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SYNTHESIS AND CHARACTERIZATION OF ALUMINIUM-BARIUM NITRATE MATRIX COMPOSITES

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ABSTRACT:

In this experimental study the Aluminum based Metal Matrix Composites were synthesized by means of melt stir casting set up in an economic manner without sacrificing the potential properties of constituent materials. The industries are focusing their interest in composites containing light weight, low density with high strength and low cost reinforcements. .In this investigation, commercially available Aluminum 6063 T1 alloy is taken as matrix and special choice of a chemical agent barium nitrate as reinforcement material to fabricate the composites. Barium is a high chemical reactivity element with symbol Ba and atomic number 56.The present investigation has been focused on the utilization of dispersing particles of 2%,4%,6%,8% and 10% of wt into aluminum 6061 to produce composites by stir casting method to prepare the specimens. The wear and hardness characteristics of aluminum with barium nitrate composites are assessed with a computerized pin-on-disc machine and Rockwell hardness tester. The mechanical parameters such as ultimate tensile strength, elongation and breaking point are evaluated and found that increases with increase in addition of reinforcement up to 6% of weight and then slightly reduces. The Hardness values of the composition of Aluminum metal matrix increases from 61 RHN to 86 RHN due to incorporation of particles. The wear rate trend starts decreasing with increase in weight percentage of $Ba(No_3)_2$ in the matrix. The impact strength of the metal matrix composites increases with increase in addition of the reinforcement material. The maximum impact strength is 5.69 J is obtained at weight percentage of 10% of barium nitrate.

Key words: Al 6061 alloy, Particulate composites, stir casting, barium nitrate, Impact strength. Tensile strength.

1. INTRODUCTION:

Aluminium alloy 6063 T1 is an architectural alloy which is having medium strength and used for intricate extrusions. The metal is having good characteristics like surface finish, high corrosion resistance, good formability, low density, low weight to high strength, easy machining, superior malleability, recyclability, and good thermal and electrical conductivity. But the monolithic materials cannot be used for various applications due to their certain limitations. If the suitable particles are reinforced with aluminium alloy it can be converted into custom made materials and their derived properties like high specific strength and stiffness, increased wear resistance, and enhanced temperature performance together with better thermal and mechanical fatigue and creep resistance could be obtained for specific applications. [1]. The development in metal matrix composites led in applications area like traffic engineering, automotive industries especially in fiber reinforced pistons, hybrid reinforced crank cases, particle reinforced brake disc for light truck, passenger cars, motor cycles and rail mounted vehicles.[2] , The composites were fabricated by the metals, plastics and ceramics as matrix and the fibers, whiskers or particulates as reinforcements in order to achieve the benefits in aerospace, construction, automobile, sports, marine etc. [3]. The strength of the developed composite is based upon the bonding between the matrix and the reinforcement. The uniform distribution of particles in matrix can be achieved by economic casting methods like squeeze casting, compo casting and vortex method. Initially AMCs are developed for air plane and space industries then found extended application in automotive industries to develop the various parts of IC engines and power transfer system elements [4,5,6,17] Due to the light weight of composites increase the efficiency of engines and improving the fuel economy and reducing the unwanted emissions.[4,7]Aluminum based MMC are used in developing the Brake rotors, pistons and connecting rods in automobile industries.[8] The performance of composites is greatly depending upon the selection of reinforcement and process method and parameter associated with particles. [9]. The hardness values can be improved by the incorporation of hard particles into the aluminium alloy. By the addition of boron carbide with aluminium metal the hardness is increased.[10]. It is observed that the hardness of aluminium – Sic composites increase with the addition of Sic particles up to 30 % vol and decreases the percentage of elongation.[11]. The mechanical properties of composites can be increased by using stir casting processing route by increase of particles weight percentage and density can be increased by certain level and improvement in porosity. The harness and density is increased with the assistance of ultrasonic probe.[12].The hardness, ultimate tensile strength, yield strength of Al 2219-TiC composites is increased by the addition of TiC particles and reduction in ductility. The yield strength is increased upto 68% by the addition of TiC particles when comparing with unreinforced alloy.[13,15]. The reinforcement of beryl and SiC into Al7075 improves the mechanical and tribological behavior.[14].The impact strength can be increased upto 30% by the addition of 20% wt SiC particles in metal matrix composites. The exploring properties like good fatigue performance ,high wear and corrosion resistance expected by aero space industry can be met by addition of silicon particles into AMC.[15].The garnet particles incorporated with zinc aluminum alloy ZA27,to improve the wear resistance of the composites. The wear loss of composites in increased by increasing the speed and applied load.[16].The addition of graphite particles in metal matrix composites led to act as lubricant and gave positive results in improvement of friction and wear resistance.[18,19]. The wear rate of MMCs varies with the sliding distance, load and speed. [20]. The wear rate got reduced with the addition of hard particles Al2O3, SiC and cerium oxide as reinforcements into Al 6061 alloy by varying the loads and sliding velocities.[21].

2. PROPERTIES OF MATERIALS.

2.1 Properties of Matrix.

Aluminum is the non magnetic material which possess light weight, low density, good tensile strength of between 70-700 MPa, Increased strength at lower temperatures, large coefficient of linear expansion, aesy to adopt various machining processes, excellent conductivity of heat and electricity, good reflectivity etc. The properties of aluminium are shown in Table 2.1. The constituent elements of Al 6063 alloy are depicted in the Table 2.2.

Atomic Weight (g/mol)	26.98
Crystal Structure	FCC
Melting Point (°C)	660.2
Boiling Point (°C)	2480
Electrical Resistivity at 20°C (&#937.cm)	2.69
Density (g/cm^3)	2.6898
Modulus of Elasticity (GPa)	68.3
Poissons Ratio	0.34

Table 2.1 : Properties of Aluminium

Chemical Element	Percentage %
Mn	0.0 - 0.10
Fe	0.0 - 0.35
Mg	0.45 - 0.90
Si	0.20 - 0.60
Zn	0.0 - 0.10
Ti	0.0 - 0.10
Cr	0.0 - 0.10
Cu	0.0 - 0.10
Others	0.0 - 0.15
Aluminium	Balance

Table 2.2. Constituents Of Al 6063.

2.2 Properties of reinforcement:

Barium nitrate is a white crystalline power and may lead to fire when it is in contact with combustible material. If the large quantities are added with fire then the combustible material is finely divided and results in explosion. it is a hazardous material so that the researchers should take safety precautions in handling of preparation of test specimens include processing and usage. Inhalation or direct contact with eyes or skin of this material causes severe irritation. It decomposes on heating and producing nitrogen oxides. It reacts with powdered metals and generates fire and explosion hazards. The properties of Barium nitrate are shown in Table 2.3..

Molecular formula	$Ba(NO_3)_2$
Molar mass	261.337 g/mol
Density	3.24 g/cm^3
Melting point	592 °C (decomp.)
Crystal structure	cubic
Appearance	white, lustrous crystals
Solubility in water	4.95g/100 ml (0 °C) 10.5g/100ml (25 °C) 34.4g/100ml(100 C)

Table 2.3. Properties of Barium Nitrate.

3. EXPERIMENTAL METHODLOGY:

3.1 MELT FURNACE.

Melt stir casting method is a liquid state method for the fabrication of metal matrix composites. From the various researches it is found that most economical method for the various applications. First the crucible is cleaned for ready to use with the removal of unwanted particles inside the furnace. Aluminium is placed in the crucible and it is heated up to elevated temperature of 600C to 700 C. The solid is melted with addition of heat by means of coke fired furnace.

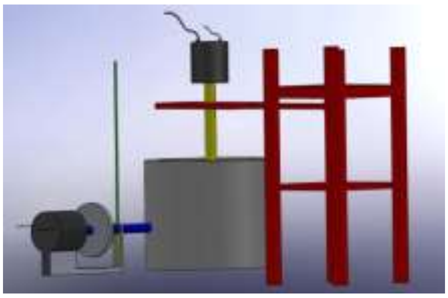

Fig 3.1 Schematic representation of stir setup

The heat is controlled by the value placed in between the air blower and furnace. Once it is melted then the particles are added with molten metal. In order to improve the uniform distribution of particles dispersed with metal matrix the stirrer is used to hold for 10 min. It is oblivious that the impeller of the stirrer should be designed to improve the wettability and interfacial bonding between the matrix and reinforcement to avoid the porosity. The stirrer is maintained with a speed of 600 rpm. Then the composite is poured in the cavity of the die and allowed to solidification. First the pure alloy specimen is prepared then the metal with various proportions of barium is prepared as indicated in the table 3.1. Then

Fig 3.2 melt stir cast set-up

The samples are machined according to their requirements of various testing for evaluation.

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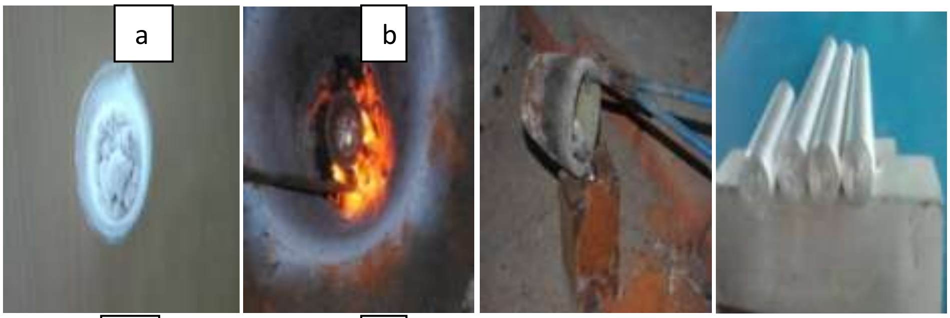


Fig 3.3 c arium powder, b.) d ting, c) pouring to mould, d) after machining.

SPECIMEN	% WT OF Al	% WT OF $Ba(No_3)_2$
1	98	2
2	96	4
3	94	6
4	92	8
5	90	10

Table 3.1 Prepared specimens.

3.2 HARDNESS TESTING

A sample of size of 45mm in length and 9 mm in diameter were prepared for hardness testing. The surface of the pin samples were polished by using emery paper with grit size 80 to ensure metallographic finish. Composite particles in aluminum matrix gave results in reasonable increase in hardness. Load used on Rockwell hardness tester was 200 gm at 100 X optical zoom with dwell time 20 second for each sample.

Fig 3.4 Hardness tester

The result of Rockwell hardness test for alloy without reinforcement and wt % variation of different reinforcements (Barium Nitrate) in Aluminum alloy are given in fig The hardness was measured with help

of hardness tester. A hardness number is then calculated using the test load, the impression length, and a shape factor for the indenter type.

3.3 TENSILE TEST

The tensile strength of a material is the maximum amount of tensile stress that it can be subjected to before failure. This is an important concept in engineering, especially in the fields of material science, mechanical engineering and structural engineering. Some materials will break sharply, without plastic deformation, what is called a brittle failure. Others, which are more ductile, including most metals, will experience some plastic deformation and possibly necking before fracture. The highest point of the stress-strain curve is the Ultimate Tensile strength.

Fig 3.6 Tensile test samples

Fig 3.5, Cylindrical samples for test.

3.3 IMPACT TESTING

The impact strength is the ability of a material to absorb shock and impact energy without breaking. The impact strength is calculated as the ratio of impact absorption to test specimen cross-section. Toughness is mainly dependent upon temperature and the shape of the test specimen.

Generally an impact is a high force or shock applied over a short time period when two or more bodies collide. Such a force or acceleration usually has a greater effect than a lower force applied over a proportionally longer time period of time. The effect depends critically on the relative velocity of the bodies to one another.

Fig 3.7 a) Impact tester , b.) specimen after test.

3.4 WEAR TEST

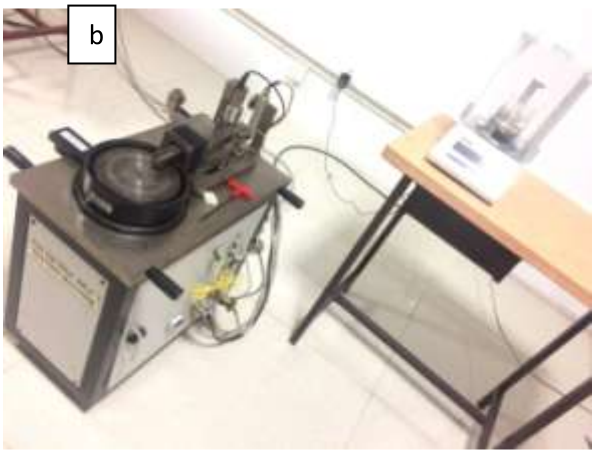
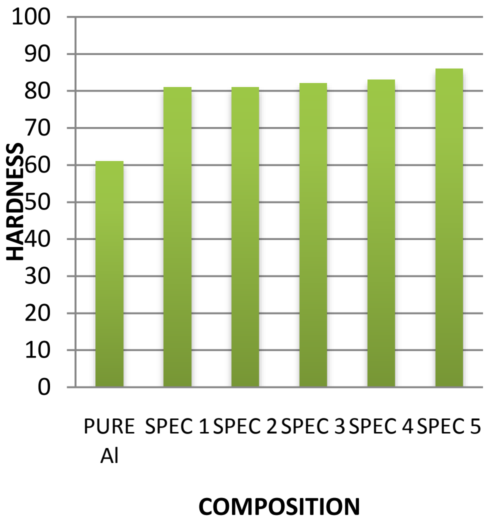


Fig 3.8 Pin on Disc machine.

Dry sliding wear test for different number of specimen was conducted by using computerized pin on disc machine, The pin samples were 45mm in length and 9 mm in diameter. The pin was held against the counter face of a rotating disc with wear track diameter 60mm. The pin was loaded against the disc through a dead weight loading system. The wear test for all specimens were conducted under normal loads of 2 kg and fixed sliding velocity of 1.5 m/s. wear tests were carried out for a total sliding distance of approximately 2900 m under similar condition as discussed above. The surface of the pin sample was slides using emery paper with grit size 80. Prior to testing the samples are ensured to ensure effective conduct of fresh and flat surface with the steel disc. The samples and the wear track were cleaned with acetone and weighted prior to and after each test**.**

4. RESULTS AND DISCUSSION.



4.1 HARDNESS MEASUREMENT.

Fig 4.1 Hardness value for various specimens.

The addition of partice acts as a barrier to the movement of dislocations and thereby increases hardness of the composite. The values are 61 RHN, 80 RHN, 81RHN, 82RHN, 83RHN and 86RHN

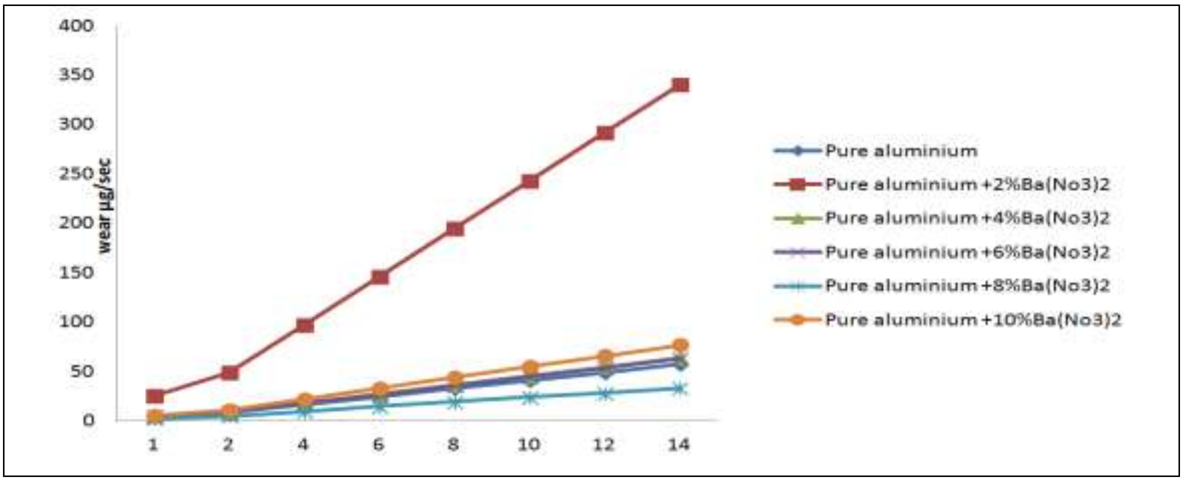


Fig 4.2 wear rate for various specimens.

Respectively for the applied load 100Kg. Al +10% $Ba(No_3)_2$ composite has the maximum value of 86 RHN. Thus addition of particles gave improvement in expected results.

4.2 TENSILE TEST

Specimen	Elongation mm	Breaking Point	UTS MPa

		KN	
Pure Al	17	12	76.33
Al + 2% of $Ba(No_3)_2$	19	12.25	77.95
Al + 4% of$Ba(No_3)_2$	22	12.5	79.25
Al + 6% of$Ba(No_3)_2$	23	12.7	81.2
Al +8% of $Ba(No_3)_2$	15	11.5	71.45
Al + 10% off$Ba(No_3)_2$	11	10.75	65.96

Tab 4.1 Tensile result.

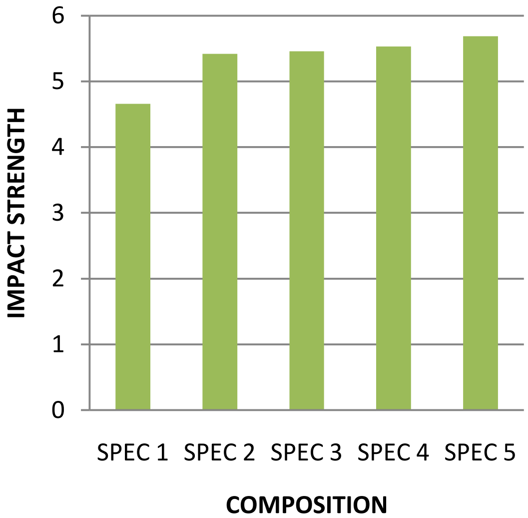
The specimens are machined to the standard size for tensile testing. The elongation, breaking strength and ultimate strength of the prepared specimens are determined by using the universal testing machine. The tabular column 4.1 show that various parameter such as ultimate tensile strength, elongation and breaking point increases with increase in addition of reinforcement upto 6% of weight and then slightly reduces. This is due to phase aggregation between the matrix and reinforcement that weakens the structure and tensile properties.

4.3 WEAR TEST:

The improvement in wear resistance is due to the hardness constituent present in barium nitrate particles The wear rate for the specimen is given in the Fig 4.2.It reveal that addition of 8% $Ba(No_3)_2$ particles to the aluminum melt significantly increase its abrasive wear resistance

4.3 IMPACT CHARACTERISTICS

The specimen prepared is machined to the standard size for impact testing. The impact strength of the



prepared specimen is determined using the impact ester.

5 . CONCLUSIONS.

The metal matrix composite is successfully prepared and mechanical properties such as hardness, elongation ,breaking point, ultimate tensile strength , impact strength and wear rate are determined for all the specimens, Aluminum based metal matrix composite have been successfully fabricated by using stir casting technique with fairly uniform distribution of barium nitrate particulates, For synthesizing of composite by stir casting process, stirrer design and stirrer position, stirrer speed, and time, particles preheating temperature, particles incorporation rate are considered. In the studied five combinations of Al 6063+ 2% $Ba(NO_3)_2$, Al 6063+ 4% $Ba(NO_3)_2$, Al 6063+ 6% $Ba(NO_3)_2$, Al 6063+ 8% $Ba(NO_3)_2$, Al 6063+ 10% $Ba(NO_3)_2$ wear and friction properties greatly depends on the particles of $Ba(NO_3)_2$. The results confirmed that as follows.

- Hardness value of AMC increases after the addition of % $Ba(NO_3)_2$ particles in the matrix.
- Dispersion of % $Ba(NO_3)_2$ particles in aluminum matrix also improves the wear resistance of the composites.
- tensile strength, ultimate tensile strength shows elongation and breaking point increases with increase in addition of reinforcement upto 6% of weight reached the maximum values.
- It is found that wear rate tends to decrease with increasing particles wt.percentage (2-10%), which confirms that $Ba(NO_3)_2$ addition is beneficial for reducing the wear rate of MMCs.
- For 8% % $Ba(NO_3)_2$ wear rate is increase compared to the 10% % $Ba(NO_3)_2$ Because stirrer was not rotated properly, thereby poor interfacial bonding takes place between the % $Ba(NO_3)_2$ and Al alloy.
- The impact strength increase with addition of particles and maximum impact strength is 5.69 J and is obtained at weight percentage of 10% of barium nitrate.

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