Wear and Impact Characterization of A356.1 Aluminium Alloy Reinforced with Magnesium Nano Particle

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***Abstract* - Aluminum matrix composites (AMCs) reinforced with Nano-sized Magnesium particles are widely used for high performance applications such as automotive, military, and aerospace and electricity industries because of their improved physical and mechanical properties. In this research, Magnesium Oxide (MgO) Nano particles were synthesized by Solution Combustion Synthesis process. Prepared Nano particles were characterized by Powder X-ray diffraction (PXRD). A356.1Aluminium alloy was successfully reinforced with a variation of 0.25 0.5,0.75and 1.0,Wt.% of the Synthesized Magnesium Oxide Nanoparticle, via stir casting Technique at a temperature of 800^0C.Prepared composites were then characterized by scanning electron microscopy (SEM). Wear tests were carried out at Varying Wt. % ratios with varying Conditions of Speed, Load and Time. The results reveal that the Nano Metal Matrix Composite (NMMC)'s containing 1.0 Wt.% reinforcement particle hasshown improved mechanical properties.**

Keywords— Nano Metal Matrix Composite, Magnesium Nano A356.1 aluminium alloy, Stir casting

INTRODUCTION

The aluminum-based metal matrix composites (AMCs) have a high potential for advanced applications when high specific strength and modulus as well as good wear resistance are important [1,2]. The properties of the composites are influenced by the chemical nature of the components, morphology of particles, their spatial distribution and interface interaction. The high volume fraction of fine and thermally stable reinforcement yields good mechanical properties of the composite [3].Development of new structural materials with higher strength to-weight ratios is one of the biggest challenges in transportation industry to reduce fuel consumption and to reduce greenhouse gas emissions [4–10]. Accordingly, close attention is paid to light metals and alloys such as magnesium, due to its intrinsic characteristics of low density, good machine ability and availability in the global market [5]. However, the relatively low strength, poor room temperature ductility and toughness limit the range of magnesium applications. Alloying with Al, Zn, Mn, Ca and other elements is a conventional way to improve properties of magnesium. The enhancement in mechanical properties of the obtained alloys, however, might not be as high as those obtained by composite reinforcements [5]. Since composite materials have several advantages over pure metals and alloys, numerous studies have been conducted on the addition of discontinuous particles in micron- to Nano-scale and their effects on the achieved properties during the last two decades. Selection of reinforcements is typically governed by cost, availability and compatibility with matrix. Most research studies have investigated the properties of magnesium composites containing different hard ceramic nanoparticles.

Aluminium based metal matrix composites (NMMCs) have been extensively studied as an attractive choice for aerospace and automotive applications due to their low density and superiorspecific properties including strength, stiffness and creep resistance [1–13]. To fabricate aluminium based NMMCs, Nano sized magnesium particle used. As compared to the unreinforced aluminium alloy matrix, Magnesium reinforced aluminium NMMCs have a considerably improved strength, but also a significantly reduced ductility, Nano particle reinforcements can significantly increase the matrix mechanical strength by more effectively promoting particle hardening mechanisms than micron size particles. Solidification processing such as stir casting that utilizes mechanical stirring is a widely used technique of producing aluminium matrix composites that are reinforced by Nano sized magnesium particles. A combination of good distribution and dispersion of Nano particles can be achieved by mechanical stirring.

In the present work, we attempted to synthesis magnesium Nano particle using combustion synthesis method and to fabricate aluminum alloy Nano metal matrix composite with different volume fractions of Nano magnesium particles using stir casting technique. The aim has been to study the effect of Nano reinforcement in to A356.1 aluminium alloy and characterization of the NMMCs.

Experimental procedure

Preparation of magnesium Nano particle

Table 1. A356.1 Aluminium alloy composition

Elements	Al	Si	Fe	Cu	Mg	Mn	Zn	Ni
Wt. %	91.73	7.23	0.32	0.18	0.38	0.02	0.05	0.05

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Nano particle are produced by using combustion synthesis method. In this method crystalline sugar is used as fuel. Base material is used for preparation of Nano particle is magnesium oxide. The Magnesium Nano particle was prepared by dissolving magnesium oxide (MgO), Nitric Acid (HNO_3) and crystal sugar ($C_6H_{12}O_6$) as fuel in a minimum quantity of distilled water is taken in ceramic crucible. For the preparation of Nano magnesium, magnesium oxide and crystal sugar are added in the ratio of 1:3 volumes. Silica crucible is used for the preparation of Nano. Silica crucible can withstand up to temperature of1200°C. The crucible containing the solution was placed into a preheated muffle furnace maintained at a temperature of 850°c. The solution initially boils and undergoes dehydration followed by the decomposition with the evolution of large amount of gases. The solution boiled resulting in a transparent gel. The gel then formed will be in white foam, which expanded to fill the vessel. Shortly thereafter, the reaction was initiated somewhere in the interior and a flame appeared on the surface of foam and proceeded rapidly throughout the entire volume, leaving a white powder with an extremely porous structure. The entire combustion process for producing Magnesium Nano particle takes place. The reaction for combustion synthesis in the present case can be written in the equation.

$MgO+HNO_3+ C_6H_{12}O_6 + H_2O \rightarrow MgO + N_2 + 6CO + 7H_2O$

Fig.1 Prepared magnesium Nano particle

Stir casting method

The prepared Nano particle is reinforced in to A356.1 aluminium alloy with a varying weight percentage of magnesium Nano particles using stir casting technique using ceramic coated mechanical stirrer with a stirring speed of 50 rpm at a constant temperature of 900^0 C with duration of 15 min.

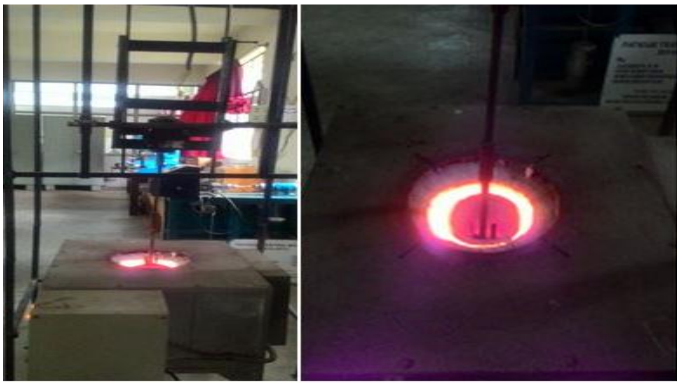

Fig 2 Stir casting method

Preparation of specimens

The specimen required for the various tests for mechanical properties are prepared by machining the cast rods.

The specimens are prepared according to ASME E23 standards for Izod Impact test with a dimension of 10×10mm and a length of 75mm.

The specimens are prepared according to ASME G91 standards for wear test with a diameter of 8mm and a length of 30mm.

RESULT AND DISCUSSION

The powder X-ray diffraction studies were carried out using Phillips X-ray diffracto meter(model PW 3710) with Cu Kλ radiation (λ = 1.5405A˚) The X-ray diffraction pattern of Nano MgO powder confirms the crystalline phase and mean crystal size determined was around 40 nm. In the PXRD observations three strongest peaks shown in Fig. 5 were detected with Miller indices (80), (102) and (50), corresponding to Bragg angles 22.48°, 42.74°and 62.298°respectively. The characteristic peaks are higher in intensity which indicates that the products are of good crystalline nature. No peaks corresponding to impurities are detected, showing that the final product is pure magnesium Nano powder. It is observed that intensity of the peaks increases with thermal treatment due to Agglomeration, which means that the crystalline has been improved. The full width at half maxima of major peaks decrease and confirms the grain size growth.Fig.2 PXRD pattern of Nano particles fabricated at 850^o C

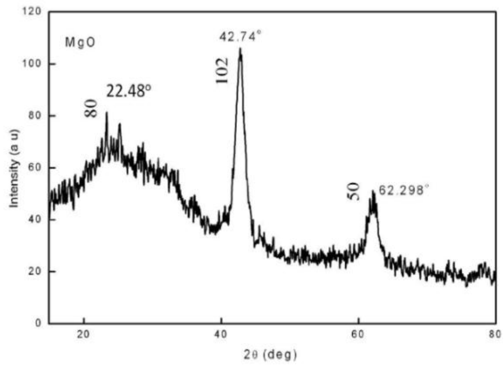

Fig 3 PXRD pattern of magnesium Nano particle

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Nano particles obtained at a of size 40-60nm

Wear test

Wear test were performed magnesium Nano made up of A356.1 alloy incorporating 0, 0.25, 0.5, 0.75 1.0, Wt.% respectively. Tests were performed using Pin on Disc machine using samples in the form of 30 X 8 mm cylindrical block. One side of sample was put in contact with rotating disc at different loading conditions.

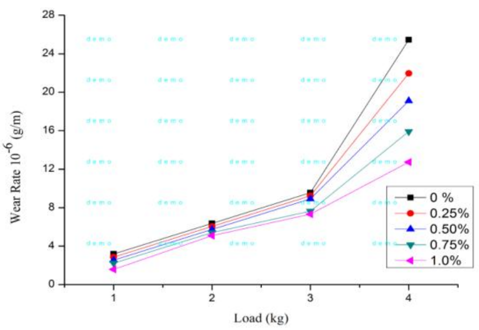

Fig 4 Wear Rate VsLoad

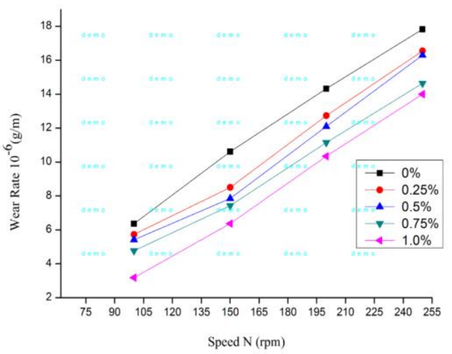

Fig 5 Wear Rate Vs Speed

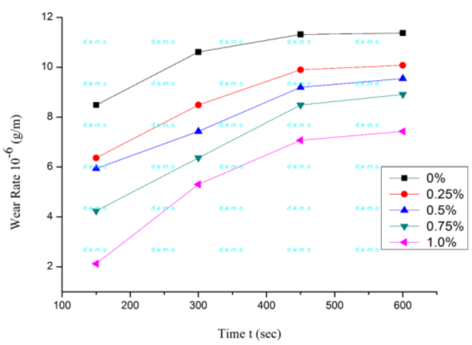

Fig 6 Wear Rate Vs Time

Effect of load on wear rate

The Fig 4 depicts of as cast and different varying Wt% of MgO Nano metal matrix composites (NMMC). The wear rate of 1.0 Wt% of MgO Nano particles shows better wear rate to as cast as other Wt% NMMC's. The Fig 4 reveals that when a varying % of MgO Nano particles is added, it increases the wear rate with increase of loads.

Effect of speed on wear

To investigate the speed effect of reinforcing particulates with MgO Nano is added to the A356.1 alloy at varying percentages, at different speed rates. It is generally believed contribution of Nano particles to A356.1 alloy results in improvement of base alloy to great extent. Based on the results from Fig 5, when speed increases, wear rate increases as cast to Wt% added.

Effect of time on wear rate

Operating time is proportional to wear rate, as shown in the Fig 6.Based on this graph, For as cast A356.1 alloy at the operating time 600 sec, wear rate is 11.371×10-6 g/m and for the same time with 1.0 Wt% reinforcement of Nano particle to base alloy the wear rate is considerably decreases to 7.427×10-6 g/m.

Impact test analysis

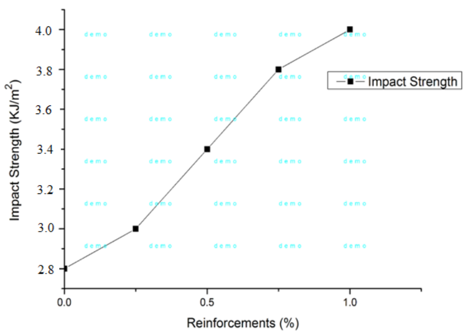

Fig 7 Impact Strength Vs Reinforcements

The Fig 7 depicts of as cast and different varying Wt% of MgO Nano metal matrix composites (NMMC). The impact strength of 1.0 Wt% of MgO Nano particles shows better impact strength to as cast as other Wt% NMMC's.

SEM analysis

Fig 8.SEM images of A356.1 aluminium alloy reinforced with different varying weight percentage ratios of magnesium Nano particle

Samples for (SEM) optical microscope were mounted in Acrylic resin. Polishing was performed using the standard procedure, whereas the mixture of 5 g alumina powder and 50 ml HCl in 100 ml distilled water was used for etching. Morphological analysis of A356.1 aluminium alloy reinforced with MgO Nano particle at varying weight percentage ratios. SEM images are shown in Fig.10.Magnesium Nano particle are shows well embedded in the grains of aluminium matrix as a result of which the structure becomes closer and grains compact.SEM Images reveals that the sample has non-uniform structure and steady performance at reinforcement percentages less than 0.25%. At higher reinforcement percentages agglomeration of Magnesium Nano is more common in the aluminium matrix and the Magnesium Nano particles are not evenly distributed. This uneven distribution and agglomeration of Magnesium Nano in the aluminium matrix is due to the variations in density from one region of the matrix to another. The presence of Nano particles in the grain boundaries was the cause for suppression of non-columbic loss of the grains. Almost similar observations were made on the SEM micrographs of the other samples containing different wt% of Magnesium oxide in A356.1 aluminium alloy. The irregularly shape and the ultrafine particle size favors the formation of larger spherical particles to further reduce the surface energy.

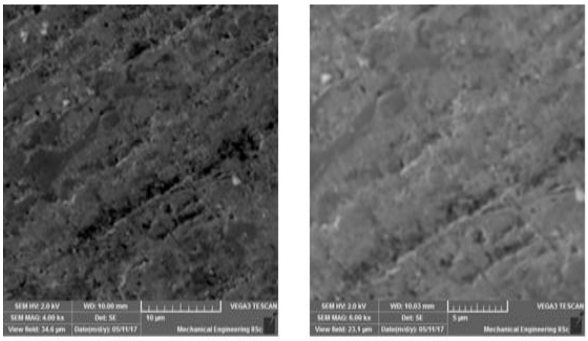

Fig 8(a).As cast specimens

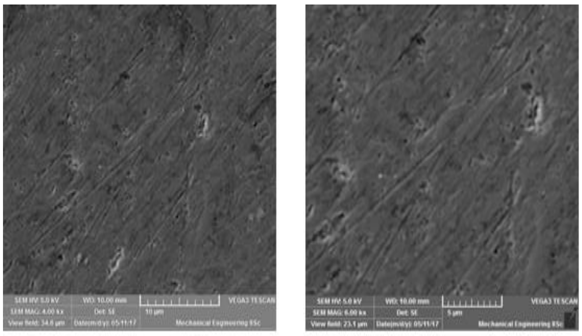

Fig 8 (b). 0.25% Reinforcement

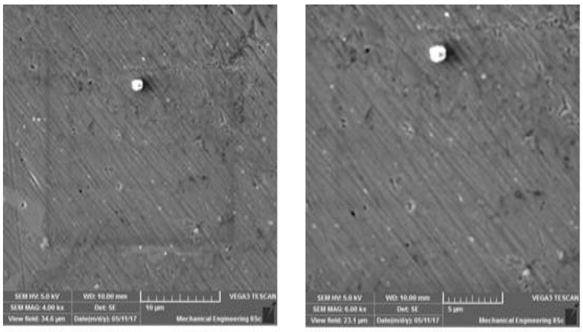

Fig 8 (c).0.5% Reinforcement

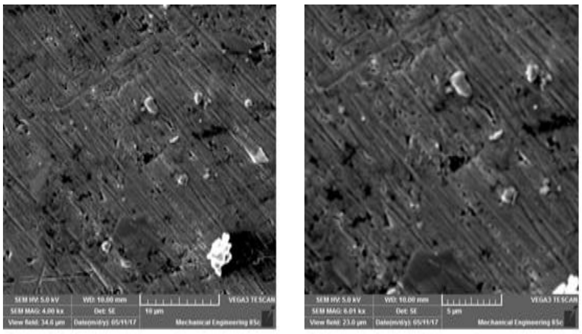

Fig 8 (d).0.75% Reinforcement

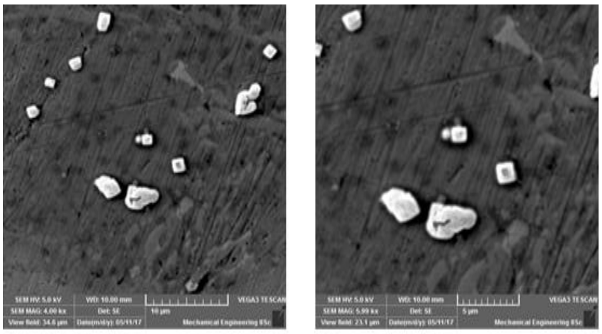

Fig. 8 (e).1.0% Reinforcement

CONCLUSIONS

1. Magnesium Nano particle was successfully synthesized using combustion synthesis method and it confirms that the prepared particles are in Nano phase as per PXRD micrograph

2. Powder X-Ray Diffraction (PXRD) data confirms that Magnesium particles are well in Nano size.

3. Prepared Magnesium Nano particle were fabricated via stir casting technique at a stirring speed of 50 rpm and A356.1 Aluminum alloy successfully reinforced with varying Wt% of 0.25%, 0.5%, 0.75% and 1.0% at a temperature of850 ± 5° C

4. Wear test was performed with considering three different parameters such as Load, Speed and Time.Based on the all parameters Wear resistance of the composite was found to be considerably higher than that of matrix alloy, with the increase in Nano particle content the hard Nano particles resist against destruction action of the abrasive and to protect the surface. 1.0Wt% reinforced content shows better wear resistance and enhances wear rate of 18% compare to base alloy.

5. Impactstrength gradually increases when the weight percentage of magnesium Nano particle reinforced in to A356.1 aluminium alloy

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