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RESEARCH ARTICLE

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MECHANICAL PROPERTIES OF AL METAL MATRIX COMPOSITES BY USING POWDER METALLURGY TECHNIQUE

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ABSTRACT

Aluminium metal matrix composites are one of the new materials used for various applications due to their light weight and less cost. Reducing structural weight is one of the major ways to improve aircraft performance. Lighter and stronger materials allow greater range and speed and may also contribute to reducing operational costs. The aim of this study is to investigate the effect of the amount of Magnesium reinforcement on the properties of Aluminum and Copper composite. Magnesium particles were mixed with Aluminum particles in the range of 2.5–10 Vol. %. The average particle sizes for the matrix and reinforcement were 15, 44 and 60 µm, respectively. The samples were prepared at sintering temperature of 550°c for a constant sintering time of 30min. The mechanical properties were studied with different compositions of the reinforcement of Mg to Al MMC. Results show that by increasing the amount of Magnesium from 2.5% to 10%, the hardness increased from 52 to 70 HRB, while the compressive strength was raised from 25 to 48 MPa. The addition of Magnesium decreased the wear rate from 159µm to 72 µm.

Keywords: Hybrid Composition, Sintering, wear, compression, hardness.

1.INTRODUCTION

Among various reinforcements, Magnesium is widely used because of its light weight, low cost and ready availability, high strength, good wear resistance, good compatibility with the aluminium matrix.

The use of high performance materials in both the propulsion and airframe systems enables the modern aircraft to rotate larger degree while retaining its strength. The attractiveness of aluminum is that it is light weight metal, relatively low cost relatively low cost that can be heat treated to fairly high strength levels and it is one of the most easily fabricated high performance materials, which usually correlates with lower costs.[1]

Aluminium alloys with a wide range of properties are used in engineering applications. Selecting the right alloy for a given application entails considerations of its density, formability, weldability, tensile strength, ductility, workability, and corrosion resistance, to name a few. Aluminum alloys are used extensively in aircraft, space ships, military and automobiles due to their high strength-to-weight ratio. Thus various alloying elements are added to aluminium to enhance the mechanical properties of aluminium. Copper has been the most common alloying element almost since the beginning of the aluminum industry, and a variety of alloys in which copper is the major addition were developed. Magnesium (Mg) used to harden and strengthen aluminum composites.

Aluminum alloys are alloys in which aluminum is thepredominant metal. The typical alloying elements are magnesium, copper, silicon, manganese and zinc.[2]

Present automotive marketplace has moved towards calculating the total operating cost of cars, rather than just the initial cost, which provide a better justification for the use of light weight metal matrix composites. These composites may be initially more expensive but could provide significant saving over the life time of the vehicle. Aluminium , which is the lowest density structural metal, has been considered as a viable option to address the aforementioned issues such as weight reduction and fuel efficiency in automotive and airplanes structures.[3-4]

Aluminum–magnesium based alloys have received considerable attention due to their high strength to weight ratio. The reduction in weight of components such as clutch housing, pistons and liners leads to significant impact on fuel economy in dynamic systems. In addition, these alloys are reported to have a reasonably high wear resistance. Porosity is a common feature of cast and sintered Al-Mg alloys and strongly influences their properties and applications.

The presence of pores is effect on mechanical properties, that is, increase in compressive strength and decrease of ductility of the materials. [5]

Powder metallurgy process

Powder metallurgy is the process of blending fine powder materials, pressing them in to a desired shape or form (compacting), and after heating the compacted materials in a controlled atmosphere to bond the material (sintering). The powder metallurgy process generally consists of four basic steps: powder manufacturing, compacting, powder blending and sintering. Compacting is generally performed at room temperature, and the sintering is usually conducted at atmospheric pressure. [3]

2. Experimental Procedure:

Mixing of Powders

Total four compositions of mixture were prepared.

- 92.5% Al + 2.5%Mg+5%Cu
- 90% Al + 5%Mg+5%Cu
- 87.5% Al + 7.5% Mg
- 85% Al + 10% Mg+5%Cu

Blending is performed in rotary mixing chamber (Fig1) which consists of one cubical containers made of steel rotating about its axis. In this the powders are mixed at a speed of 60 rpm, with changing the rotation direction for every 5 minutes with time period of 90 minutes, To get a uniform degree of fineness in the mixture.

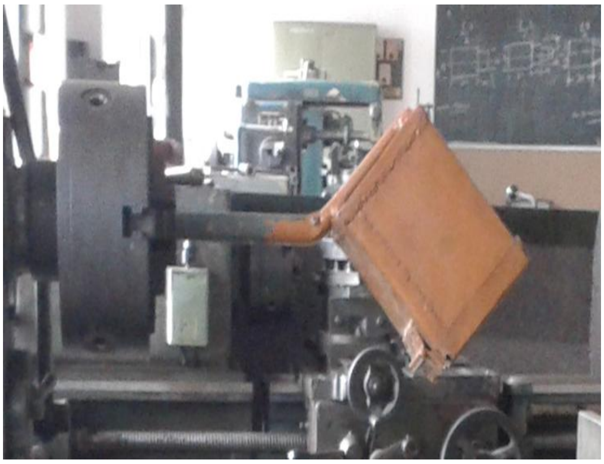

Fig2: Mixing chamber

Compacting on UTM

The blended powders are compacted using universal testing machine (UTM) at a load of 300Mpa and the maximum load of 40 tons UTM (fig2.a) is used for the process. The cylindrical die (Fig 2.b) cleaned with a siliconspray so that no dust particles or any other foreign materials are notstick the die. A load of 300 MPa is applied gradually in a time period of 15 seconds on 40 tons UTM. The compacted specimens(fig2.c) are weighed over the weighing machine and the weights are noted, and the further calculations are done accordingly.

Fig2(a): Universal Testing Machine

Fig2 (b): Cylindrical Die

Fig2(c): Compacted Green Specimens

Sintering of the green samples

The compacted specimens were sintered on horizontal tubular furnace (Fig3.a) in which the green compacts are parched at an elevated temperature but kept below the melting point of the base metal for sufficient time. A total of sixty sintered samples (fig3.b) from each of the five specimens per mixtures containing 2.5%, 5%, 7.5%, 10% Mg were sintered for 35minutes at a temperature of 550° C respectively. The existence of Mg and Cu also holdup the aluminium melts from one particle to join melts from another.

Fig2(d): Sintering Machine

Fig2(e): Sintering Specimens

Density

Density of the sintered and un-sintered compacts was determined by theoretically as follows below

Green density (ρ_g) $= \frac{4000 \times w_g}{\pi \times d^2{}_g \times l_g}$

Where w_g= weight of green compact

D_g= diameter of green compact

L_g= length of green compact

Sintered density (ρ_s) $= \frac{4000 \times w_s}{\pi \times d^2{}_s \times l_s}$

Where w_s= weight of green compact

D_s= diameter of green compact

Ls= length of green compact

Ejection pressure

Ejection pressure of compact is analyzed by using theoretical formula as follows

Ejection pressure$= \frac{F_e}{\pi \times d_g \times l_g}$

Where F_e= ejection load

d_g=diameter of green compact

l_g= length of green compact

Porosity

Porosity of the sintered as well as un-sintered compacts was determined by theoretically as shown below.

Green/ True porosity = $\left[1 - \frac{\rho_g}{\rho_{th}}\right] \times 100$

Where ρ_g=green density

P_{th}= theoretical density

Sintered porosity= $\left[1 - \frac{\rho_s}{\rho_{th}}\right] \times 100$

Where ρ_s = sintered density

P_{th}=theoretical density

Wear test:

Wear tests were conducted using pin-on-disc method at room temperatures under dry sliding conditions.

Cylindrical samples of diameter 9 mm. and height 12 mm. were used. Cast iron discs of diameter of 9 cm. and hardness HRC-47 were used as counter discs. All tests were conducted applying a fixed load of 10N at 425 rpm of revolving counter disc.

Fig2(f): Pin On Disk Machine

Compression test:

Compression test was performed on Al-Mg composite specimens with length to diameter ratio of 1.5. Tests were performed on Compression testing machine of 1000 KN capacity. The sample was compressed between two flat platens and the maximum failure load was recorded.

Fig2(g): Compression Testing Machine

Hardness test:

The average Rockwell hardness values of Al-Mg composites measured on the polished surfaces of the samples and the samples were tested using Rockwell hardness tester. A minor load of 10 kg was first applied to seat the specimen. Then the major load of 100 kg was used on the B Scale, with a 1.6 mm diameter steel ball.

Fig2(h): Rockwell Hardness Tester

3. Results and discussion:

In this work, we analyzed density (green and sinter), ejection pressure, porosity (green and sinter), and their mechanical properties are wear resistance, compression strength and hardness of different compositions are tested, analytically and graphically.

The increment of magnesium in the Al composite shows significant decrease in density (both green and sinter). The behavior of the material changes with addition of magnesium and the results are shown below tables and graphs.

Mg percentage	Green density
2.5	22.7
5	22.21
7.5	21.28
10	21.11

Table3(a): Green Density Values

Magnesium percentage	Sintered density
2.5	24.02
5	23.53
7.5	22.54
10	22.33

Table3(b): Sintered Density Values

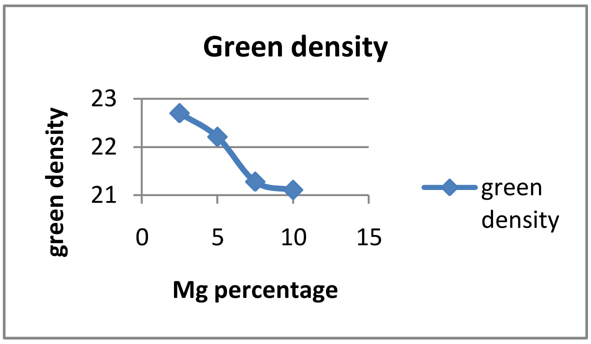

Fig3 (a): Green Density

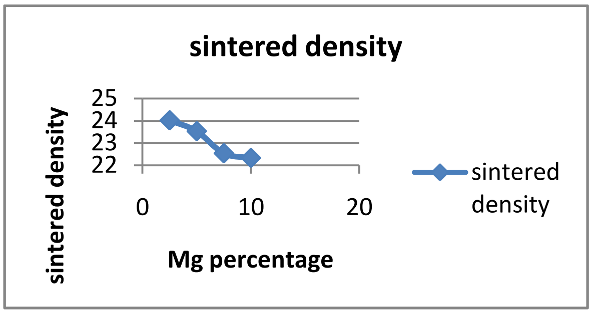

Fig3 (b): Sintered Density

The porosity (Green and Sintered) decreases with increase the amount of magnesium in the Al composite. The behavior of the material changes with decreasing the number of pores and interfacial bonding strength of Al composite and the porosity results are shown below in tables and graphs.

Mg percentage	True porosity
2.5	16.69
5	16.02
7.5	15.6
10	14.8

Table3(c): True Porosity Values

Magnesium percentage	Percentage of sintered porosity
2.5	14.26
5	13.89
7.5	11.76
10	11.16

Table3(d): Sintered Porosity Values

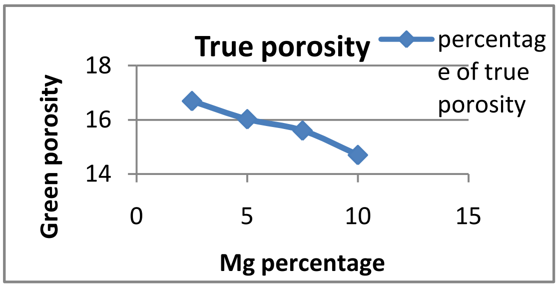

Fig3(c): True Porosity

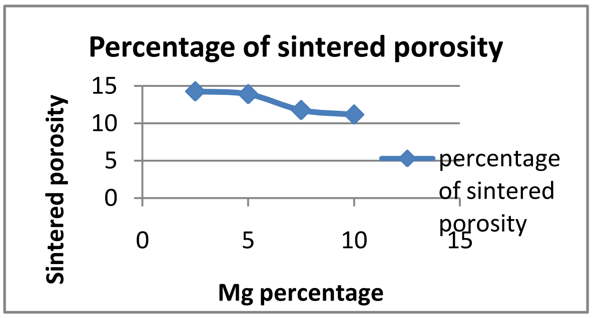

Fig3 (d): Sintered Porosity

The ejection pressure decreases with increasing magnesium percentage in the Al composite. Because the cohesive nature between Al and Mg particles.

Mg percentage	Ejection pressure in N/mm^2
2.5	31.98
5	30.27
7.5	28
10	27.8

Table3(e): Ejection Pressure Values

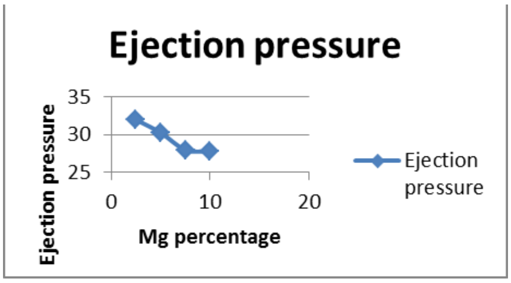

Fig 3(e): Ejection Pressure

Wear test:

The effect of wear resistance on Al MMC increased with increasing of Mg content with average particle size of 60µm on wear resistance of the specimens. As magnesium is introduced in the composite, the wear decreased from 159µm to 72µm and the wear resistance increases by 50%, under identical test conditions

The average wear resistance values of Al-Mg composites measured on the polished surfaces of the samples and measured for five samples of each composition of the Al-Mg composites and the average value of the wear test for PM samples were plotted in the graphs(fig5.a-5.e) with volume % of magnesium. The wear test results are tabulated (table2) and plotted graphs as shown below

Table:

Mg percentage	Wear rate in micrometers
2.5	159
5	133
7.5	82
10	72

Table3(f): Wear Rate Values

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Graphs:

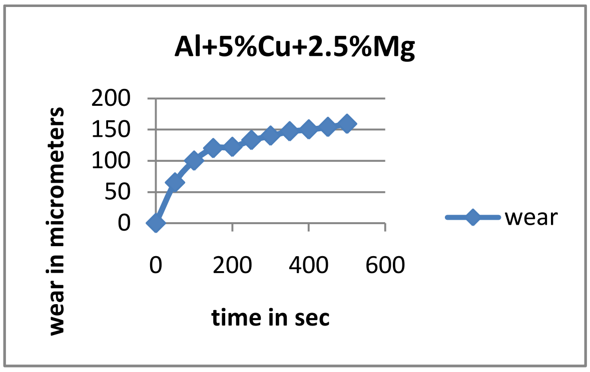

Fig3(f): Graph for Al+5%Cu+2.5%Mg composition

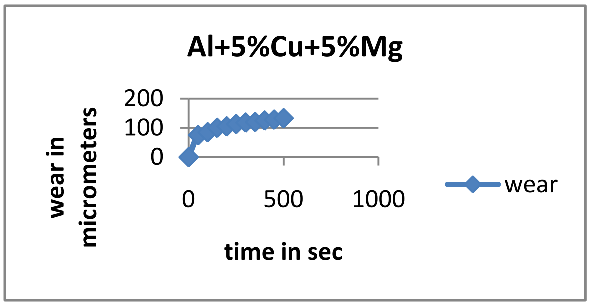

Fig3(g): Graph for Al+5%Cu+5%Mg composition

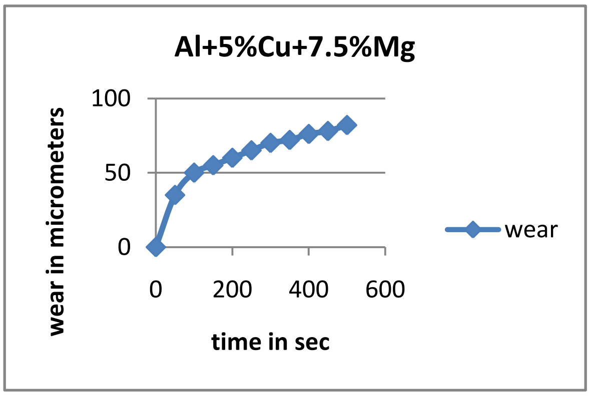

Fig3(f): Graph for Al+5%Cu+7.5%Mg composition

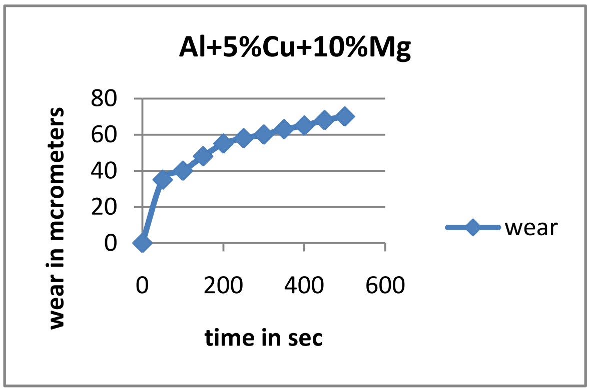

Fig3(h): Graph for Al+5%Cu+10%Mg composition

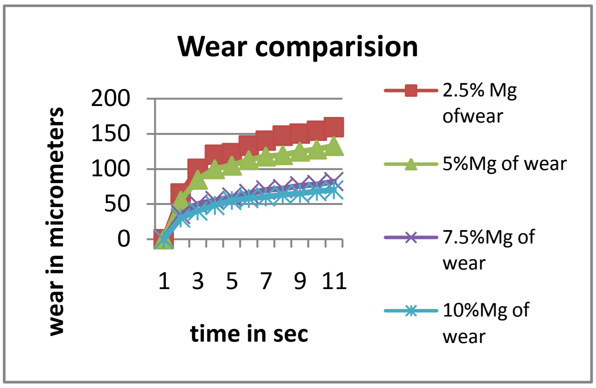

Fig3(i): Wear test comparision graph

Compression test:

The compressive strengths were also measured for five samples of each composition of the Al-Mg composites and the average value of the compressive strength for PM samples were plotted in the graphs(fig6.a) and tabulated(table3) with vol. % of Mg. The compressive strength of PM Al-Mg composites increases with increase in vol. % of Mg from 5 to 10 vol. % of Mg and the compressive strength increased from 25 to 45N/mm^2. Figure 6 show the compressive strength for powder metal of Al-Mg composites.

Compression test table:

Mg percentage	Compression strength in N/mm^2
2.5	25
5	29
7.5	33
10	45

Table3(j): Compression test values

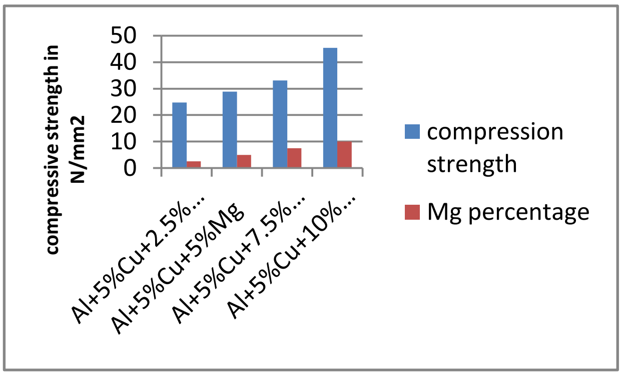

Fig3(j): Comparision between four compositions

Hardness test:

The average Rockwell hardness values of Al-Mg composites measured on the polished surfaces of the samples and the samples were tested using Rockwell hardness tester (fig7). A minor load of 10 kg was first applied to seat the specimen. Then the major load of 100 kg was used on the B Scale, with a 1.6 mm diameter steel ball. The result was then recorded automatically on the dial gauge in terms of arbitrary hardness numbers. This was then recorded with the value first and HRB at the end. The Rockwell hardness of powder metal Al-Mg composites increases with increase in volume % of Mg from 5 to 10 vol. % of Mg. The values (table4) shown in the graph (fig7.a) are average of the five readings for each composition of the composite

Mg percentage	Hardness in HRB
2.5	51
5	53
7.5	60
10	70

Table3(k): Hardness values

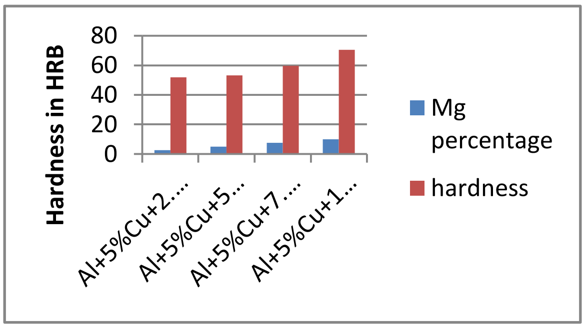

Fig3(k): Comparision between four compositions

4. Conclusion:

The increase in the amounts of Magnesium in Aluminium-composites shows significant decrease in density.The behaviors of the material have changed with the addition of magnesium.

The increase in the amounts of Mg in Al-composites shows increasing of Wear Resistance, Compression and Hardness properties.

Green density, Sintered density, True porosity, Percentage of sintered porosities are decreased with increasing Mg percentage in the Al metal matrix composite. So that the amount of porosity and the size and shape of pores have a great impact on material removal during wear

Results show that by increasing the amount of Magnesium from 2.5% to 10%, the hardness increased from 52 to 70 HRB, while the compressive strength was raised from 25 to 48 MPa. The addition of Magnesium decreased the wear rate from 159µm to 72 µm.

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I would like to thank my guide and technician for providing us to fabricate specimens on UTM at V.R.Siddhartha Engg College.

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