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Magnesium Metal Matrix Composite Fabrication with Fly Ash by Using Electric Stir Casting

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Abstract: *In present condition, there are many challenges in automotive, aerospace and marine applications like enhancement of fuel economy, reduction in weight, maintaining safety, quality maintenance. To satisfy these requirements, there's need for develop new and advanced materials with new fabrication processes. The requirement for environmental friendly, light weight and high-performance material within the automotive applications has made us to think on research on developing magnesium metal matrix composites and their economical fabrication. Composite materials are like smart materials which can give us multiple properties at a time. Reinforcing materials can be used to boost various mechanical properties of magnesium metal matrix composites. The economical and environment friendly ways of manufacturing of composite materials is, hence, an essential element for expanding their use in large areas for applications. The supply of enormous quantity of reinforcing materials makes them attractive for research work. Magnesium materials have unique characteristics and have high performance rate of composites which give effective approaches to strengthen the properties of magnesium alloys. In this fabrication process, we have used magnesium metal as a base element and the second element is fly ash cenosphere which acts like reinforcement. The process used for fabrication purpose is electric stir casting. The change in mechanical properties like hardness, tensile strength and nature of microstructure was observed.*

Keywords: Electrial Stirrer, Fly ash cenospheres, Magnesium Metal Matrix Composites.

I. Introduction

A. Magnesium [Mg]: Magnesium is among the foremost lightweight materials on the earth. Magnesium can be easily available on the planet. The machining of magnesium is easy. Thin layer of magnesium oxide i.e., mineral is present on the surface of Mg, which prevents further oxidation easily and makes magnesium more corrosion resistant. Magnesium alloys are 77% lighter than stainless-steel, 33% lighter than aluminium and 61% lighter than titanium [15]. Atomic number of Mg is 12. It is ductile and soft, its having low weight, it is long lasting and having high yielding with gray-white colour.

B. Fly Ash Cenospheres: Cenosphere is one among the foremost fraction of coal ash. Thier internal structure is hollow in nature and it is useful in different applications because of its enhanced properties such as high workability, high temperature resistance, low bulk density, and high strength [09]. Low expanse or low surface area is created due to spherical shape of the cenosphere to volume ratio. It is basically originated from burning of coal which is waste material from thermal power plant.

The main element present within cenosphere are the mixture of aluminium silicates with a small amount of ferrous, calcium, potassium, and limited occurrence of sodium, sulphur, titanium and other elements. The particle diameter size of the ash particles can range from 10 to 450 μm.

C. Magnesium metal matrix composite: Metal matrix composite is manufactured by a combination of light metal which is sunshine metal magnesium matrix and also the second element is termed as reinforcing element or reinforcement which can be particles or fibers of metals, non-metals, ceramics or organic elements. In this case, here composite of magnesium metal matrix, the sunshine element, matrix is Magnesium molten metal whereas also the additional element i.e., reinforcement is fly ash cenospheres. Metal matrix composites exhibit various properties like high specific strength, reduction in weight, high strength to weight ratio, improves resistence to corrosion and improves creep and wear resistance. [12]

Figure 1: Fly Ash Cenospheres

II. Fabrication Process

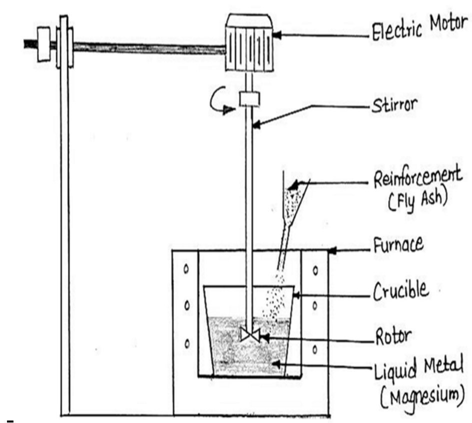

Figure 2: Stir Casting Process Setup

Methods to manufacture magnesium metal matrix composites are– Squeeze casting, pressure infiltration, stir casting and powder metallurgy. The most cost-effective and feasible methodology of liquid state fabrication process is stir casting. Here we have used electric stir casting technique to fabricate the magnesium metal matrix composite. Stir casting is also additionally known as 'vortex technique'. Fig. 2 shows the required setup for stir casting process.

In this method a furnace or metal crucible is heated and then the electric motor is attached with the same assembly to take care of maintaining uniformity of the molten metal. The reinforcing elements are hollow, in the form of cenospheres and are included in molten magnesium metal means of feeder and are mixed with electrical stirring for a particular period of time. In this work, reinforcing element is mixed by means of electrical stirrer into the molten magnesium metal. Fig. 2 shows the specified stir casting process set up. It is suggested to maintain the maximum percentage of reinforcing material upto 30%[14]. As we are adding the reinforcing element at molten stage of magnesium, better homogeneity can be maintained during solidification and cooling phase. Fig. 3 shows the flow chart of fabrication of magnesium metal matrix composite. Actual processing for manufacturing of given magnesium composite is as follows:

1. **Magnesium Metal Matrix Material Melting:** Magnesium metal is melted upto semi molten stage in crucible or furnace under controlled temperature conditions.
2. **Molten Magnesium Stirring with Electric Stirrer:** For uniform stirring of the molten magnesium metal, electrical stirrer is fitted to the assembly. Here, the stirrer speed is controlled with the assistance of electrical motor. Stirring of molten metal is done at constant, uniform speed of stirrer.
3. **Reinforcing Element Feeding:** Reinforcement, 0% 5%, 10%, by weight of magnesium is added to the molted metal by feeder which is provided in the aseembly.

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Three samples are made with following concentration of the reinforcing element i.e., fly ash cenosphere sand and small quantity of other alloying elements.

Size of Sample:

- Length: 50 mm - 100 mm
- Diameter: 20 mm
- Shape : Cylinder
- Nature: Solid

Three Samples:

- Magnesium metal alloy
- Magnesium + 5% by mass of fly ash+ Small amount of Aluminium oxide and Silicon carbide
- Magnesium + 10 % by mass of fly ash+ Small amount of Aluminium oxide and Silicon carbide

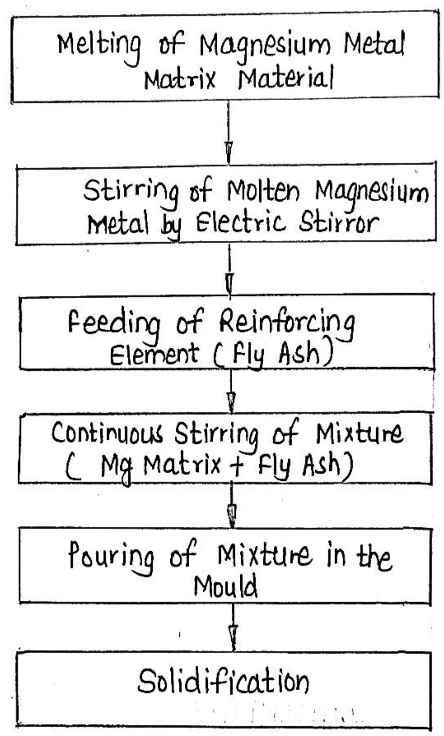

Figure 3: Flowchart of fabrication process

4. **Stirring the Mixture**: The mixture of metal matrix and reinforcement is stirred continuously with the help of electric stirrer to maintain mixture homogeinity.
5. **Pouring the Sample:** After successful mixing of molten metal and fly ash, the mixture of matrix and reinforcement is poured into the mould with the assistance of holding stands. Fig. 4 shows the pouring of molted magnesium and fly ash in the mould.

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Figure 4: Pouring of molten metal in moulds

6. **Solidification State:** The fabricated matrix composite is then kept for solidification. Fig. 5 shows solidification state.

Figure 5: Solidification phase

III. Effect Of Fly Ash Cenospheres On Mechanical Properties Of Composites

The inclusion of fly ash cenospheres results into the refinement of the microstructure nature of matrix composite. It is found, with the addition of increasing percentage of reinforcement, hardness of the matrix increases whereas there is decrease in the mass density. As the percentage of fly ash increases, the ultimate tensile strength of the matrix composite increases but the compressive strength decreases. But, as compared to percentage increase in ultimate tensile strength, we can observe very small variation in value of compressive strength.

IV. Lab Experimentation for Calculation Of Mechanical Properties

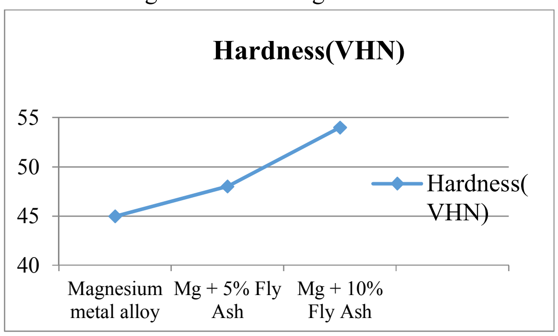
Various mechanical properties and the enhancement in the given properties can be found out by different experimentations as follows: Mechanical properties like hardness value, corrosion value, weight density, tensile strength, compressive strength, etc., can be calculated.

1. Nature of microstructures of given prepared composite can be seen and studied under metallurgical microscope, optical image analyzer or scanning electron microscope.
2. Ultimate tensile strength and compressive strength of the given metal matrix composite can be found by using universal testing machine[UTM]
3. Hardness of the given metal matrix composite can be found with the help of hardness tests like Brinell hardness test, Rockwell hardness test. Here we have used Vickers Hardness test. The actual value of hardness of Magnesium and the calculated hardness value of metal matrix composite can be compared, and hence the improvement in percentages of harness value can be calculated.

V. Observations

5.1 Hardness Testing

With rise in percentage of fly ash cenospheres, the nature of micro structure becomes more refined and grain structure becomes fine. There is improvement in hardness value from 5 to 13% when it is compared with the magnesium alloys. Graph. 1 shows comparison of hardness of Magnesuim and Magnesium metal matrix composite

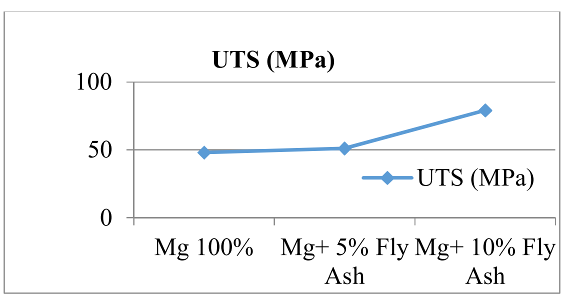


Graph 1: Hardness of samples obtained

5.2 Ultimate Tensile Strength Testing

Universal testing machine of capacity 10 tons is used for calculation of ultimate tensile strength (MPa). The ultimate tensile strength of magnesium metal matrix composites is increased by 60% with the addition of content of fly ash cenospheres. Hence we can say that with fly ash content 10 % by weight we got enhanced mechanical properties than previous samples of metal matrix composites.

Graph No. 2 shows comparison of Ultimate Tensile strength values (UTS) of Magnesuim and Magnesium metal matrix composite



Graph 2: Ultimate Tensile strength values (UTS) of samples obtained

VI. Conclusion

From this work study, magnesium metal matrix composites can be fabricated with the help of electric stir casting processeasily. Fly ash cenospheres can be successfully used as reinforcing element which is environmental friendly, cost effective and easily available. There is improvement in mechanical properties with the inclusion of fly ash as reinforcement. Hence, Magnesium metal matrix composite can be used as alternative element for aluminium in automobile, aerospace and marine industries due to its better mechanical properties than aluminium.

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