Effect of Fly ash on the Mechanical Properties of Magnesium based composites Using Powder Metallurgy

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Abstract - Metal matrix composites are used abundantly in space ships, automotives, aero space and in many more goods industries, but due to their high cost researches were done more to reduce the cost of those materials hence the matrix materials were reinforced with some of the easily available and inexpensive materials to get the same strength. Magnesium based fly ash (FA) reinforced composites were synthesized using the powder metallurgy technique followed by sintering. Up to 0.5 to 2 wt. % of fly ash were added as reinforcements. Fly ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste byproduct during combustion. The effects of FA on the mechanical properties of Mg were investigated. Mechanical characterizations reveal an improvement of hardness with higher weight percentage of FA incorporated. An attempt is made to compare the values of pure base and the reinforcement material with mixed compact.

Key Words: Magnesium, Fly ash, Powder metallurgy, Hardness, sintering, Density, Strength.

I INTRODUCTION

The properties like mechanical and physical have made the metal matrix composites (MMCs) more demanding materials for aviation, automobile spares and various other applications. In recent days, metal matrix composites with particle reinforcement have attracted and got large attention among the researchers because of comparatively low cost and distinguished isotropic properties. A material in which one or more phases are distributed in a solid metal or alloy matrix can be regarded as Metal matrix composite (MMC). The need for light weight, high strength materials has been recognized since the invention of the airplane. The inadequacy of metals and alloys in providing both strength and stiffness to structure has led to the development of metal matrix composites. Among the various types of MMCs, light-weight MMCs such as magnesium (Mg) based composites are arousing more interest due to their potential applications in aerospace, automotive and sports equipment industries. Magnesium (Mg) and its alloys are gaining more recognition as a lightest structural material for lightweight applications, due to their low density and high stiffness-to-weight ratio.

Fly ash is finely divided by product resulting from the combustion of coal in thermal power plants with a mean particle size of less than 60 microns. It possesses low density, Inexpensive; abundantly available hence, it is an excellent candidate reinforcement material for metal matrix composites. Additions of fly ash particles reduce the cost and density of matrix.

The objective of this investigation involves in fabrication of fly ash reinforced magnesium composite by powder metallurgy technique which involves Blending of reinforcement in magnesium powders, Compaction of these blended samples to form a billet, Compacted billets are then sintered at a temperature less than the melting point of the base metal i.e., matrix material, Finally the sintered billets are characterized for mechanical properties.

II LITERATURE REVIEW

Fly ash is one of the deposits produced by burning of coal. It is a byproduct collected from flue gases of burning coal by electric power plants in industries. Based on the type and form of coal burning the constituents of the fly ash produced will vary remarkably but all the verities of fly ash comprises of substantial quantity of silica in the form of silicon dioxide, SiO2 in both amorphous and crystalline forms and lime as calcium oxide, CaO. Generally, fly ash involves SiO2, Al2O3, Fe2O3 and oxides of Mg, Ca, Na, K etc. as major & minor constituent. In general the shape of the fly ash particles are mainly spherical which ranges from 1 μm to 100 μm with a specific surface area, and on avg. between 250 and 600 m2/kg as well the range of specific gravity of fly ash varies between 0.6-2.8 gm/cc. The condition of burning & the type of coal burnt decides mainly the Physical properties of fly ash. The mechanical properties such as strength, stiffness, reduced density and wear resistance of matrix materials can be improved by adding a precipitator fly ash having a density between 2.0–2.5 g cm^3 .

K. S. Sreenivasan *et al* [1] explained Metal matrix composites (MMCs) exhibit important enhanced characters such as high specific strength, specific modulus, damping capacity and good resistance wear when compared to alloys with no reinforcements. Any of the following methods can be utilized to fabricate MMCs amongst Stir casting, Liquid Infiltration method, Osprey and Powder metallurgy technique. For the fabrication of MMCs through high fraction of reinforcement with reasonably equal dispersionne effectively by powder metallurgy technique. In the present work the fabrication of aluminium matrix reinforced with particles of SiC and fly ash reinforced aluminium composite samples were prepared by powder metallurgy method followed by conventional and microwave sintering. The composite materials are Aluminium powders of 44 micron and SiC particle size of 37 micron and Fly ash powder with 20 micron size are used with a volume fraction of 5% to 20% of SiC and 20% of SiC, Flyash 10% was processed. For the preparation of samples about 4000kg to 8000kg of compaction load is applied. Microwave furnace is used for sintering of samples. Rockwell Hardness test machine with acceptable indenters were used to check the hardness number of samples & about 81 hardness number was recorded using Rock well B scale of the machine.

Jayakumar R *et al* [2] the study reveals fabrication of Sic particle reinforced aluminium 6063 alloy along with other reinforcement material fly ash were produced by the method of stir casting & the mechanical and wear properties are investigated. By addition of more reinforcement with weight fraction the hardness of the composite materials can be enhanced and is revealed by conducting Brinell hardness test of specimens. By using pin on disc wear test machine the dry sliding of hybrid metal matrix composites can be conducted and wear resistance & frictional properties can be discussed. The tests can be performed for different loads of 3kg, 4kg & 5kg by adding Sic particle weight fraction about 5% is tested at 1.04m/s constant sliding velocity with a sliding distance of 628m and also by varying the weight fraction of fly ash from 4% to 14%.

M. Rajesh *et al* [3] reported that the Metal Matrix Composites (MMCs) of other rank of materials have been invented in the past decades are fetching significantly more concentration of the engineers and researchers. In this work friction stir welding is utilized to check the possibility of joining aluminium alloy of series 6063 with magnesium and fly ash as reinforcements is studied. The samples of composites were produced using stir casting technique with varying weight percent of 5, 10 & 15 and magnesium vary in weight percent of 1,2 &3 as reinforcements were blended in aluminium as base metal matrix. The experiments were conducted to study the mechanical properties of aluminium 6063 metal matrix composites friction stir weld joint capabilities. The hardness and tensile strengths were revealed by the evaluation of mechanical properties. The hardness and tensile values of the composites with the addition of fly ash as reinforcement has considerably enhanced as compared with the matrix material without reinforcement. The enhancement in the ultimate tensile strength of about 105.94 MPa has been noticed for aluminium 6063 composite reinforced with 10 weight percentages of fly ash composite samples.

M. Ramachandra *et al* [4] In this work, by utilizing new vortex method synthesization of fly ash about 15 wt. % as reinforcement with Aluminum matrix material the metal matrix composites were fabricated. Using the fabricated samples of composites the mechanical properties such as hardness & micro hardness using Rockwell or Brinell, ductility with strength at ultimate tension were characterized. Other than these properties the specimens of metal matrix composite were also conducted tests for corrosion, slurry erosion & wear under dry sliding has been inspected for various behavior of composite materials condition under wearing loads. It is noticed for the composite samples that the hardness number is greater at the areas where fly ash is surrounded in good quantity. It is clear from the investigation that the mechanical properties of the fly ash reinforced composite samples enhanced as well the density of the samples can be further reduced by adding fly ash. The properties of wear to resistance have been enhanced by the addition of fly ash as compared to matrix material. By the addition of fly ash it has been noted that resistance to corrosion was also decreased. The importance of dispersion of particles of fly ash in matrix material is also examined by using macro and micro structural behavior of the MMCs. The uniform dispersion of fly ash throughout the composite sample is clearly noticeable by Macro structural test. The results of the analysis of fractured surface of samples used in conducting test for tensile has revealed the metal matrix composites having the behavior of brittle fracture.

Ravi Shankar [5] *et.al*. Were worked on the Effect of Fly Ash Particles on the Mechanical Properties and Microstructure on Compacted Magnesium Reinforced With SiC Particles. It shows that Composites samples with fly ash can be used to reduce the cost of the metal matrix for applications in automotive and small engine applications and it was achieved by reinforcing the Mg-composites with a high strength component. The experiment mainly concentrated on the evaluation of thermal behavior of Mg-composites reinforced with SiC in addition with variation of fly ash. Magnesium reinforced with SiC particles were prepared by powder metallurgy technique and the micro structural analysis and micro hardness test were carried out to see the behavior of material properties towards heating and cooling. The micro hardness of composite increased by 30 % than that of aluminum composite. Wear rate shows a greater improvement of 10% wear resistance than that of aluminum composite.

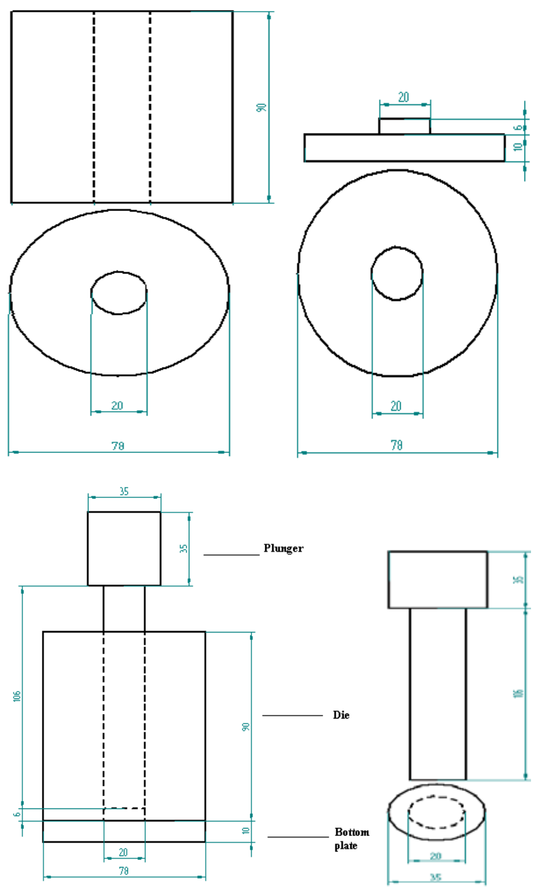
The literature survey reveals that there is no clear information on the role of size, distribution and the amount of fly ash reinforcement with pure magnesium to achieve the good mechanical properties. In addition there is no clear literature exists on the influence of fly ash using powder metallurgy to achieve the properties with results. There fore the present investigation is taken up to throw a light on the effect of composite with light weight materials and reinforcement with individually very good properties and to identify the microstructure of mixture and various mechanical properties involving Hardness, tensile, studies at various amount of materials.

III METHODOLOGY

Selection of Material : Magnesium powder of purity more than 99.65% was used as the matrix material of 40 micron size supplied by Libra Magnesium Products and & reinforcement material Fly ash was collected from Polyfibres, Harihara.

Processing and compaction:

The powder metallurgy technique was used to get green compact of the composite using suitable compact die assembly under universal testing machine. The die should be prepared with steel material as per the design drawing.



All dimensions are in mm

Fig. 1: Part drawing of compaction die

The base material and reinforcements with wt % of 0.5%, 1%, 1.5% and 2% with a interval of 0.5% Fly ash were added in pure magnesium powder using ball mill. The Mg powder was homogeneously mixed with the respective weight percentages was compacted in the die assembly using a 40 Ton capacity universal testing machine.

IV EXPERIMENTATION RESULTS AND DISCUSSIONS

i. Density

The Archimedes' principle was used to measure the density of Mg and Mg nano composites. The mass density of a material is its mass per unit volume and specific weight is defined as its weight per unit volume. The density of a material varies with temperature and pressure. Increasing the pressure on an object decreased the volume of the object and thus increases its density. Increasing the temperature of a substance decreases its density by increasing its volume.

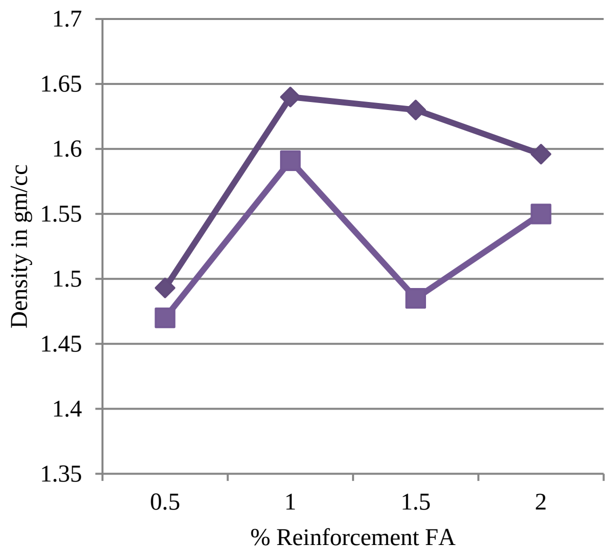


Fig 2: Density trend of Mg/FA before and after sintering

Fig.2 shows the trend plotted density against percentage of reinforcement FA in the matrix as per the values in table.1 and the trend clearly indicates the density of composites will decrease as the reinforcement increases and the values of specimens before sintering are higher than that of sintered specimens.

ii. Hardness

Hardness of specimen of Magnesium and Flyash reinforced composites were determined by using Vickers Hardness Testing apparatus as per ASTM B-925. The results are tabulated in Table. It is inveatigated that Magnesium MMC composites, the hardness increases with the addition of Fly ash upto 2 wt %.the table 1 shows the tensile strength values of pure magnesium sample.

Table 1: Tensile properties of Pure Mg

Hardness (VHN)	Young's Modulus (GPa)	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	% Elongation
43	44	126	195	8

Table 2: Hardness of Mg/FA nanocomposites

Composition	VHN
Magnesium+ 0.5 Wt% of FA	44
Magnesium+ 1 Wt% of FA	45
Magnesium+ 1.5 Wt% of FA	47
Magnesium+ 2 Wt% of FA	46

The table 2 shows that the hardness values for 1.5wt % & 2 wt % samples increased with increment in reinforcement, where as 2 wt % composite's hardness is reduced and nearer or equal to 1.5 wt % samples.

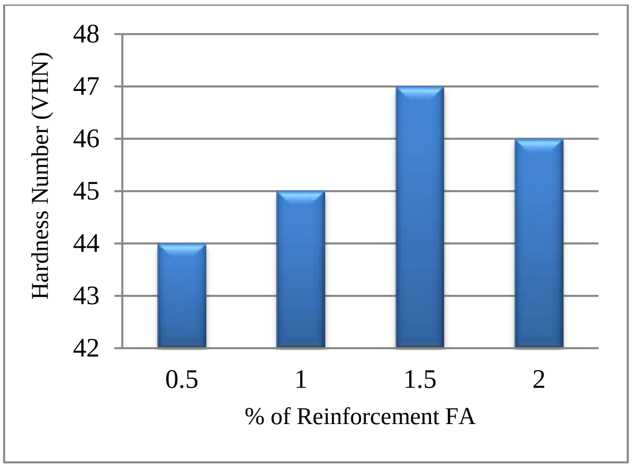


Fig. 3: Hardness P/M samples of Mg/FA nanocomposites

Fig. 3 shows the graph of Hardness of the powder metallurgy samples of Mg/FA nanocomposites compared to the base matrix hardness there is 5 to 10% improvement can be observed. This is achieved due to the fine dispersion of the reinforcement in the matrix. It has been observed that the hardness value has increased considerably compared to base matrix between 0.5 wt % to 1.5 wt % of addition of reinforcements and better result is revealed for 1.5 wt % of reinforcement of FA and it is clearly observed from the test that for 2 wt % of reinforcement the hardness number has been decreased and their after there is no improvement in the hardness numbers and its stagnant hence it is advised to consider the reinforcements from 0.5 wt % to 1.5 wt % as better values.

iii. Tensile strength

Tensile tests were generally carried out on a universal testing machine but in this study Tensometer is used to conduct tensile test as the specimens were of subsize and unmachined flat as per the ASTM E8 standards. The test samples were prepared as per the ASTM E8 standard as shown in fig using die prepared for powder metallurgy technique. Under static loading conditions the test was conducted for yield strength & tensile strength

Table 3: Tensile properties of Mg/FA nanocomposites

Composition	Young's Modulus (GPa)	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	% Elongation
Magnesium + 0.5 Wt % FA	45	127	197	12.825
Magnesium + 1 Wt % FA	50	129	199	13.87
Magnesium + 1.5 Wt % FA	55	135	206	14.25
Magnesium + 2 Wt % FA	54	137	207	13.3

Table shows the tensile properties of Mg/FA nanocomposites, the result reveals, Young's modulus & yield strength of the composites show an increase trend with an increase in weight percent of particle indicating an adequate load transfer from the matrix to reinforcement in powder metallurgy samples. The ductility of the composite in samples has shown a increased trend compared to matrix material individual with increase in weight percentage of reinforcement FA in Mg/FA nanocomposites.

The results show that for 1.5 wt % FA reinforced Pure Magnesium composites, Young's modulus increased with 25 %. In Yield strength also there is an improvement of 8 %. For 2 wt % Mg/Fa nanocomposites where the Young's modulus, yield strength & ultimate strength have shown an increase of 22.72 %, 9 %, & 6.5 % for compacted reinforced samples respectively.

It was also shown that for 1 wt % FA reinforced Magnesium composite. The young's modulus & yield strength show an increase from the matrix value with 13.6 % & 2.5 % for samples. However the ultimate strength shows an improvement from the matrix value, but a reduction compared to 1wt % & 1.5 wt % Mg/FA composites. The increase in strength is a reduction in ductility.

Magnesium composites with 2wt % FA exhibited lower values for young's modulus and elongation compared to 1.5

wt %, which was attributed to the presence of micro voids & poor interfacial strength. But here the reinforcement distribution is spread across the matrix & shown good results in yield strength to the base matrix.

V CONCLUSION

Magnesium powder as matrix mixed with Fly ash (FA) in weight percentages of 0, 0.5, 1, 1.5, and 2%(wt) as reinforcement were produced through powder metallurgy route. The specimens were sintered and tests were conducted successfully. Specimens were subjected to evaluate the behavior of mechanical properties of MMc's. From the investigation, following points are concluded.

- Hardness of Mg/FA composite is greater than pure Mg.
- Yield strength increases remarkably with the increase in Reinforced Samples
- Tensile strength increases with the addition of FA for 1.5 wt % and elongation also increased and better with the same wt. percent of reinforcement.

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