A Study of Manufacturing and Mechanical Properties of Mg-foam Using Dolomite as the Blowing Agent: A Review

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***Abstract*-Metallic foam is a type of cellular solid structure that consists of gas filled in its pores. The cell wall of pores can be opened or closed. Much development has been done in recent years to increase the applications of metallic foam in real life such as clinical, medical and engineering applications. There are various engineering applications such as aerospace, railway industries, heat exchangers, automobile industries and many more. However main emphasis is laid on automobiles. For which it is found that $CaCO_3$ is the best suitable agent for the manufacture of Mg-foam. However, no research had been done on Dolomite for the fabrication of Mg-foam. In this paper, an attempt is made to use the Dolomite as the foaming agent.**

Keywords- Metallic Foam; Mg; Al; CaCO$_3$; Dolomite

I. INTRODUCTION

Since last few years, interest about metallic foam has gradually increased due to their wide range of applications. These applications are due to properties of metallic foams such as high energy absorbing ability, sound vibration dampening, high stiffness and less weight. These properties are what make the metallic foam different from pure metals. Like Al foams, scholars are also arousing interest for Mg foams [1-4]. However most of scholars have worked on Al foam [5-8], because Al is cheaper, light weight and easily available. They have found out the different processes [9, 10] and mechanical properties for instance porosity %, yield strength, energy absorption capacity [11] by varying the different parameters such as the effect of working temperature [12], addition of ceramic microspheres [8], without foaming agent [13], other foaming agent instead of TiH2 [5], effect of blowing agent composition [14] and so on.

Mg-foam is one of the metallic foams which is drawing much attention nowadays, although it has less availability (Pure Mg). There are two types of metallic foams that can be produced i.e. open cell type or closed cell type. However closed cell type is of high importance due to its greater scientific properties than the open cell type. Many methods have been used in manufacturing of metallic foam such as solid state method, high pressure casting method, vacuum foaming method, powder metallurgy method, and melt foaming method [1]. Out of which there are two methods of fabricating the cellular Mg-foams i.e. melt foaming method also known as Alporas Method and powder metallurgy method (Fraunhofer method) [15]. However it is found that melt foaming process is best for fabrication of Mg-foam because it can be easily controlled and is cheaper than others [1].

Different foaming agents were found for production of Al foam [15]. However, in conclusion it is found that $CaCO_3$ and Dolomite are the best suitable agents due to their cost and stability [15]. So much research has been done using $CaCO_3$ [1, 4, 5] and TiH_2 [12] as blowing agents in fabrication of metallic foam. However Dolomite usage as a blowing agent for the manufacture of Mg-foam had not been investigated. Moreover reaction of $CaCO_3$ with Mg releases CO [1] which is very dangerous. However dolomite releases the CO_2 gas, which is less dangerous as compared to CO. We are expecting that Mg reaction with dolomite will also release CO_2 (as per processing temperature). In the present study, Dolomite is used as a foaming agent for the fabrication of Mg-foam and the mechanical properties are also studied.

A. Experimental Procedure

Melt foaming process is one of the cheap and effective methods to prepare the Mg-foam [1].

Fig. 1 shows the apparatus for the manufacture of Mg or Mg alloy foams in which motor drives the impeller at specific rpm and gaseous covers the melt from being oxidized [1]. For Mg/Mg alloy, the general procedure is described as follows:

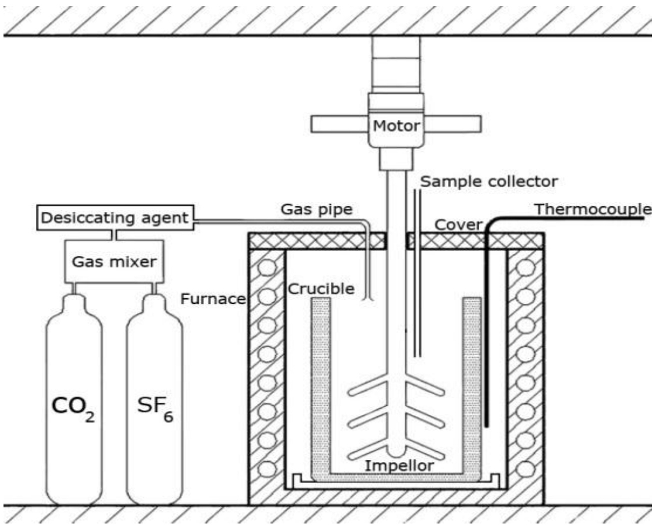

Fig. 1 Apparatus for the manufacture of Mg foams [1]

1) Raw Materials:

1 kg of commercial Mg ingot is used as the matrix material. Foaming agent as $CaCO_3$ [1, 4] (purity>99.6 Wt. %) was selected as blowing agent.

2) Mg Foam Fabrication:

Fabrication procedure involves the following steps:

Melting: Certain amount of Mg (~1kg) is melted at fixed temperature in crucible furnace.

Thickening: Add a set amount of Ca or Si particulates (~2Wt.%) and then stir it with impeller at revolution speed of 400rpm for 10min. Ca or Si particles make the Mg melt thicken.

Stirring: Foaming agent i.e. $CaCO_3$ (~2Wt. %) is added to the melt and revolution speed of 1000rpm is maintained for 30s so as to make foam gradually. This stage is known as melt foaming stage.

Holding: The melt is kept in a furnace to make the cellular structure completely. Time interval for holding is also kept as 30s. Total foaming time is defined as the sum of stir time and hold time.

Cooling: Foamed crucible is removed from the furnace and is kept for solidification by action of water jet or blowing air.

A gas atmosphere of Ar [7] or CO_2+SF_6 (volume ratio 6:1) is provided to prevent the melt from being oxidized [1].

3) Chemical Reaction:

Chemical reaction of Dolomite is stated as below:

$$CaMg\,(CO_3)_2=CaCO_3+MgO+CO_2 \text{ [15]}$$

There is the release of CO_2 in case of dolomite as a foaming agent. However, reaction of $CaCO_3$ with Mg, releases CO [1]. As CO is more dangerous than CO_2, so it is safer to use Dolomite as foaming agent.

II. LITERATURE REVIEW

Literature review shows that in recent years much emphasis has been laid on increasing the mechanical properties such as porosity [13], good strength, effect of cell size [2] and energy absorption capacity [2, 3] by using different parameters such as foaming agents [15], different alloys with different melting temperature [12] and so on. Complex processes were carried out to get the optimum results. The following are outcomes from different scholars that are referred (Table 1).

TABLE 1 RESULTS OF THE LITERATURE REVIEW

S No.	Results	References
1.	• Sample at 750 ℃ has coarse pore structure while from 690 ℃-720 ℃ have fine structure • Gas evolved is CO but not CO_2 • $CaCO_3$ decompose to CO2 & CaO at 825 ℃ • Porosity at 750 ℃ is 69.8%	[1]
2.	• Cells are polygon in shape with porosity of 87% and cell edge size decreases with cell size • Mg foams are brittle • Smaller cell size required for stable compressive process.	[2]
3.	• Specimen with reduced Aspect Ratio(AR) have higher yield strength, longer elasticity deformation region but shorter plateau region • Specimen with greater AR can maintain high energy absorption efficiency • Specimen with AR=1 possesses good combination of properties	[3]
4.	• Porosity (53-71%) • Absorption capacity(4.21 MJ/m ^{3}to 12.72 MJ/m ^{3}by decreasing porosity • Strength (8.69 MPa to 27.11 MPa) • Highest specific strength of Mg= 33.2 MPa gm/cm ^{3}	[4]
5.	• Particle size has more influence of processing variables • Partial $CaCO_3$ decomposition allows foam development with low degree of Aluminium drainage & pore coarsening • Compressive properties are found to be better if marble is used	[5]
6.	• Pore structures can be improved by adding Ca particles and Rare earth element (Re) in pure Al melt. • Ca addition can improve flame retardant temperature of Al-Mg melt • Al-Mg-Re have high corrosion potential	[6]
7.	• Adding thickening agent stabilizes the gaseous bubbles by decreasing surface tension and increasing viscosity • By increasing temperature, viscosity decreases • Addition of Si, Zn and Cu increases viscosity but decreases surface tension	[7]
8.	• Ceramic microspheres were distributed uniformly in cell walls. • Ceramic microspheres addition had improved the yield strength, average plateau stress and energy absorption capacity of foams.	[8]
9.	• 2 step ECAE was performed to control the microstructure and properties (mechanical) of AZ31 by lowering the processing temperature up to 453K • Ultra-fine grains of 0.5μm were obtained, moreover ductility and strength is improved by 2 step ECAE	[9]
10.	• $CaCO_3$ coating was prepared by ion exchange method • Coating of $CaCO_3$ decreases contact angle(~15°) in comparison with uncoated carbonate • Coated carbonate for 40min had optimum impact on reducing foam density	[10]
11.	• With increase in mean pore size, mean plateau strength increases first and then decreases • Specimen with mean pore size of 1.5 mm possesses good combination of properties • Increase in porosity decreases the energy absorption capacities	[11]
12.	• Porosity increases with increase in hold temperature (580 to 600 ℃) • Pore number increases with hold temperature. • Best hold temperature is between 585 to 605 ℃ • Yield strength increases with decrease in porosity % • Porosity achieved is 74%	[12]
13.	• Formation of highly porous structure in AlCuFe alloy without foaming agent • Max. porosity at 900 ℃ for 360min is 65% • Macro pores are formed up to 1.3mm ^{2}	[13]
14.	• Ethyl lactate is biocompatible, green and economical viable to a traditional toxic solvents • By control of blowing agent composition and operating temperature was possible to fabricate PLC foam • Process can be improved by controlling and maintaining the pressure quench profile in 2 step depressurization mode	[14]
15.	• The TiH_2 foam had a coarse and rounded cell structure • $MgCO_3$ and ML-$CaMg(CO_3)_2$ were selected as the suitable foaming agents of AlSiCu • The $CaMg(CO_3)_2$ foam had a specific gravity of 1.19 and a homogeneous, spherical and fine cell structure	[15]

III. SCOPE FOR FUTURE WORK

Mg-foam properties can be enhanced by modifying the techniques used for preparation of foams. We are inspired from the different types of foaming agents that are found for manufacturing of Al Foam [15]. This work includes the fabrication of Mg-foam by the use of the same outcome [15], i.e. Dolomite as a blowing agent. Better properties of Mg-foam are expected because Dolomite is combination of $CaCO_3$ and $MgCO_3$.

For future work, High Carbon Steel or titanium foam will be the new advancement because of their high strength, extreme temperature bearing capacity and sound vibration absorbing capacity.

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