



# Fabrication of Magnesium Metal Matrix Composites Reinforced with Fly Ash Cenospheres

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**Abstract:** In today's world, there are many challenges in automotive and aerospace applications like enhancement of fuel economy, reduction in weight, maintaining safety, quality maintenance. To meet these requirements, there is need to develop new materials with new fabrication processes. The requirement for high-performance and lightweight materials in the automotive and aerospace application has led to extensive research and work efforts in the development of magnesium matrix composites and their cost-effective fabrication technologies. Composite materials are versatile in terms of constituent selection so that the properties of the materials can be modified. Addition of reinforcing materials such as rice husk, fly ash cenosphere, machining chips, Al<sub>2</sub>O<sub>3</sub>, SiC, B<sub>4</sub>C, metallic glass, etc., is one of the ways to enhance various mechanical properties of Mg based MMCs. The cost-effective methodology of composite materials is, therefore, an essential element for expanding their applications. The availability of a wide variety of reinforcing techniques is attracting interest in composite materials. This is especially true for the high performance magnesium materials due to certain unique characteristics of composites which offer effective approaches to strengthen the properties of magnesium alloys.

**Index Terms -** Magnesium, Metal Matrix Composites, Magnesium composites, fly ash cenosphere, tensile strength, hardness, microstructure nature

## I. INTRODUCTION

1.1 Magnesium [Mg]: Magnesium is among the most lightweight materials on the earth. Magnesium can be easily available on earth. Magnesium alloys are 77% lighter than stainless steel, 33% lighter than aluminium and 61% lighter than titanium [8]. Atomic number of Mg is 12. It is soft, low weight and long lasting and high yielding with gray-white colour. The machining operations on magnesium can be performed easily. Thin layer of magnesium oxide is present on the surface of Mg, which prevents further oxidation easily and makes magnesium more corrosion resistant.

1.2 Fly ash cenospheres: Cenosphere is one of the most value added fraction of coal fly ash. They have a hollow spherical structure and can be applied in many industrial applications due to superior properties such as low bulk density, high thermal resistance, high workability and high strength. The spherical shape of the cenosphere creates low surface area to volume ratio which required less resin, binder and water to wet out the surface which are the demanding properties for the various polymeric composites [9].

The chemical compositions of the cenosphere are originated from the coal source material and the combustion process. The major element in the cenosphere are the mixture of aluminium silicates with a moderate amount of Ca, Fe, K, Mg and limited occurrence of Na, Ti, S, P and trace elements. The particle size of the cenosphere can range from a diameter of 5 to 500 µm. Fig. 1 shows the nature of fly ash cenospheres



Fig. 1. Fly ash cenospheres

1.3 Magnesium metal matrix composite: Metal matrix composite is manufactured by a combination of light metal called matrix and the second element is called as reinforcing element or reinforcement which could be particles or fibers of metals, non-metals, ceramics or organic elements. In this case of magnesium metal matrix composites, the matrix is Magnesium molten metal whereas reinforcement is fly ash cenospheres. Metal matrix composites exhibit various properties like high specific strength, reduction in weight, high strength to weight ratio, improves corrosion resistance and improves creep and wear resistance. [6]

## II. FABRICATION OF MAGNESIUM METAL MATRIX COMPOSITES

Generally there are three methods to fabricate magnesium metal matrix composites – Stir casting, squeeze casting and powder metallurgy. The most cost-effective and simplest methodology of liquid state fabrication is stir casting. In this work study, stir casting technique is employed to fabricate the magnesium metal matrix composite. Stir casting is also known as ‘vortex technique’. The reinforcement particles are in the form of cenospheres and are mixed with a molten magnesium metal by means of electric stirring for a particular period of time. In this work, reinforcing element is added by means of electric stirrer into the molten magnesium metal. Fig. shows the required stir casting process set up.

Many authors have suggested that reinforcing element can be upto 30 %by weight in given molten metal, for achieving better distribution of reinforcing element[9]. As we are adding the reinforcing element at molten stage of magnesium, better homogeneity during solidification can be achieved. Fig. 2. shows Stir casting process setup

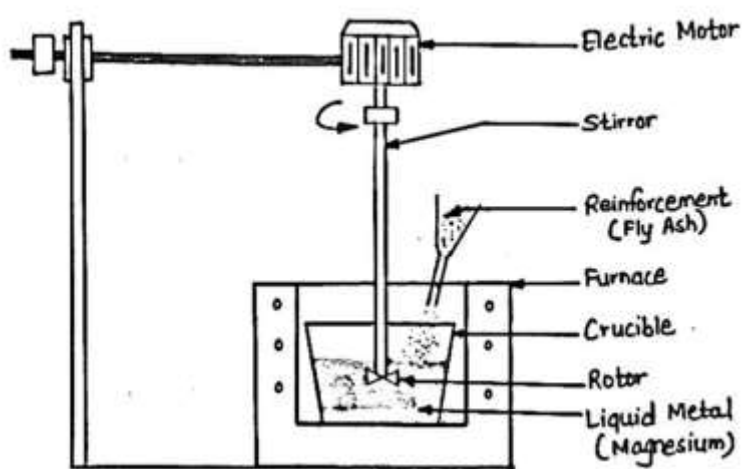


Fig. 2. Stir casting process setup

Fig. 3. shows the process flow chart of fabrication of magnesium metal matrix composite

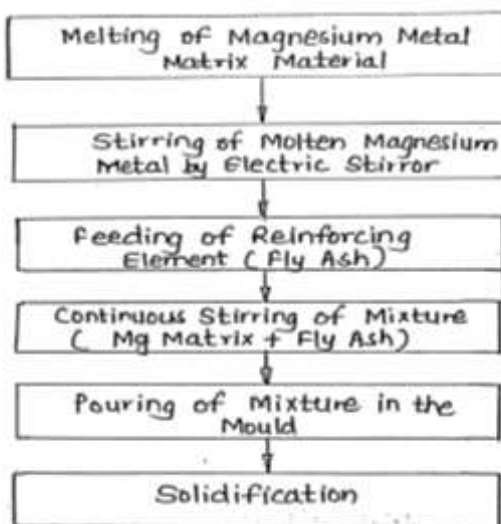


Fig. 3. Flowchart of fabrication process

2.1. Melting of magnesium metal matrix material: Magnesium metal is melted to semi molten stage in furnace under controlled conditions of temperature and pressure and under proper precautions.

2.2. Stirring of molten magnesium by electric stirrer: For uniform stirring of the molten magnesium metal, electric stirrer is used. Here, the stirrer speed is controlled with the help of electric motor. Stirring of molten magnesium metal is done at constant speed of stirrer.

2.3. Feeding of reinforcing element: Reinforcement i.e.; fly ash by 5% and 10% weight of magnesium is added to the molten metal via feeding system.

2.4. Continuous stirring of mixture: The mixture of magnesium metal matrix and fly ash is stirred continuously with the help of electric stirrer to maintain the homogeneity of mixture.

2.5. Pouring of the mixture in the mould: After successful mixing of magnesium molten metal and fly ash cenosphers, the mixture is poured into the mould with the help of holding stands. Fig. 4. shows process of pouring of molted magnesium and fly ash in the mould.



Fig. 4. Pouring of molten metal in moulds

2.6. Solidification: The fabricated magnesium metal matrix composite is then kept for cooling and for solidification. Fig. 5. shows solidification of molted metal matrix composite.



Fig. 5. Solidification process

### III. EFFECT OF FLY ASH ON MECHANICAL PROPERTIES OF COMPOSITES

The reinforcement led to the refinement of the microstructure. It was observed that the hardness of the matrix increases with the increase in the fly ash content whereas the density decreases with the increasing percentage [9]. The ultimate tensile strength of the matrix increases as the content of the fly ash increases whereas the compressive strength decreases. However with the increase in the fly ash cenosphere content we can see very rear deviation in the compressive strength.

#### IV. EXPERIMENTATION FOR CALCULATION OF MECHANICAL PROPERTIES

- 1) Different mechanical properties and the enhancement in the given properties can be found out with the help of different experimentations as follows: Mechanical properties like tensile strength, compressive strength, hardness value, corrosion value, weight density, etc., of the magnesium metal matrix composite can be calculated.
- 2) Microstructures of given metal matrix composite can be observed under metallurgical microscope, optical image analyzer or scanning electron microscope to find out the nature of that microstructure.
- 3) Tensile strength and compressive strength of the given metal matrix composite can be calculated using universal testing machine.
- 4) Macro hardness of the given metal matrix composite can be calculated with the help of hardness tests like Brinell hardness test, Rockwell hardness test, Vickers hardness test. And hence the hardness of Magnesium and the calculated hardness value of metal matrix composite can be compared, and hence the increase in percentages of hardness value can be calculated.
- 5) All the mechanical properties can be calculated with the help of analysis softwares like Ansys and again these values can be compared with the manual experimented values. The result data obtained by manual experimentation and with analysis softwares can be compared in MATLAB software for further detailing.

#### V. CONCLUSION

From the above study, magnesium metal matrix composites can be successfully fabricated with the help of stir casting process. Fly ash can be used as reinforcing element which is cost effective and easily available. There is enhancement in mechanical properties of the metal matrix composite with the addition of fly ash as reinforcement. Hence, Magnesium metal matrix composite can be used as alternative for aluminium in automotive and aerospace industries due to its better mechanical properties as aluminium.

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