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Fabrication of Magnesium Metal Matrix Composites Reinforced with Fly Ash Cenospheres

Priyanka V. Kadam[1], Vidyadhar Kale[2]

[1]Student of final year M.E. Mechanical Engineering,
R. H. Sapat College of Engineering, Management Studies and Research, Nashik- 422005, India
[2]Professor, Mechanical Engineering,
R. H. Sapat College of Engineering, Management Studies and Research,
Nashik- 422005, India

Abstract - *In today's world, there are many challenges in aerospace and automotive applications like enhancement of fuel economy, quality maintenance, maintaining safety, reduction in weight .To meet these requirements, there is need to find out 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 processes. 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 metallic glass, fly ash cenosphere, machining chips, rice husk, Al_2O_3, SiC, B_4C, etc., in proper amount is one of the ways to enhance various mechanical properties of Mg based MMCs. It also helps in improving its microstructure nature. The cost-effective processing 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.*

***Key Words*: Magnesium, Metal Matrix Composites, Magnesium composites, fly ash cenosphere, tensile strength, hardness, microstructure nature**

1. INTRODUCTION

1.1 Magnesium [Mg]: Magnesium is among the most lightweight materials on the earth. Magnesium can be easily available on the planet earth. Magnesium alloys are 33% lighter than aluminium, 77% lighter than stainless steel and 61% lighter than titanium [7]. Atomic number of Mg is 12. It is soft, low weight and long lasting, high yielding with gray-white colour. The machining and drawing operations on magnesium can be performed easily. Thin layer of magnesium oxide is present on the surface of Mg, which prevents further oxidation of magnesium 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 [6]. The spherical shape of the cenosphere creates low surface area to volume ratio which required less resin, binder and water to wet out the surfaces which are the demanding properties for the various polymeric composites [6]. 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 available 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 cenosphere. 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. [7]

2. 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 cenosphere 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.

Many authors have suggested that reinforcing element can be upto 30 %by weight in given molten metal, for achieving better distribution of reinforcing element [12]. As we are adding the reinforcing element at molten stage of magnesium, better homogeneity during solidification can be achieved.

Fig. 2. shows the required setup of stir casting process.

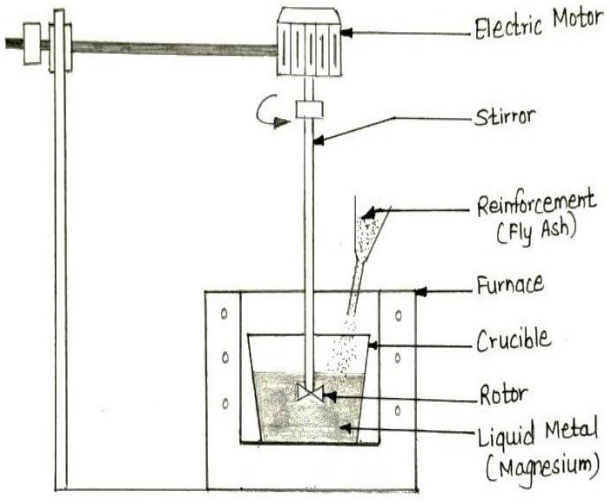

Fig. 2. Stir casting process setup

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.

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

2.3. Feeding of reinforcing element: Reinforcement i.e.; fly ash by 5%, 10% and 20% weight of magnesium is added to the molted metal through feeder.

2.4. Continuous stirring of mixture: The mixture of magnesium metal matrix and fly ash cenospheres 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. 3. shows the pouring of molted magnesium and fly ash in the mould.

Fig. 3. Pouring of molten metal in moulds

2.6. Solidification of molten metal: The fabricated magnesium metal matrix composite is then kept for cooling and for solidification. Fig. 4. Shows the solidification process of molted composite

Fig. 4. Solidification process

Fig. 5. shows the flow chart of fabrication of magnesium metal matrix composite

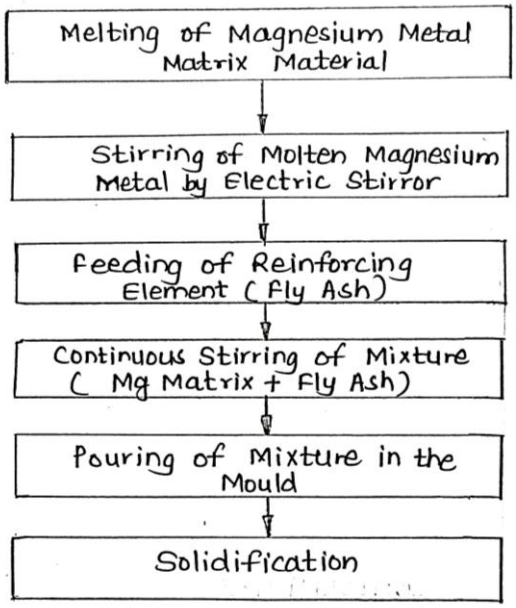

Fig. 5. Process flowchart of fabrication process

3. EFFECT OF FLY ASH ON MECHANICAL PROPERTIES OF COMPOSITES

The addition of reinforcement led to the refinement of the microstructure of given metal matrix composite. It was observed that the density decreases with the increasing percentage. And hence, there is reduction in weight. Hardness of the matrix can be increased by 10-15 % with the increase in the fly ash content. The ultimate tensile strength of the matrix can be increased by 15-20%, 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 value. Overall, we can say that, with the addition of fly ash as a reinforcing element, there is enhancement in mechanical properties of the magnesium metal matrix composite.

4. EXPERIMENTATION FOR CALCULATION OF MECHANICAL PROPERTIES

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.

Nature of microstructures of given metal matrix composite can be observed under optical image analyzer, scanning electron microscope or metallurgical microscope.

Hardness i.e., macro hardness of the given metal matrix composite can be calculated with the help of hardness tests like Vickers hardness test, Rockwell hardness test, Brinell 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 harness value can be calculated.

Tensile strength and compressive strength of the given metal matrix composite can be calculated using universal testing machine [UTM].

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.

5. CONCLUSIONS

From the above study, magnesium metal matrix composites can be successfully fabricated with the help of electric stir casting process by reinforcing it with fly ash cenospheres. Fly ash cenosphere can be used as reinforcing element which is cost effective and easily available in the market. Metal

matrix composites have refined microstructure nature. There is enhancement in many mechanical properties of the metal matrix composites 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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