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Development and Analysis of Aluminium Based Alloy A356 Reinforced with Aluminium Nitride and Magnesium by Stir Casting Technique

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Abstract: The present work is focused on the study of behavior of Aluminium Alloy (A356) with Aluminium Nitride (AIN) and Magnesium (Mg) composite produced by the stir casting technique. Different % age of 3, 6 & 9 AlN and 0.5 & 1 Mg of reinforcement are used. Tensile Test, Micro Hardness Test, Impact Test are performed on the samples obtained by the stir casting process. Microstructure analysis has done to know the presence of the structure of reinforced material. Hardness tester is employed to evaluate the interfacial bonding between the particles and the matrix by indenting the hardness with the constant load and constant time. Microscopy was done to know the distribution of AlN/Mg particles in Aluminium alloy.

It has been observed that with the addition of reinforcements 3, 6 & 9 % AlN and 0.5 & 1 % Mg in base metal A356, ultimate tensile strength, impact strength and hardness were found maximum corresponding to 9% aluminium nitride (AIN) and 1% Magnesium (Mg).

Keywords: AlN, Mg, Stir Casting.

I. INTRODUCTION TO COMPOSITES

Materials are so important in the development of human civilization that the historians have identified early periods of civilization by the name of most significantly used material, e.g. Stone Age, Bronze Age. It is obvious that materials have affected and controlling a broad range of human activities through thousands of decades.

Classification of Engineering Materials

In general the materials are classified as:

- Metals and Alloys
- Ceramics, Glasses and Glass-ceramics
- Polymers (plastics), Thermoplastics and Thermo sets
- Semiconductors

Composites are not just useful in making things fly. Cars of the future must be safer, more economical, and more environmentally friendly, and composites could help achieve all three. Although composites such as GRP have been used in the manufacture of automobile parts since the 1950s, most cars are still made from steel. High temperature matrix composites are also making possible cleaner-burning, more fuel-efficient engines for both cars and trucks. Composites are increasingly used in place of metals Sin machine tools. Therefore conventional engineering materials are unable to meet this requirement of special properties. Hence there is a great need for materials with special properties with emergence of new technologies. Thus, emerged new class of engineering materials i.e. composites. A composite material is composed of reinforcement embedded in a matrix. The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix.

Classification of Composites

On the basis of matrix material or matrix phase composites are classified as Metal Matrix Composites (MMC), Ceramic Matrix Composites (CMC), Polymer Matrix Composites (PMC). Metal matrix composites (MMCs), like all composites consist of at least two chemically and physically distinct phases, suitably distributed to provide properties not obtainable with either of the individual phases. A metal matrix composite (MMC) combines into a single material a metallic base with a reinforcing constituent, which is usually non-metallic and is commonly a ceramic. By definition, MMC"s are produced by means of processes other than conventional metal alloying**, (Singh, 2012).**

Metal Matrix Composites

A composite material in which one constituent is a metal or alloy, the other constituent is embedded in this metal matrix and usually serves as reinforcement. Due to combination of metallic properties with ceramic properties, metal matrix composites show greater shear and compression strength with capabilities to perform at high temperature. Metal

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Matrix Composites (MMC's) are considered a group of advanced materials which represent low density, good tensile strength, high modulus of elasticity, low coefficient of thermal expansion, and good wear resistance, **(Baghchesar,2009).**

Conventional engineering materials are unable to meet this requirement of special properties like high strength and low density materials especially in aircraft applications. Hence there is a great need for materials with special properties with emergence of new technologies. Thus, emerged new class of engineering materials i.e. composites. Any multiphase material that is artificially made and exhibits a significant proportion of the properties of the constituent phases is composite. So increase stiffness, strength and dimensional stability, mechanical damping, chemical wear and corrosion resistance. Moreover to reduce permeability to gases and liquids to reduce cost & weight and decrease thermal expansion and to modify electrical properties composites are important, **(Ray and Kerketta, 2010).**

Aluminium metal matrix composite (AMMCs)
The most popular types of MMCs are aluminum alloys reinforcing with ceramic particles. These low-cost composites provide higher strength, stiffness and fatigue resistance with a minimal enhance in density over the base alloy. The major advantages of aluminum metal matrix composites (AMMCs) include greater strength, reduce density, improved high temperature properties, controlled thermal expansion coefficient, thermal/heat management, enhanced and tailored electrical performance, improved abrasion and wear resistance and improved damping capability. Reinforcement materials include carbides (e.g. SiC, B_4C), nitrides (e.g.Si_3N_4, AlN), oxides (e.g. Al_2O_3, SiO_2) as well as elemental materials (e.g. C, Si). The reinforcements may be in the form of continuous fibers, chopped fibers, whiskers, platelets or particulates**, (Singh, 2010).**Development of lightweight materials has provided the automotive industry with possibilities for vehicle weight reduction. Since fuel consumption relates directly to vehicle weight, reducing weight can improve the fuel usage and price-to-performance ratio. Aluminium metal matrix composites have attracted increasing attention due to their combined properties such as high specific strength, high stiffness, low thermal expansion coefficient and superior dimensional stability at elevated temperatures **(Shanmughasundaram et. al., 2011).** Aluminium alloys are widely used in aerospace and automobile industries due to their low density and good mechanical properties, better corrosion resistance and wear, low thermal coefficient of expansion as compared to conventional metals and alloys. The excellent mechanical properties of these materials and relatively low production cost make them a very attractive candidate for a variety of applications **(Ashutosh, 2007).**

II. LITERATURE REVIEW

Rajasekaran and Sampath, 2011 formed composite of aluminium alloy AA2219 reinforced with TiB_2 particles by the salt metal reaction technique. They found that the addition of TiB_2 particles results in increased mechanical properties, such as YS, UTS and hardness and the improvement in mechanical properties is correlated to the microstructure.
Dyzia and Oeleziona, 2008 obtain ultrafine aluminium nitride particles via in situ reaction between aluminium alloys (with addition of Mg) and nitrogens and the experiments were performed in a reaction chamber. Samples were heated at 1000°C and held at that temperature for 1 hour at the suitable gas pressure. Vaporization of Mg and indirect nitridation depend on gas pressure in reaction chamber was concluded. Using the in situ reaction in order to form AlN dispersion reinforcement in the aluminium alloy matrix seems possible but the control of the reaction was difficult.
Kheder et. al (2011), employed liquid state mixing technique for preparing composite of pure aluminium reinforced with SiC, MgO & Al_2O_3, and in this technique degasser was added to the content of the composite while mixing to minimize gas bubbles at the final cast. It was found that the addition of SiC, MgO & Al_2O_3 particulates into the matrix increased the yield strength, the ultimate tensile strength & the hardness, & decreased elongation (ductility) of the composites in comparison with those of the matrix. Increasing wt% of SiC, MgO & Al_2O_3 increased their strengthening effect but SiC was the most effective strengthening particulates, for higher strength, hardness, & grain size reduction but it decreases ductility & toughness**.**

III. STIR CASTING PROCESS

Stir casting process is a liquid state process which is used to fabricate MMCs conveniently. The function of a stirrer is to agitate liquids for speeding up reactions. Stirrer was designed for homogenous mixing of liquid, solution, viscous material and solid liquid. It is the important parameter of stir casting process. It is mainly required for vortex formation of uniform distribution of particles. There are generally two types of stirrer used i.e. either stirrer is adjusted 90^o from the shaft or it is bent at 45^o from the shaft.

IV. MMCs

For the preparation of AMC the matrix Aluminium alloy A356 is used as matrix for manufacturing of composites.
Reinforcements: Aluminium Nitride and Magnesium was used as a reinforcement material.

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V. SETUP

To heat the material at desired temperature pit furnanace is used. The pit furnace used for present work. A356 was melted in Graphite crucible by heating it at 750^{o}C for four hours in the furnace.

VI. EXPERIMENTATION

Aluminium alloy A356 is used as matrix for manufacturing of composites. Aluminium alloy was cut from the ingot size into smaller pieces by a power hacksaw in order to feed them into crucible properly. Aluminium Nitride and Magnesium was used as a reinforcement material. The compositions used for making composites are described in the below table.A sieve analysis is used to assess the particle size distribution of a granular material. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal, and soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. In this experiment AlN and Mg particles in powdered form is used. Stirring was carried out with the help of machine for about 15 minutes at stirring rate of 250 RPM.

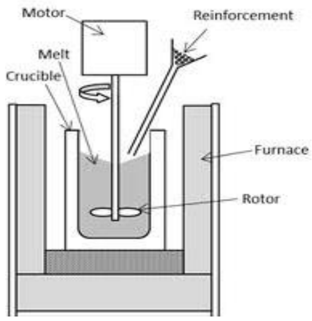


Fig:-Stir casting setup

The AlN particles and Mg were preheated at 1100oC respectively for three hours to make their surfaces oxidized. The furnace temperature was first raised above the liquid us temperature of Aluminium up to 750oC to melt the Al alloy completely and then cooled down just below the liquid us to keep the slurry in Semi solid state.

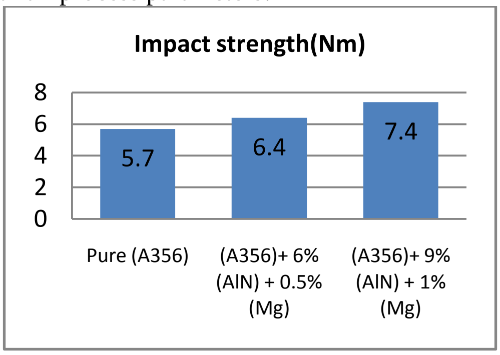
Table 1: Samples with all parameters

SAMPLE No.	COMPOSITION
S1	Pure (A356)
S3	Aluminium (A356)+ 6% (AlN) + 0.5%(Mg)
S7	Aluminium (A356)+ 9% (AlN) + 1%(Mg)

VII. RESULTS

7.1 Charpy Impact test

The Charpy impact test was performed on the Impact testing machine provided by the institute. This result is shown in the figure in the form of bar chart with all process parameters.



Graph shows that with the increase in AlN constituent Impact strength increases as compared to base metal. It is observed from figure that for a given percentage of AlN and Mg, higher value of impact strength is obtained with AlN. the increase is nominal which gives an indication that further increase in reinforcement may not have any considerable effect in impact strength. This increase and further saturation may be due to the complete dispersion of AlN and Mg into matrix and strong interfacial bonding between Aluminium alloy A356, AlN and Mg.

7.2 Ultimate Tensile Strength

Tensile test is used to assess the mechanical behavior of the composites and matrix alloy. Ultimate tensile strength (UTS), often shortened to tensile strength (TS) or ultimate strength, is the maximum stress that a material can withstand

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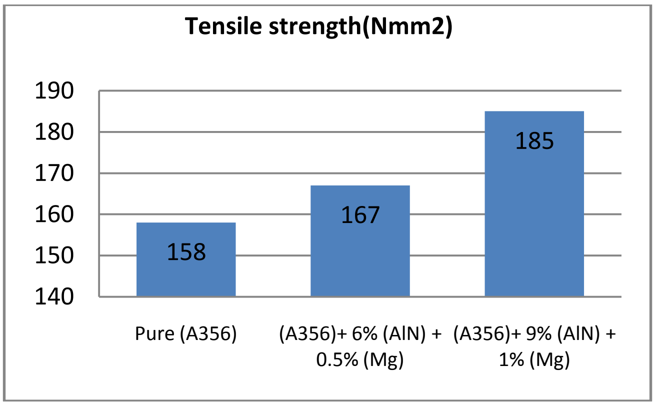
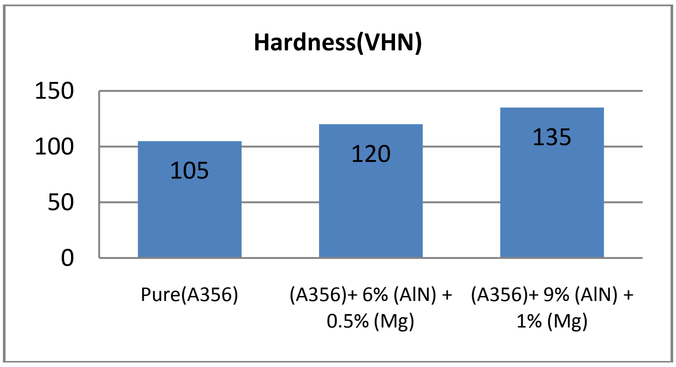
while being stretched or pulled before necking, which is when the specimen's cross-section starts to significantly contract. The samples for the tensile test were cut from the composite blanks with power hacksaw followed by the cutting on the shaper machine.



7.3 Vicker's Hardness Test

A Vicker's hardness tester was used for the hardness measurement. The specimens were prepared are metallographic finished with different grades of emery paper and subsequently rubbing with a keller solution. The hardness of composite samples was measured at 10 kgf load for 20 seconds for 25 to 30 times repeatedly on a sample. The result of Vicker's hardness test for A356 without reinforcement and the wt. % variation of different reinforcements AlN/Mg and A356 are shown in Table.



In results Vicker's hardness test base metal had 105 VHN. But with the addition 6 % of AlN and 0.5% Mg in base metal it increases the tensile strength 120 VHN and when added the 9 % of AlN and Mg 1% in base metal it increases the strength 135 VHN. It is observed that hardness of AlN reinforced composite is more than that of Mg reinforced composite. Hardness of composite depends on the hardness of the reinforcement and the matrix. From the graphs it is clear that, as the reinforcement percentage increases the micro hardness also increases. The reason for this may be either the proper mixing due to high viscosity of molten composites or good interfacial bonding between the particle matrix interfaces.

VIII. CONCLUSION & REMARKS

In this investigation, it is observed that with the use of different experimental techniques we were able to characterize some physical and mechanical properties of Stir casted Aluminium alloy A356 and its composites containing different weight fractions of AlN and Mg particles.

- Aluminium based composites with the addition of AlN and Mg was successfully achieved with stir casting process. It has been observed that stir formed Al alloy A356 with AlN/Mg reinforced composites is superior to base Al alloy Al6063 in terms of tensile strength, Impact strength and Hardness.
- Optical microstructures were analyzed to observe the presence and distribution of reinforcing particles in aluminium alloy. The investigations have revealed the presence AlN, Mg particles in alloy matrix in a uniformly distributed manner. The phases like AlN and Mg etc. have dispersed uniformly throughout in the MMC thus strengthening the resulting composite.

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