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Utilisation of fly ash as a potential reinforcement material for better mechanical properties of Aluminum

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ABSTRACT: The remarkable strength and durability characteristics found in light-weight alloys-based Metal Matrix Composites (MMC) assisted in enhancing their widespread use in automobile, aircraft and marine sectors. The present study consists of utilising conventional stir casting setup for fabricating Aluminium-based MMCs having fly ash as reinforcement. The fly ash was reinforced with aluminium matrix in proportions: 2, 4, and 6 % to get three different homogeneous samples of MMCs. The prepared samples were examined for microstructure and mechanical characterization. The MMCs samples exhibited successful incorporation and homogeneous dispersion of fly ash particles. The fly ash addition assisted in enhancing the hardness and decrease in strength of aluminium MMCs.

Keywords: aluminium; stir casting; fly ash; metal matrix composites.

I INTRODUCTON

The introduction of Metal Matrix Composites (MMCs) in the regime of modern engineered materials is a significant breakthrough. The recent technology is emphasized on the development of alloys having composition near or equivalent to certain intermetallics such as magnesium silicide, titanium aluminides etc [1-3]. The intermetallics and alloys based on them often exhibit excellent combinations of low density, high melting point and superior elevated characteristics. On the other hand, such compounds suffer from poor ductility due to their coarse and brittle morphology. The MMC classification depends on the type of matrix material primarily lightweight alloys such as aluminium, copper and magnesium [4].

The enormous investigations [5-10] performed by researchers on aluminium based MMCs can be attributed to the fast-growing application of aluminium and its alloys in industries. Juang et al. [5] fabricated 5 % fly ash reinforced aluminium MMCs by stir casting method followed by multipath Friction Stir Processing (FSP). The multipath FSP helped in significant fragmentation of fly ash leading to size reduction from 53–106 μm to 10 μm. The tensile strength and ductility of aluminium fly ash composite enhanced due to processing from 143 MPa to 227 MPa and 1.19 % to 7.18 % respectively. Prakash et al. [6] fabricated a low-cost composite using powder metallurgy route with Al6061 T6 as matrix material and natural rock dust as second phase particles. The rock dust reinforcements having size 20 μm were employed in a ratio ranging from 0% to 50%. The powders were compacted at three pressure values ranging from 100 to 200 MPa. Further, ceramic coating of Al_2O_3 was applied on the fabricated composite by Type III Sulphuric acid hard-coating. Microstructural results exhibited the homogeneous dispersion of reinforcement in a matrix along with the hard ceramic coating. The composite reinforced with 10% rock dust excellent wear characteristics as compared to other compositions. Moreover, as the compacting pressure increase, there was an incremental trend for hardness and wear resistance property. It was concluded that coated samples exhibited superior performance than uncoated at all parameters. Shin et al. [7] investigated microstructural and mechanical characteristics on Al2024 reinforced with Few-Layer Graphene (FLG) composites prepared by ball milling and hot rolling. The high specific surface area attribute of FLGs helped in significant enhancement of composite strength. The composite sample having 0.7 vol. % reinforcement of FLGs exhibited a tensile strength of 700 MPa, twice of parent Al2024 alloy, and 4 % elongation. Alaneme et al. [8] conducted microstructural, mechanical and wear characterisation on Aluminium alloy based hybrid MMCs having reinforcement as alumina, Rice Husk Ash (RHA) and graphite. The reinforcements were blended in varied weight ratios to prepare a 10 wt % hybrid Al-Mg-Si composite by employing two-step stir casting set up. The reinforcement helped in enhancing the characteristics of aluminium hybrid MMC. Sharma et al. [9] studied the effect of graphite reinforcement on the microstructure of Al6082 MMCs manufactured by the conventional stir casting. The graphite content was reinforced in the range from 0% to 12% in a step of 3%. The microstructural investigation revealed that all weight percentages composites displayed non-uniform distribution of graphite particles. Kumar et al. [10] developed in-situ AA5052/ZrB_2 composite having varying percent: 0, 3, 6, 9 and 10 % of ZrB_2 particles. Microstructural studies revealed that the presence of ZrB_2 particles assisted in grain size reduction of Al-rich phase. Further the uniform distribution, clean interface, good bonding and excellent morphology was exhibited by ZrB_2 presence in the parent alloy. The ZrB_2 particles were found to be available in nano size having hexagonal/rectangular shape along with some micron size particles. The mechanical characteristics revealed that with increase in volume fraction of ZrB_2 particles, density and hardness of the prepared composites was found to be increased. In a similar fashion, strength also improved continuously with volume fraction of ZrB_2 particles but only up to 9 %, beyond that composite strength was found to be reduced.

The above literature survey clearly depicts that there is a lot of potential in developing low cost MMCs through stir casting. Reinforcements such as fly ash, rice husk, coconut shell and sugarcane bagasse are presently the major investigated candidates for obtaining the economical mono/hybrid composites. The current investigation is also focused on developing low cost aluminium MMCs through stir casting by utilizing fly ash as reinforcement. The aim was to examine the effect of varying amount of fly ash on the Microstructural and mechanical behavior of the aluminium alloy.

2. EXPERIMENTATION

2.1 Fabrication of composite materials

The Al-Fly ash composite material was prepared using the stir casting technique [11-15]. In this technique, the aluminium and fly ash melt was continuously stirred for the complete mixing of the reinforcement in the matrix. The parameters of the stir casting method are listed in Table 1.

Table 1. Input parameters used for the fabrication of composite

Parameter	Value
Temperature (ºC)	800
Flyash amount (w/w %)	2, 4 and 6
Stirring speed (rpm)	100
Stirrer shape	Zig-zag

For the casting process, the Al alloy was first placed in the crucible and heated to 650ºC temperature. The alloy was melted for about 30 minutes and thereafter reinforcements were added in steps of 2, 4, and 6 w/w%. The

composite mixture was stirred for about 20 more minutes so that no agglomeration of the reinforcements took place.
The melt from the crucible was poured into a preformed metal mould by removing the aluminium oxide layer. The solidified material was later cleaned and machined to obtain the specimens for further testing.

2.2 Mechanical Testing
To investigate the effects of fly ash particles on the mechanical properties of the Al alloy, tensile strength and Rockwell hardness tests were performed on the fabricated composite materials. The tensile tests were performed on the universal testing machine, and Rockwell hardness tester was used for the evaluation of hardness.

3. RESULTS AND DISCUSSION

The Rockwell hardness test measured the depth of indentation produced by an indenter. Two values were taken, which are tabulated below along with their average. It has been observed that the hardness of the specimen with the highest fly-ash content is comparable to the parent material (53 HRC). While for the other specimen, the hardness was found to be reduced.

Table 2. Hardness Values for prepared composites

Material	Hardness1(HR)	Hardness2 (HR)	HardnessAvg (HRC)
Sample 1	37.5	39.0	38.25
Sample 2	49.0	49.2	49.1
Sample 3	57.8	54.0	55.9

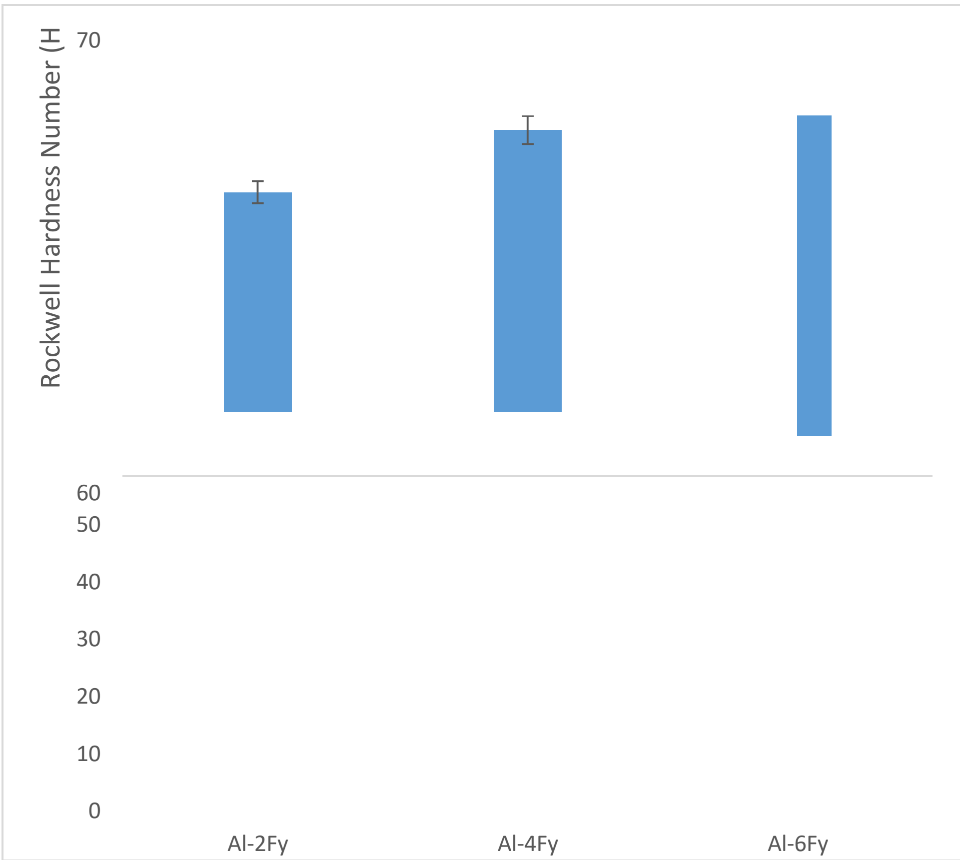

Figure 1. Variation of Rockwell Hardness Number

The tensile test was performed to test the nature of fabricated specimens by observing their surface after fracture by using UTM. It was observed that the surface was perpendicular to the axis of applied tensile force, thus concluding that the material has adopted brittle nature. By observing the nature of fracture of the specimens, it was found that ductility was compromised as compared to parent material pure Aluminum. The variation of tensile strength is presented in Figure 2.

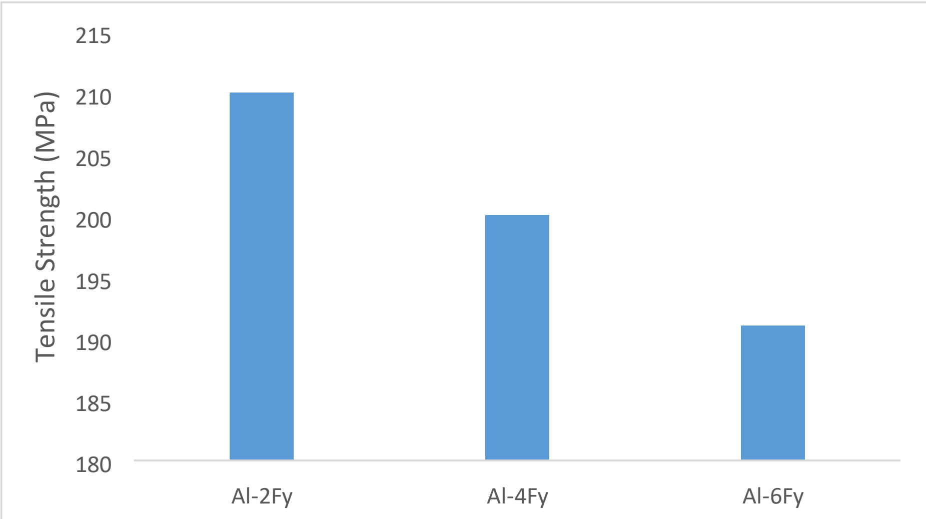

Figure 2. Variation of tensile strength of the fabricated composites

IV CONCLUSION

The stir casting technique was successfully employed for preparing three Fly ash reinforced aluminium metal matrix composites. The microstructural analysis revealed the homogeneous dispersion of fly ash particles in the parent matrix of aluminium alloy. The presence of fly ash particles proved to improve the hardness of fabricated composite. The composite with 6% w/w fly ash particles have 46.14 % more hardness as compared to the 4% w/w composite. Further, it was also concluded that the fly ash particles does not have any positive effects on the tensile strength of the composite. The tensile strength was found to decrease with increase in fly ash reinforcement.

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