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Preparation of Al-Mg/$MgAl_2O_4$ metal matrix composite using stir casting and its comparing its effect on mechanical and morphological behaviour with base Al-Mg alloy and Al-Mg/Al_2O_3composite

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Abstract— **In need of low cost, high performance and good quality materials it has lead to a shift in research from alloys to composite materials. In present study Al-Mg (2.5%,5%) alloy matrix composites reinforced with different volume fractions of complex oxide $MgAl_2O_4$ particles were synthesized by stir casting process, and the effect of the volume fraction of reinforcement on the mechanical and micro structural properties was studied. Various tests revealed considerable improvement on mechanical properties as compared to unreinforced matrix. The hardness has increased to about 80% for samples having 5% of reinforcement when compared to base matrix alloys. The tensile properties of the material were retained and not much effected. As it is a complex oxide this paper also compares the difference in properties between a composite of a complex and a basic oxide which is Al_2O_3**

I. Introduction

In recent past aluminium based alloys are being widely used in automotive, electronics and aerospace industries due to their low density, high strength to weight ratio and their good machinability. As there is a need to improve mechanical and physical properties of these alloys to extend their limits in applications ranging from automotive components such as cylinder blocks, pistons and connecting rods, to aeroengine and airframe components, to electrical and electronic devices, and various such applications. This can be achieved through the addition of ceramic reinforcements. Metal matrix components combine the high hardness of ceramics and ductility of metals.

AMC's have been tested and proved useful in different engineering sectors including functional and structural applications because of variation in mechanical properties depending upon the proportion of reinforcement and chemical composition of Al matrix. The disadvantage of producing AMC's usually lies in the relatively high cost of fabrication and of the reinforcement materials. The cost effective method for manufacturing composites is very important for expanding their application. Particulate - reinforced aluminium-metal matrix composites (AMCs) because of their isotropic properties and relatively low cost are attracting researchers. With the evolution of new processing techniques stir casting process has proved to be relatively economical and easy to use method.

Reinforcing of ductile Al matrix with hard particles such as oxides provides a suitable combination of the properties of both phases which, in turn, results in an improvement of physical and mechanical properties of composites .Uniform dispersion of the fine reinforcements and a fine grain size of the matrix contribute to improve the mechanical properties of the composite . Therefore, this paper focuses on the investigation of the effect of MgAl2O4 content (2.5 & 5 wt.%) and the effect of Mg content (2.5 & 5 wt.%) on morphological, microstructural and microhardness changes of Al–Mg/$MgAl_2O_4$ composite which has been researched very less.

II. Materials and Experimental procedure

A. Materials

Pure Aluminium metal plates and pure magnesium was used as matrix alloy. Aluminium was cleaned using NaOH to remove the impurities and cut into smaller pieces for ease of melting.
Magnesium Aluminate spinels were used and crushed into fine particles to be added as reinforcements in the matrix alloy.

Similarly aluminium oxide particles were also used for one set of the experiment.

B. Stir casting

The metals were added into a graphite crucible with presence of salts which act as flux material. The salts were added in equal proportions for all prepared samples. The first two samples prepared was an alloy with 2.5 and 5 wt% Mg variation the remaining be Aluminium.

Then the remaining samples were prepared with addition of magnesium aluminate as reinforcement into the matrix alloy and stirring it continuously till it was uniformly dispersed into the alloy. The alloy was first melted and fine powder of magnesium aluminate was added into the melt. The magnesium as well as the reinforcement composition was varied in different samples. The temperature at which the stirring was done was approximately at 800C. The melt was then poured into rectangular graphite dies and the samples were left to cool before removed.

C. Morphological analysis

The samples for undergoing SEM were prepared from the stir casted materials. The samples were cut into a $1cm^2$ plates and then cleaned using emery papers for smooth surfaces and better study of morphology. The samples were investigated using TESCAN Vega SB SEM attached with an EDX unit (Energy Dispersive X-ray Analyses). Morphology and particle distribution were examined of the casted material and were quantified by visual basic software using several SEM images and their morphology was characterized by scanning electron microscopy.

D. Structural Analysis

X-ray diffraction (XRD) patterns were carried in a Bruker D8 X-ray diffractometer .The XRD patterns were recorded in the 2h range of 10-90L with a step size of 5L and a scanning rate of 5L/min.

XRD peaks are estimated using William-Hall method as follows:

$$B \cos h = \frac{0.9k}{D} + 4e \sin h \quad (1)$$

where B is the full-width at half-maximum (FWHM) of the diffraction peak, 2h is the position of peak maximum, k is the X-ray wave-length (k = 0.15406 nm), D is crystallite size, and e is lattice strain.

E. Microhardness

The hardness of composite samples was determined by microhardness measurements using a Vickers indenter at a load of 50N and dwell time of 5 s. For measurement of microhardness, the samples were cut into small plates of size 10mmx10mm, with flat surfaces for accurate results. Prior to indentation, the surfaces of the samples were polished using a sequence of increasing grit sand paper.

The following formulae was used t calculate the hardness of the material.

$HV = 0.102F/S = 0.1891F/d^2$.,

Where F is the test load, S is the surface area of the indentation ($1mm^2$) and d is the average diagonal length of the indentation.

F. Tensile strength

For tensile strength test samples of ASTM standards were prepared. In this case ASTM E8 was used which was 105mm in length. The equipment used was Universal testing machine of model UTN 40. The test method used was ASTM B557M.

III. Results and Discussion

A. Morphology

All the samples were cut into 1cmx1cm thin plates of thickness of about 1-2 mm and then cleaned and polished using a sequence of increasing grit sand papers Fig. 1 shows the SEM micrograph taken to Al-Mg base alloy samples with different contents Magnesium being 2.5 and 5 wt%. There is no such remarkable difference between the two samples as there is no presence of any reinforcement in the base alloy. The cavities which can be observed in the SEM images are due to the pores which were developed due to the stir casting of the component.

Fig. 2 illustrates the SEM micrographs of Al–xMg/yMgAl_2O_4 composite samples which were prepared using the stir casting. Increasing of Mg and magnesium aluminate content causes considerable diminution in particles size with disappearing of agglomeration due to the dispersoid addition. It is worthy to mention that, Al–Mg matrix is more brittle than pure Al due to the presence of Mg atoms and solid solution hardening, which accelerates fracture phenomenon and leads to particle size reduction.
Fig2 and Fig3 Al–5%Mg/5%Al_2O_3 and Al–5%Mg/5%MgAl_2O_4 illustrate the particles are more fine that refinement because of high amount of Mg and reinforcements are seen to be more uniformly dispersed into the component.

It is noticeable in further mechanical experiments that there has been an increase in the work hardening and fracture toughness and hardness which indicates that there has been a uniform distribution of the reinforcement in overall composite.

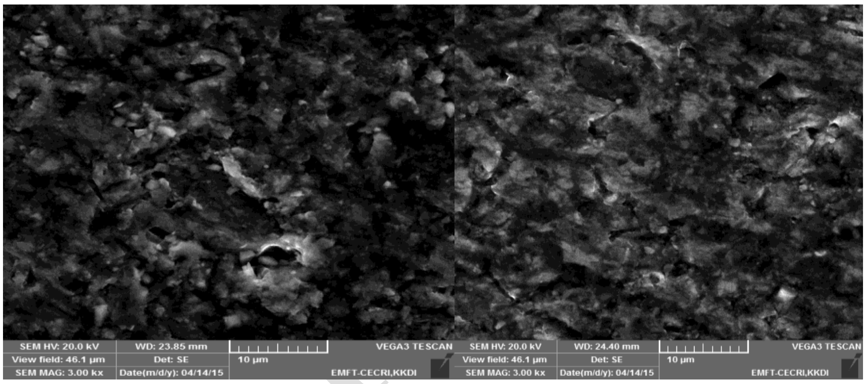

Fig1. SEM images (a) 2.5%Mg alloy (b)5%Mg alloy at 3000x magnification

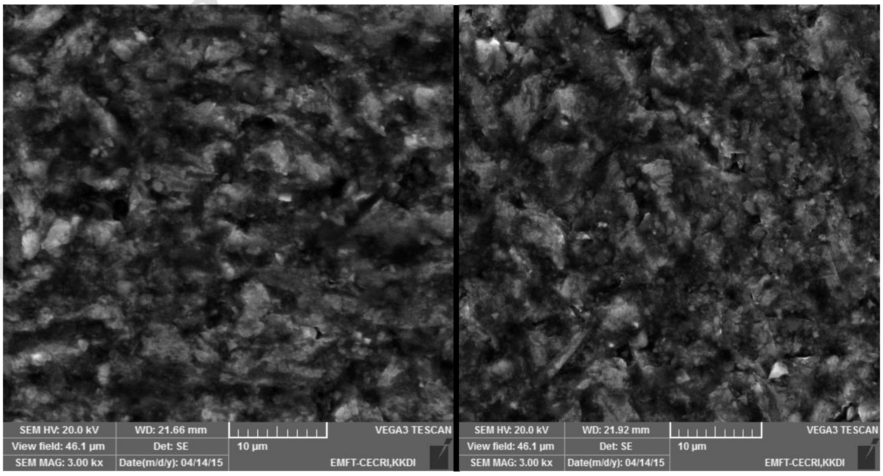

Fig2.SEM images with 2.5%Mg (a) 2.5% MgAl_2O_4 (b) 5% MgAl_2O_4 .Dotted particles of dispersoid can be observed

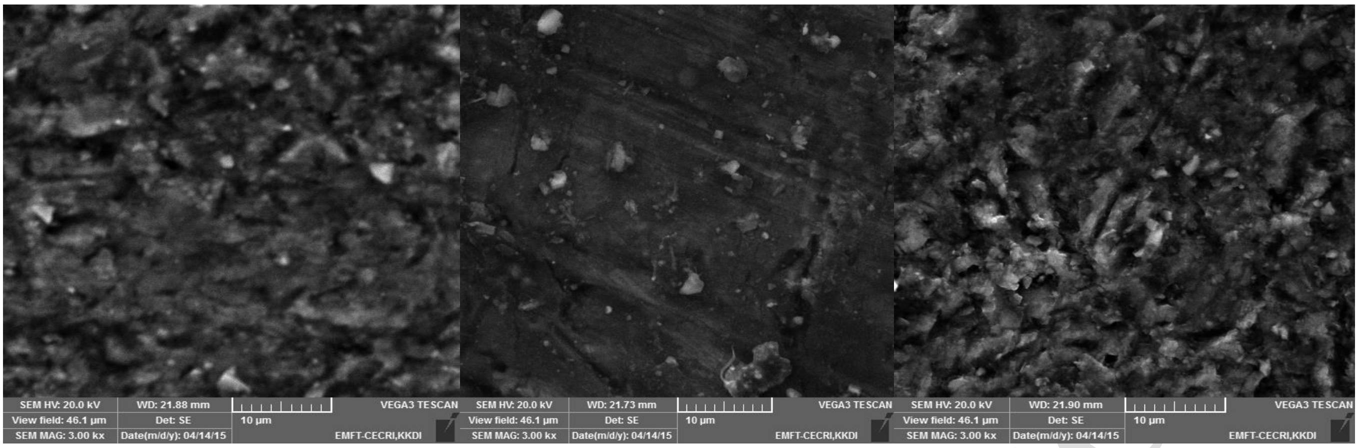

Fig3. SEM images of 5%Mg (a)2.5% $MgAl_2O_4$ (b)5% $MgAl_2O_4$ (c)5%Al_2O_3

B. Structural Analysis

X-Ray Diffraction patterns of Al-Mg base alloy and Al-Mg/$MgAl_2O_4$ were carried out in Bruker D8 diffractometer. The samples were cut into small plates of 1x1 cm^2 for the analysis. The samples were then polished and cleaned using acetone for attaining no s=disturbance in the peaks formation of XRD. Fig 3 shows various XRD patterns which were developed using the system software Origin.

Fig 4a and 4b show the XRD patterns of base alloys in which the maximum peak was attained at 38° (two-theta), that is the peak shifts towards lower angles caused by the solution of magnesium atoms. The next graphs include the composite samples, which show a shift toward larger angles with same peak intensity. This could be due to the environmental effects onto the samples whilst and after preparation of the composite.

The oxygen effect and the reactions within the crucible has caused the peaks to vary to large content. The peaks match for various forms of aluminium and magnesium oxides, which are in complex forms. The variation in the peaks could also be due to the polishing of the samples using acetone which has effected the surface layer and affected the XRD results.

C. Microhardness measurements.

The hardness (H) can be calculated from the maximum load (F) and the maximum penetration depth of the indentation curves by the following equation
$HV = 0.102F/S = 0.1891F/d^2$.

Fig4 shows microhardness changes against Mg and reinforcement content. For samples, with 2.5 and 5 wt.% Mg microhardness increases slightly from 90 to 96 Vickers (HV) which is in case of the base alloy. With the addition of reinforcements the hardness increases considerably up to 155HV with increase of wt% of reinforcements and magnesium. The hardness increment is caused by the increase of the $MgAl_2O_4$ concentration and dislocation density. Addition of $MgAl_2O_4$ increases dislocation density and grain refinement which increases the hardness of the composite when compared to the base alloy.

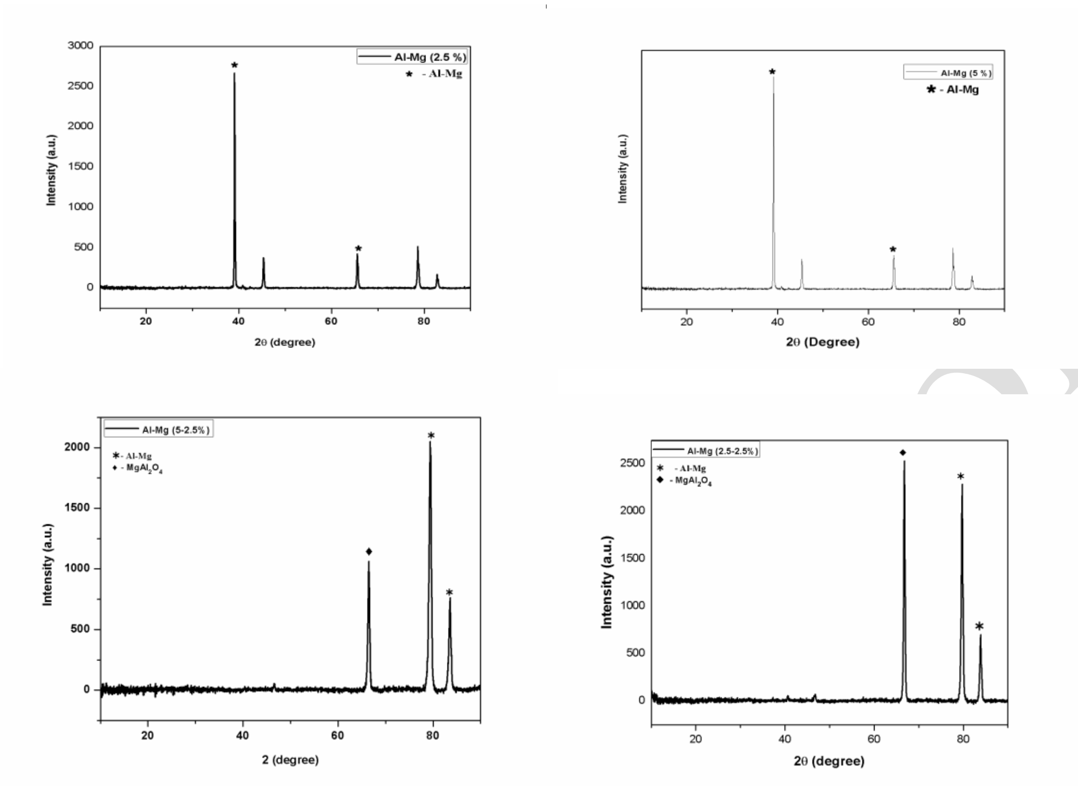

Fig4 (a)XRD images of alloy 2.5% and 5%Mg (b)XRD images of 2.5% $MgAl_2O_4$ and 5% $MgAl_2O_4$.

Additionally, when Al_2O_3 particles are added the hardness reached to a reasonable level of 125HV, which is lesser when compared to the addition of complex oxide $MgAl_2O_4$.

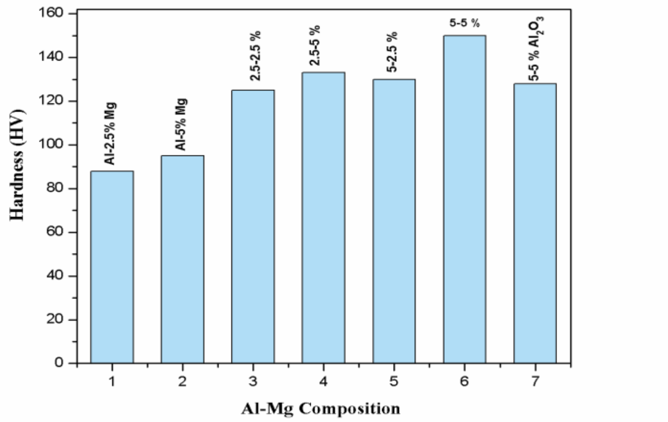

Fig5. Hardness Bar dig.

	Reinforcement %	HV
Al-Mg alloy	2.5%Mg	86
	5%Mg	95.4

Al-Mg/ $MgAl_2O_4$.	2.5%Mg, 2.5% $MgAl_2O_4$.	125
	2.5%Mg,5% $MgAl_2O_4$.	133.01
	5%Mg 2.5% $MgAl_2O_4$.	130.8
	5%Mg, 5% $MgAl_2O_4$.	154..6
Al-Mg/Al_2O_3	5%Mg, 5% Al_2O_3	126.5

Table 1. Microhardness measurement for various compositons.

D. Tensile measurements

The tensile test was carried out in a UTN40 UTM where test method ASTM B557M was carried out. The samples prepared were according to the ASTM E8M04.

The tensile has been performed on the reinforced composites with the base alloy values being considered from various references, since studies on Al-Mg alloys are vast, it is likely that the tensile properties may not vary much. Whereas we do not have any sufficient study on $MgAl_2O_4$ reinforced composites which requires tensile tests to know about the ductile behaviour of the material.

From the tests we have studied that the ultimate tensile strength of the material has increased upto 163MPa, with increase in the composition of $MgAl_2O_4$ with yield stress rising to 125MPa, it can be surely said that it has retained its ductile properties, in fact the strength has increased compared to their base matrix alloys. Adding Al2O3 has also lead to almost same results in tensile strength. The elongation has bee upto 10.67% for 5% $MgAl_2O_4$.

	Reinforcement vol%	UTS (MPa)	Yeild strength (MPa)	Elongation %
Al-Mg alloy	5%Mg	140	90	8%
	2.5%Mg	135	70	6%
Al-Mg/ $MgAl_2O_4$.	5%Mg 5% $MgAl_2O_4$.	155.34	125.01	10.67%
	5%Mg 2.5% $MgAl_2O_4$.	136.10	101.44	7%
	2.5% Mg 5% $MgAl_2O_4$.	163.70	121.48	6.67%
Al-Mg/Al_2O_3	5%Mg 5%Al_2O_3	158	112	8.5%

Table 2. Tensile Measurements according to the composition of material.

IV. CONCLUSIONS

The mechanical and morphological changes of Al–xMg/y $MgAl_2O_4$ (x = 2.5 and 5 ,y=2.5 and 5%) composites using stir casting were studied. From this study the following conclusions could be drawn:

1. As the $MgAl_2O_4$ content was increased we saw a gradual increase in the hardness of the components. It was also directly proportional to the amount of magnesium added to the alloy. So overall we can conclude that the hardness has increased for the composites with $MgAl_2O_4$ up to 80% compared to base matrix alloys. Alumina reinforcement also showed good hardness but lesser when compared to magnesium aluminate.
2. The grain distribution was uniform in the composites overall the system which lead to increase in the mechanical properties.
3. Ductile properties were not affected with addition of brittle natured reinforcement but an increase in tensile and yield strength were observed when compared to the base alloy. The elongation was retained in both the cases. Alumina also had the same effect on the ductile properties.
4. The XRD structural analysis was not up to the mark due to the cleaning effect and environmental effect on the material during stir casting.

5. Formation of pores was a major issue during stir casting process which if avoided could yield much better hardness and tensile properties hence improving the overall material.
6. Stir casting if performed in vacuum shall yield more good results as outer atmosphere affects the reactions and various forms of Al and Mg oxides are formed.

References

[1] A. Fathy A. Wagih M. Abd El-Hamid , Ahmed A. Hassan The effect of Mg add on morphology and mechanical properties of Al–xMg/10Al_2O_3 nanocomposite produced by mechanical alloying. Advanced powder technology xxx 2014

[2] Investigation of microstructure and mechanical properties of nano MgO reinforced Al composites manufactured by stir casting and powder metallurgy methods: A comparative study Hossein Abdizadeh [a, b], Reza Ebrahimifard [b], Mohammad Amin Baghchesara Composites Part B56 *(2014) 217-22

[3] preparation of aluminium matrix composites using stir casting.Rajeshkumar bhandare, Parshuram s. IJEAT Vol 3, Issue 2, December 2013

[4] Reactive stir mixing of Al–Mg/Al_2O_{3np} metal matrix nanocomposites: effects of Mg and reinforcement concentration and method of reinforcement incorporation Daniel R. Kongshaug · J. B. Ferguson · Benjamin F. Schultz · Pradeep K. Rohatgi, J. Material science, Aug 2013

[5] M K SURAPPA, "ALUMINIUM MATRIX COMPOSITES: CHALLENGES AND OPPORTUNITIES," Sadhana Vol. 28, Parts 1 & 2, February/April 2003, pp. 319–334

[6] B.C. PAI, R.M.PILLAI AND K.G.SATYANARAYANA "LIGHT METAL MATRIX COMPOSITES - PRESENT STATUS AND FUTURE STRATEGIES"

[7] Muhammad Hayat Jokhio, Muhammad Ibrahim Panhwar, And Mukhtiar Ali Unar "MANUFACTURING OF ALUMINUM COMPOSITE MATERIAL USING STIR CASTING PROCESS"

[8] Mehran University Research Journal Of Engineering & Technology, Volume 30, No. 1, January, 2011 [Issn 0254-7821]

[9] J Hashim, L Looney, M.S.J. Hashim "THE ENCHANCEMENT OF WETABILITY SIC PARTICLE IN CAST ALUMINIUM MATRIX COMPOSITE" Journal of material processing technology 119(2001) 329- 335

[10] Dunia Abdul Saheb "ALUMINUM SILICON CARBIDE AND ALUMINUM GRAPHITE PARICULATE COMPOSITES" ARPN Journal of Engineering and Applied Sciences VOL. 6, NO. 10, OCTOBER 2011 ISSN 1819-6608

[11] Su H, Gao W, Feng Z, Lu Z. Processing, microstructure and tensile properties of nano-sized Al_2O_3 particle reinforced aluminum matrix composites. J Mater Des 2012;36:590–6.

[12] Lai J, Zhang Z, Chen XG. Precipitation strengthening of Al–B_4C metal matrix composites alloyed with Sc and Zr. J Alloys Compd 2013;552:227–35.

[13] Zhang Q, Ma X, Wu G. Interfacial microstructure of SiCp/Al composite produced by the pressureless infiltration technique. J Ceram Int 2013;39:4893–7.