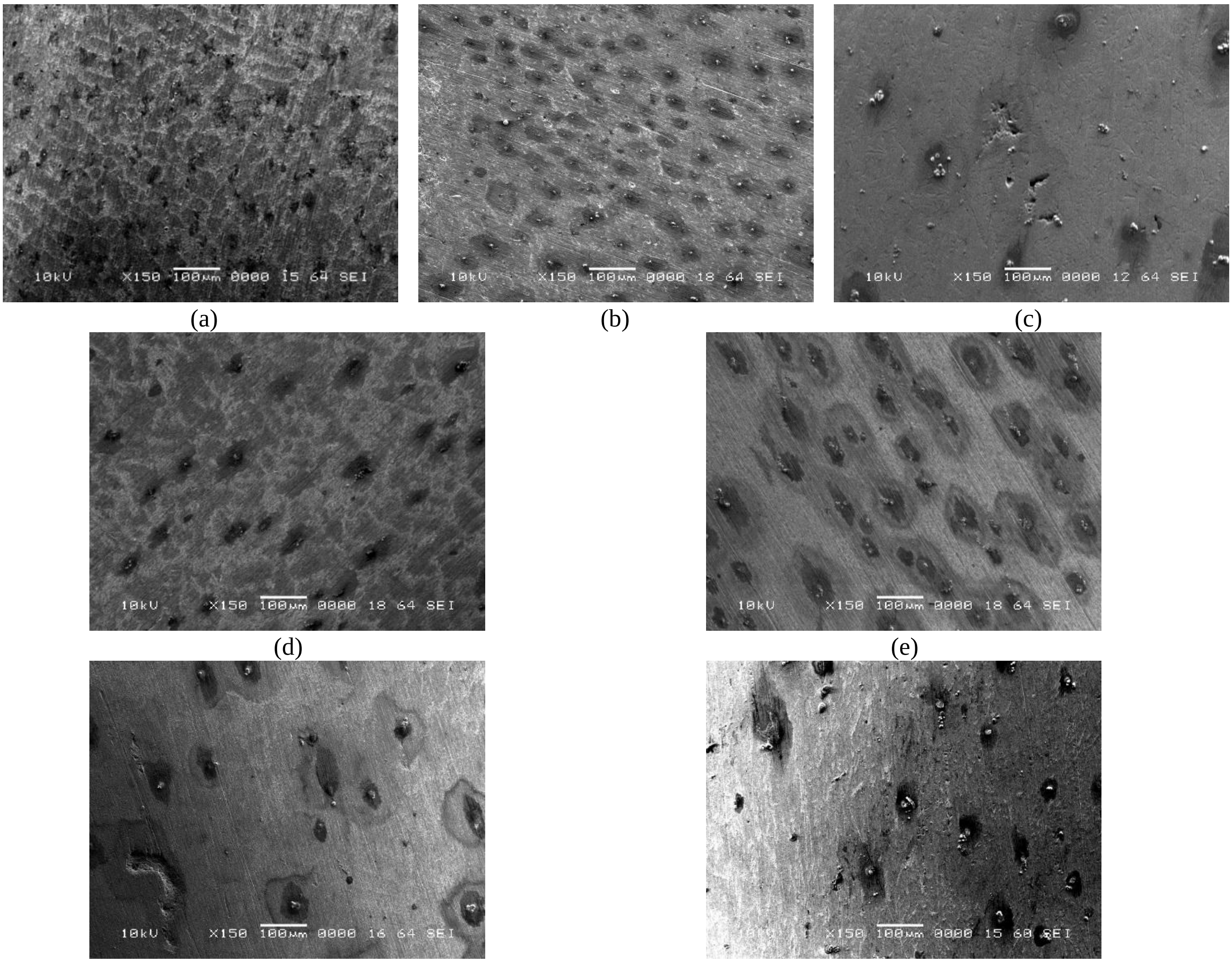


Fig. 2: Cumulative particle distribution of 30min and 60 min ground sample

The surface morphology of aluminum -5% zinc-ceria samples observed under Scanning Electron Microscope is shown inFig. 3. It can be seen that pits are rarely visible in all types of anode tested. It is also visible in the Fig. 3(g) that agglomeration of ceria particles was increased with the addition of ceria particles ground for 60 min. The agglomeration of ceria particles can be attributed with their fine size distribution. Inappropriate distribution and clustering of ceria particles recommended that more efficient mechanical mixing is required at elevated temperatures(Jokhio et al., 2011a).

Fig. 4 shows the hardness result of aluminum-5% zinc-ceria composite sampleson the basis ofconcentrationof ceria particles, which indicates that with increasing micro-ceria particles concentration hardnesswas increased.Significant riseinhardnesscan be explainedwith the understandingthat ceria is a ceramic material,whileceramicshave highhardnessand wear resistance properties.In addition, thesolution strengthening mechanism may explain the role of ceria in increasing hardnessof the samples.



(a) (b) (c) (d) (e) (f) (g)

Fig. 3: Aluminum-5% zinc- ceria composite SEM micrographs at 150 X

(a) AZC-1,) (b) AZC-2, (c)) AZC-3, (d)) AZC--4, (e)) AZC-5, (f)) AZC-6 and (g)) AZC-7

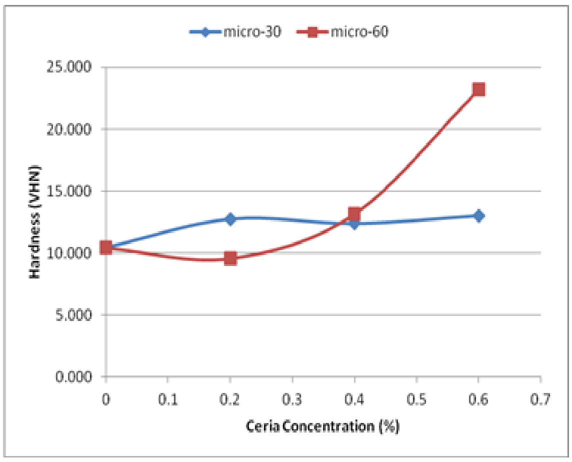


Fig. 4: Aluminum-5% zinc- ceria composite Hardness

Fig. 5indicates theemf(OCP) of all Aluminum-5% zinc- anodes, the emf was remain at -1.0 volts (mean) excluding AZC-3 anode whose emf was -0.8 volts (mean). The emf trend for seven days of anodes with and without addition of ceria indicates that ceria has efficiently stabilized the emf at -1.0 volts. To know for how long emf of anode of AZC-6and AZC-7 composition can stabilized the emf at-1.0 volts, the emf results were extrapolated for three month and was noted that emf of ceria added anodes were remained at -1.0 volts ±0.1 whereas emf of anode without ceria reached below -0.8 volts.

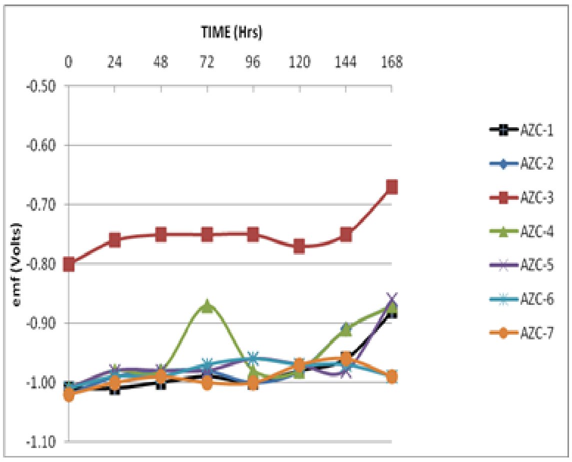


Fig. 5:Time vs.OCPgraph [AZC-1 to AZC-7]

Emf trend of Aluminum-5% zinc- ceria anodes in CCP shown in Fig. 6,**Error! Reference source not found.** point out that emf difference of AZC-3 and AZC-7 anodes was moved to -0.8 volts, whereasCCP emf of remaining was remained at -1.0 volts (mean). Furthermore, AZC-1 and AZC-4 anodes reveal unstable emf in comparison with rest of the anodes samples.Quite constancy in emf was seen after one day in cathode emf is evident.

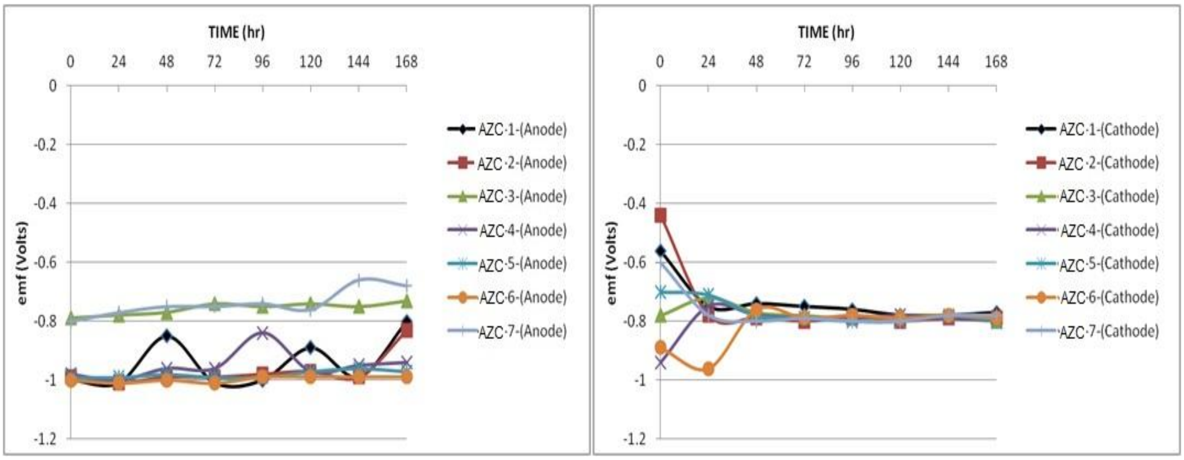


Fig. 6: Time vs. CCP graph [AZC-1 to AZC-7 (anode+cathode)]

4. Conclusion:

Composite casting of Aluminum-5%Zn with ceria particles was successfully done and good mechanical and electrochemical properties were achieved. Open and asymmetrical pits were rarely noted in samples containing ceria particles. In few samples by raising the amount of ceria in the composite, clustering of fine particles becomes the cause of wide pits.The hardness of Aluminum-5% Zinc anode is considerably increased by the addition of ceria particles. Adding ceria in Aluminum-5% Zinc anode did not alter the emf of anodes. It was worth eminent that by the addition of ceria in Aluminum-5% Zinc anode emf is stabilized. In OCP and CCP system it was clear that Aluminum-5% Zinc anode samples added with micro-60 samples efficiently inhibit the emf of mild steel cathode.

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