MECHANICAL INVESTIGATIONS ON MICRO TITANIUM AND B_4C REINFORCED AL-Mg ALLOY USED IN AUTOMOTIVE APPLICATIONS.

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ABSTRACT - *Aluminum-Magnesium alloy have been increasingly used in the automotive industry in recent years due to their lightweight. The density of magnesium is less compared to other metals. As a result, AL-Mg alloy offer a very high specific strength among conventional engineering alloys. In addition, magnesium alloy possess good damping capacity, excellent cast ability, and superior machinability. Accordingly, AL-Mg alloy have a relatively low absolute strength, especially at elevated temperatures. Hence Ti and B_4C are used as the reinforcement to improve the mechanical properties at elevated temperatures, the most widely used magnesium alloy are based on the AL-Mg system, efforts to develop high temperature magnesium materials have led to the development of several new alloy systems such as Mg-Al-Ca, Mg-Re-Zn-Zr, Mg-Sc-Mn and Mg-Y-Re-Zr alloys. However, this progress has not engendered extensive applications of these magnesium alloying the automotive industry, either because of insufficient strength or high cost. Hence in our present study we have developed a new hybrid composite with the addition of Ti and B_4C powders to AL-Mg alloy and have investigated the mechanical properties. This has resulted in the improvement in the properties of the hybrid composites.*

Keywords: AL-Mg, Magnesium, light weight, strength, Ti, B_4C, Mechanical, tribological properties.

I. INTRODUCTION

Aluminum-Magnesium and its alloy have low density, high specific mechanical properties and excellent damping characteristics. Due to these reasons, they exhibit tremendous application potential in automobile and aerospace industries, where weight reduction is critical. However, they inherent poor mechanical characteristics such as low strength, elastic modulus, ductility and poor high temperature stability of magnesium and its alloy restrict its extensive utilization in critical engineering applications. In this regard, AL-Mg metal matrix composites reinforced with ceramic elements in the form of fibers/particulates exhibit superior elevated temperature strength alongside improved elastic modulus, and hardness. However, the incorporation of such ceramic reinforcements in pure AL-Mg and its alloy often results in brittleness. Recently, high strength, high modulus metallic elements like Ti, Ni, B_4C and Cu were added to improve the mechanical properties of AL-Mg and its alloys. When 5wt% Micro Ti and 1%, 2%, & 3% wt of B_4C was added to AL-Mg, an overall improvement in yield strength by 30% and ductility by 15% was reported. When soluble metallic elements like Ni and Cu (with limited solubility in Mg) were added to pure Mg, significant strength improvement was reported, but with poor ductility. On the other hand, an overall enhancement in strength and ductility was reported when micro-sized ceramic reinforcements (such as Al_2O_3, ZrO_2 or ZnO) were added to Mg and its alloys. Recent works have shown the positive influence of hybrid reinforcement (prepared by mechanical alloying). In the present work, micron-sized Ti particulates are added with varying weight fractions of B_4C particulates and this hybrid (5wt. % Micro-Ti, 1%, 2%, & 3% wt of B_4C) mixture are used as reinforcements in pure AL-Mg. The results of mechanical properties were increased compared to base matrix.

1I. MATERIALS AND EXPERIMENTAL DETAILS

AL-Mg is one of the alloy in which Magnesium is the major alloying element usually it is in combination with Manganese. Alloy of this type have the highest strength among all. This kind of Alloy possess highest mechanical strength when heat treated.

AL-Mg based metal matrix composites (AMCs) are of lightweight high performance material systems. Among the several types of aluminum alloy being used, AL-Mg is extensively used in marine and aerospace applications because of their superior corrosion resistance, excellent formability and good welding characteristics. AL-Mg is broadly used for the construction of ship buildings/structures, however due to low strength and poor wear resistance the application of this material is limited. The addition of reinforcement to aluminum-magnesium matrix drastically alters mechanical properties. The reinforcement could be in the form of continuous/discontinuous fibers, whiskers or particulates. The hybrid composites have been prepared by incorporating different types of fibers into a single matrix. Due to two or more fibers in the hybrid composite, the advantages of one type of fiber could complement with what are lacking in the other. The properties of hybrid composite primarily depend upon fiber content, length of individual fibers, orientation, extent of inter- mingling of fibers, fiber to matrix bonding and arrangement of the fibers.

AL-Mg alloy is one type wrought Aluminium alloy, containing Magnesium as a major alloying element. The density of AL-Mg is taken as 3.9 g/cm^3 theoretically. The main advantage of introducing reinforcement material to base metal or alloy is to increase the properties there by enhancing the mechanical properties of composites. In the current research work Boron Carbide and Titanium particulates of size 100 microns (μm) were used as reinforcement materials.

Boron Carbide is a nonmetal material that poses very useful physical and chemical properties. This material has an excellent potential because it is the third hardest material after diamond and boron nitride and the density of Boron Carbide is 2.51g/cm^{3}which is lower than the base matrix, contributes in weight saving. Boron Carbide and Titanium retains high melting point which is above 2450°c as well as high resistance to chemical agent.

Preparation of AL-Mg/B_4C/Ti hybrid Composite.

There are many techniques used to manufacture Metal Matrix Composites (MMCs), but Stir-Casting and Powder Metallurgy are extensively used to manufacture the composites. The powder metallurgy technique is more cost effective than the casting methods, but it cannot be used for the production of complex shapes. Compared with Powder Metallurgy, Stir-Casting which involves stirring of the particles into melt has some advantages: better matrix bonding, easier control of matrix structure, low-cost, simplicity, a nearer net shape can be produced and there is a wide selection of materials that can be used in this method. The fabrication of AL-Mg hybrid composite used in this study was carried out by using Stir Casting method. In this, firstly AL-Mg alloy was placed in a clay graphite crucible. It was then melted in a resistance heated muffle furnace to the desired temperature of 720°c. In the meantime B_4C and Ti powders of 100 mesh size were heated in another crucible to a temperature of 250°C to remove moisture, and the die was pre heated to a temperature of 300°c. Then the Boron Carbide and Micro Titanium powders were mixed in into the molten metal. The crucible was covered with flux and degassing agents to improve the quality of Aluminium composite casting. The mixture was stirred continuously by using mechanical stirrer for about 10-15 minutes at an impeller speed 300 rpm. The melt temperature was maintained at 730°c during addition of the particles. The molten metal was then poured into the preheated die to cast plates.

Fig1: Stir casting equipment

Fig 2: Tensile test specimens (before and after testing)

Fig 3: Compression test specimens (before and after t

III. RESULTS AND DISCUSSION

(a) Tensile test

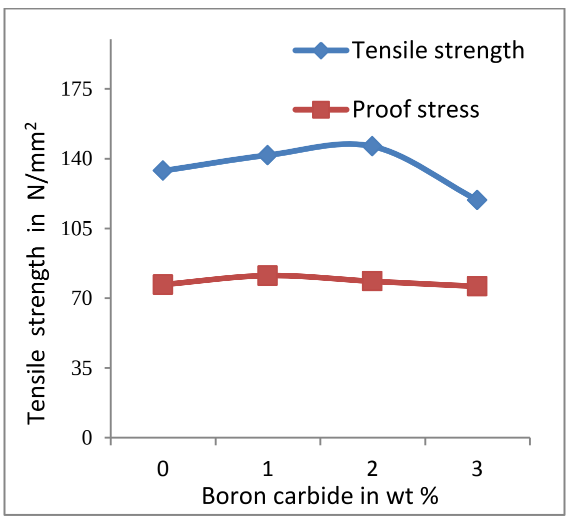
Fig 4- Tensile and compression Test equipment

The test specimens were prepared according to the ASTM

Standards and tests were carried out in the universal testing machine. The tensile testing is carried out by applying longitudinal or axial load at a specific extension rate to a standard tensile specimen with known dimensions (gauge length and cross sectional area perpendicular to the load direction) till failure. The applied tensile load and extension are recorded during the test for the calculation of stress and strain. A range of universal standards provided by Professional societies such as American Society of Testing and Materials (ASTM), ASTM B557 is standard test methods of tension testing wrought and cast aluminium and magnesium alloy products.

no	AL-Mg+Ti (%)	boron carbide (%)	Tensile strength (N/mm^2)	Proof stress (N/mm^2)
1	100	0	133.932	76.846
2	94+5% Ti	1	141.765	81.340
3	93+5% Ti	2	146.147	78.46
4	92+% %Ti	3	119.185	75.91

Table 1- Tensile strength of different compositions



Graph 1- comparison between tensile strengths of AL-Mg hybrid composite.

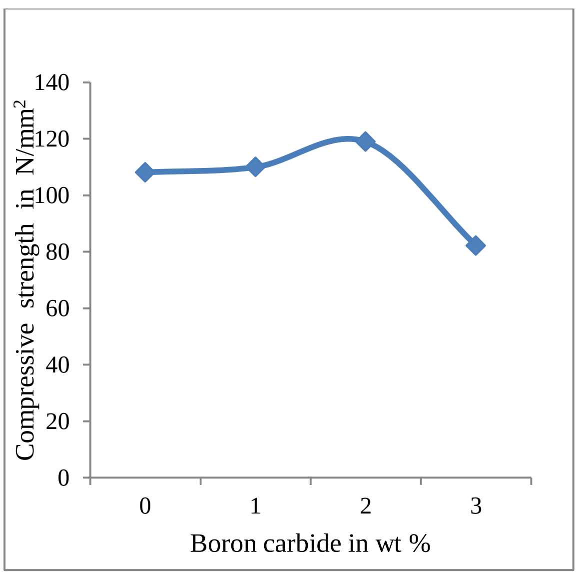
From the comparison graph it is observed that the tensile strength of hybrid composite is higher compared to unreinforced matrix. However with increasing wt. % of B_4C the tensile strength increases and also from the graph we can see that the tensile strength increases up to 2wt% of B_4C this is due to the strong interface bonding, load from the matrix transfers to the reinforcement resulting in increased ultimate tensile strength. This increase in ultimate tensile strength mainly is due to presence of B_4C particles which are acting as barrier to dislocations in the microstructure. The improvement in ultimate
Tensile strength may also be due to alloy strengtheningof the matrix, followed with a reduction in grain size of the composites, and the formation of a high dislocation density in the AL-Mg alloy matrix due to the difference in the thermal expansion between the metal matrix and the B_4C reinforcement. And further increase in the wt. % of B_4C results in the drop of tensile strength this is due to the addition of B_4C beyond 2 wt. % results in the reduction in the bonding strength between the matrix and reinforcement phase hence there is a drop in the strength.

(b) Compression test

The test specimens were prepared according to the ASTM standards and tests were carried out in the universal testing machine. The specimen of standard dimensions is located between the compression grips that are adjusted manually. Constantly increasing load is applied to the specimen which is being constantly monitored. The load at which fracture occurs is noted down.

no	AL-Mg+Ti (%)	boron carbide (%)	Compressive strength (N/mm^2)	Peak load (N)
1	100	0	108.13	18930.01
2	94+5 %Ti	1	110.00	19938.85
3	93+5 %Ti	2	118.91	20845.04
4	92+5 %Ti	3	82.17	14348.62

Table 2- Compressive strength for different compositions.



Graph 2- comparison between compressive strengths of AL-Mg hybrid composite.

Graph 10 shows variation of compressive strength of AL-Mg alloy matrix with wt. % of B_4C particulate reinforced composite. It can be seen that by adding wt. % of reinforcement particulates compressive strength of the AL-Mg alloy increased. This increase in compressive strength is in agreement with the results obtained by several researchers, who have reported that the strength of the particle reinforced composites is highly dependent on the volume fraction of the reinforcement. The increase in compressive strength of the composite is obviously due to presence of hard B_4C particles which impart strength to the soft aluminium-magnesium matrix

Resulting in greater resistance of the composite against the applied compressive load. In the case of particle reinforced composites, the dispersed hard particles in the matrix create restriction to the plastic flow, thereby providing enhanced strength to the composite. Further increase in the wt. % of the reinforcement results in the drop of compressive strength the presence of shear bands. It attributes to the heterogeneous deformation and the work hardening behavior. The supreme value of compressive strength is obtained for the composition of 93%AL-Mg+5%TI+2%B_4C.

VI. CONCLUSION

The important conclusion on the Evaluation of AL-Mg MMC reinforced with Micro Ti and B_4C particulates are as follows.

- Stir casting process were used in the preparation of AL-Mg hybrid composites containing varying % of Micro Ti and B_4C particulates as reinforcement.

And the test specimens were prepared according to ASTM standards.

- The tensile strength and ultimate stress of the hybrid composites were found to be higher than that of the AL-Mg base matrix.
- The tests were conducted for the different variation of reinforcement it was found that a maximum of 2% wt. of B_4C can be added further addition of B_4C will decrease in the tensile property.
- Compressive strength was found to be increased with the addition of the reinforcement compared to base alloy matrix.
- The study tells that the addition of B_4C and Micro Ti particulates beyond 2% wt. will result in the decrease of compressive property.
- From this Research work it can be concluded that the Micro Ti and B_4C proves to be a good reinforcement combination with AL-Mg matrix phase. And stir casting techniques were used effectively for uniform dispersion of less denser reinforcements eg: B_4C, Ti.

VII. REFERENCES

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