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Studies on Aluminum – Fly-Ash Composite Produced by Impeller Mixing

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ABSTRACT: The present investigation is focused on the utilization of abundantly available industrial waste, i.e., fly-ash in a useful manner by dispersing it into aluminum/aluminum–magnesium matrix to produce composites by a liquid metallurgy route. Composites are produced with different percentage of reinforcing phase. Further, these composites are characterized using XRD, wet chemical analysis, and image analysis. Mechanical and wear properties of the composites are evaluated.

KEY WORDS: particulate composite, industrial waste, applied load and sliding velocity.

INTRODUCTION

CAST ALUMINUM MATRIX particle reinforced composites are gaining significant acceptance because of higher specific strength, specific modulus, and good wear resistance as compared to un-reinforced alloys [1–8]. While investigating the opportunity of using fly-ash as a reinforcing material in the aluminum melt, Rohatagi et al. [9,10] observed that the low density of fly-ash may be helpful for making a lightweight composite. The particulate composite can be prepared by injecting the reinforcing particles into solid/semi-solid or liquid matrix by a powder metallurgy technique or through a liquid metallurgy route by casting [11–15]. The casting route is preferred as it is less expensive and amenable to mass production. Among the entire liquid state production routes, stir casting is the simplest and cheapest one. The only problem associated with this process is the non-uniform distribution of the particulate due to poor wettability and gravity regulated segregation. In the present work, fly-ash which mainly consists of refractory oxides like silica, alumina, and iron oxides, is used as the reinforcing phase and to increase the wetabbility magnesium is added. Composites are produced with different percentages of reinforcing phase. Further, these composites are characterized with the help of XRD, wet chemical analysis, and image analysis. Mechanical and wear properties of the composites were also evaluated.

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EXPERIMENTAL PROCEDURE

The required amount of commercially pure aluminum and Al–3Mg (wt%) master alloy was melted in a resistance heated muffle furnace in a graphite crucible. The melt temperature was raised to 1073 K and then degassed by purging with argon gas. The fly-ash particles were preheated to 423 K for 5 h to remove the moisture. After degassing, preheated fly-ash particles with different wt% were added to the vortex formed in the melt by stirring. A mild steel stirrer with vertical axis was used. The rpm of the stirrer was maintained at 250–300 for mixing the melt. The melt temperature was maintained at 1023–1073 K during the addition of the particles. The pouring temperature was kept at 993 K. The fly-ash used had SiO_2 (75.4%), Al_2O_3 + (17.6%), Fe_2O_3 (2.5%) as major constituents and oxides of Mg, Ca, Na, K, etc., as minor constituent. Density of fly-ash was 1.92 g/cm^3. The size range of the fly-ash particle used was between 75 and 100 μm. The composites were made with a different amount of fly-ash (i.e., 10, 20, 30 wt%). The composites thus produced with different amounts of reinforcing phase were analyzed with the help of image analyzer and by wet chemical analysis. The tensile testing of the composites was conducted using an Instron testing machine at a strain rate of 0.5 mm/s. Standard specimens with 19 mm gauge length were used to evaluate ultimate tensile strength, yield strength, and the elongation. The hardness of the samples was determined by a Brinell hardness tester with 500 kg load and 10 mm diameter steel ball indenter. The detention time for the hardness measurement was 30 s. The wear characteristics of Al–fly-ash and Al–Mg–fly-ash composites were evaluated under dry sliding condition. Wear tests were performed on a modified pin on disk type machine, having a high carbon – high chromium steel disk.

RESULTS AND DISCUSSION

The size, density, type of reinforcing particles, and its distribution have a pronounced effect on the properties of particulate composites. The variables affecting the distribution of particles are solidification rate, fluidity, type of reinforcement, and the method of incorporation. Table 1 gives the idea about the retention of fly-ash in the castings with and without Mg addition. It is observed that addition of magnesium improves the wettability of fly-ash with aluminum melt and thus increases the retention of the fly-ash.

Table 2 shows the value of ultimate tensile strength, 0.2% proof stress, % elongation, and hardness of the composites for different compositions. It is observed that with the increase in percentage of dispersed phase, ultimate tensile strength, 0.2% proof stress, and hardness increases reasonably with appreciable percentage elongation.

Table 1. Retention of fly-ash in the composites.

Amount of fly-ash added in Al matrix (wt%)	**Amount of fly-ash retained (wt%)**
10	5.64
20	7.67
30	11.52
Amount of fly-ash added in Al–Mg matrix (wt%)	Amount of fly-ash retained (wt%)
10	7.53
20	8.12
30	17.11

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Wear behavior of composites were studied at different sliding velocities and at different loading. Figure 1 shows the effect of varying load on wear rate at a particular sliding velocity. The effect of sliding velocity on wear rate at a particular load is shown in Figure 2. From these graphs, it is clear that wear rate has improved significantly with the addition of fly-ash. The addition of fly-ash acts as a barrier to dislocation strengthening of

Table 2. Mechanical properties of the composites.

Composition of the cast composites	Hardness (BHN)	0.2% Proof Stress (MPa)	UTS (MPa)	% Elongation
As cast Al	16	35	47	40
Al–5.64 wt% fly-ash	17	37	54	35
Al–7.67 wt% fly-ash	18	39	62	30
Al-11.52 wt% fly-ash	22	47	74	25

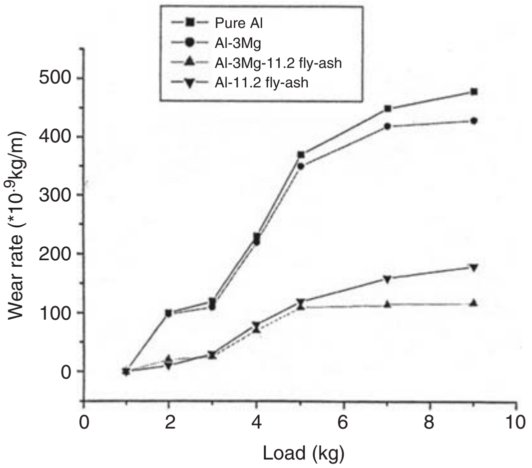

Figure 1. *Variation of wear rate with applied load at sliding velocity of 0.5 m/s.*

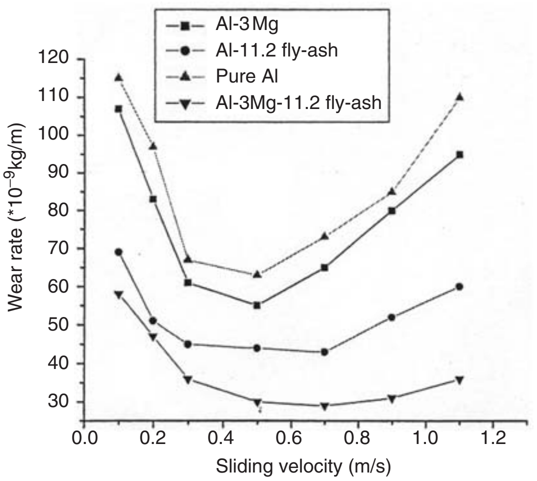

Figure 2. *Variation of wear rate with sliding velocity at 8 kg load.*

the material and at the same time it also increases the hardness but without losing much ductility. While considering Figures 1 and 2, it can be easily visualized that, like other aluminum composites, Al–fly-ash composites also have an increasing trend of wear with applied load due to deformation and generation of cracks within the oxide film that might act as a three-body wear on removal of the particles there by increasing the wear rate drastically at higher loads. Wear rate with sliding velocity shows a decreasing trend initially due to the increase in surface temperature which in turn increases the rate of form and oxide film on the surface and hence wear rate decreases. But once the thickness (of the surface film) increases it also starts cracking with further increase in sliding velocity and oxide particle are removed giving rise to three-body wear and wear rate increases with further increase in sliding velocity. While studying the nature of the debris and wear tracks at different sliding velocities (0.3, 0.7, and 1.1 m/s) for a particular load, the nature of the debris changes from oxidative to oxidative metallic to metallic as shown in Figure 3(a–c).

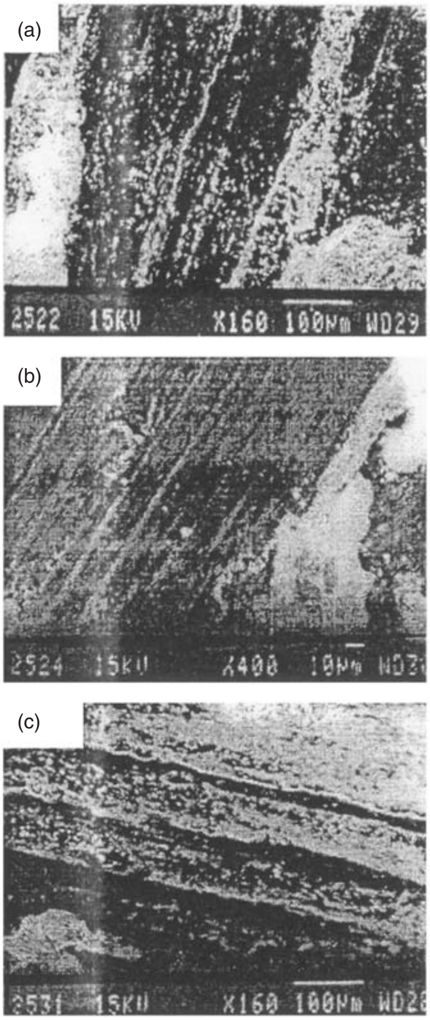

Figure 3. *SEM micrograph of wear tracks of Al–3Mg –11.2 fly-ash composite at 8 kg load and different sliding velocities (a) 0.3, (b) 0.7, and (c) 1.1 m/s.*

This observation supports the variation of wear rate with sliding velocity of an applied load, as depicted in Figures 1 and 2. Increasing the amount of fly-ash, the wear rate reduces irrespective of the load and sliding velocity.

CONCLUSIONS

- Fly-ash up to 17 wt% could be successfully added to Al–Mg alloy by stir casting technique to produce composites.
- Addition of magnesium improved the wettability of fly-ash with aluminum melt and thus increased the retention of the fly-ash in the composites.
- The strength and hardness were improved reasonably with the addition of fly-ash. The ductility was also appreciable in comparison to the composites investigated earlier.
- The wear rate has improved significantly with the addition of fly-ash and Mg.

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