High Strength Alloy Preparation with Metal Matrix Composites for Structural Evaluation and Aerospace Applications

S Sapthagiri[1], Dr K Jayathirtha Rao[2]
[1]Associate Professor, Department of Mechanical Engineering, Guru Nanak Institutions Technical Campus, Hyderabad, India
2. Director (Retd) Environmental Test facility, RCI, Hyderabad, India.

Abstract — *Composites are a mixture of two or more distinct components. One component is called the matrix (continuous phase) such as ceramic, metallic or polymeric, while the other distinct phase is interspersed within this matrix, lending different and improved properties to the material as a whole. The properties of the composite have to be different from those of the individual components that make up the composite. The process of making this material is by methods such as mixing; for example, when ceramic particles are well blended into a metal matrix leads to a ceramic–metal composite. In the present work the matrix composites are prepared as aluminium 6061, 6062, 2021 as constant and it is reinforced with Ni, TiB_2, fly ash and husk ash. The whole process of fabrication and cast taken in stir casting methods with 600 rpm of stirrer. The composite is casted in block and the specimens prepared for microstructure analysis.*

Metal matrix composites produced by stir casting method have more advantages compare with other methods. Experiments were conducted by varying weight fraction of TiB_2, (4%, 8% and 12%), and Ni (2%, 4%, 6%) while keeping all other parameters constant. The wear mechanism was studied through worn surface and wear analysis as well as microscopic examination of the wear tracks. This study revealed that the addition of TiB_2, with Ni improves the wear resistance of aluminium composites. The results showed that increasing the mechanical properties, such as tensile strength, wear resistance and hardness caused by the percentage of TiB_2, and Ni present in the samples when compared to the only addition of TiB_2. The micro structural properties are observed for internal bonding ability between the atoms.

Key words: *MMC preparation, stir cast methods, sample preparation of high strength aluminium alloys, SEM and OM analysis.*

I. INTRODUCTION

Aluminium alloys became the baseline for aircraft structures after corrosion issues were overcome in 1927. Initial advancement concentrated on the refining of aluminium alloys and the development of new materials, such as composite systems which consists of two or more phases on the macroscopic scale. The mechanical performance and properties of the combined system are superior to those of the constituent materials. These materials were first applied on civil aircraft with the Boeing 707 in 1957, with approximately $20m^2$ of polymeric composites in mainly tertiary roles, such as cabin structures. In present work fabrication of MMC's with different alloys are studied by stir casting process. The results obtained are analysed and the conclusions are made with comparison of before researches.

II. METAL MATRIX COMPOSITE

Metal matrix composites in general, consist of at least two components, one is the metal matrix and the second component is reinforcement. The matrix is defined as a metal in all cases, but a pure metal is rarely used as the matrix. It is generally an alloy. In the productivity of the composite the matrix and the reinforcement are mixed together. In recent years, the development of metal matrix composite (MMCs) has been receiving worldwide attention on account of their superior strength and stiffness in addition to high wear resistance and creep resistance comparison to their corresponding wrought alloys. The ductile matrix permits the blunting of cracks and stress concentrations by plastic deformation and provides a material with improved fracture toughness.

Cast composites, where the volume and shape of phases is governed by phase diagrams, i.e. Cast iron and Aluminium-silicon alloys have been produced by foundries for a long time. The modern composites differ in the sense that any selected volume, shape and size of reinforcement can be introduced into the matrix. The modern composites are non-equilibrium mixtures of metals and ceramics where there are no thermodynamic restrictions on the relative volume percentages, shapes and size of ceramic phases.

III. PROBLEM STATEMENT

The high toughness and impact strength of metals and alloys such as aluminium, titanium, magnesium and nickel-chromium alloys which undergo plastic deformation under impact is of interest in many dynamic structural applications of metallic composites. These materials have also been strengthened considerably by means of various strengthened principles (like grain boundary strengthening, cold working, solid solution strengthening, etc.) to improve their properties. But these approaches are often found to affect the toughness and durability at elevated temperatures and/or under dynamic service conditions. One of the important objectives of metal matrix composites, therefore, is to develop a material with a judicious combination of toughness and stiffness so as to decrease the sensitivity to cracks and flaws and at the same time increase the static and dynamic properties.

IV. METHODOLOGY

PREPARATION OF RAW MATERIALS

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STIR CASTING EQUIPMENT

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PREPARATION OF MMC'S BY WEIGHT VOLUME RATIO

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MELTING AND CASTING

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MACHINING SAMPLES FOR TESTING WITH SEM AND OM ANALYSIS

V. STIR CASTING PROCESS OF APPLICATION

Aluminium-matrix composites are not a single material but a family of materials whose stiffness, strength, density, thermal and electrical properties can be tailored. The matrix alloy, reinforcement material, volume and shape of the reinforcement, location of the reinforcement and fabrication method can all be varied to achieve required properties. The aim involved in designing metal matrix composite materials is to combine the desirable attributes of metals and ceramics.

In stir casting process, the reinforcing phases are distributed into molten matrix by mechanical stirring. Stir casting of metal matrix composites was initiated in 1968, when S. Ray introduced alumina particles into aluminium melt by stirring molten aluminium alloys containing the ceramic powders. Mechanical stirring in the furnace is a key element of this process. The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mould casting, or sand casting. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement.

Fig. 1 Ti-B_2 particles – Raw Material

Fig. 2 Nickel-pure slice – Raw Material

VI. EXPERIMENTAL WORK OF MIXING COMPOSITES

Weight-in-volume (w/v) ratios**:** When we describe a concentration as a percentage without specifying the type of formula, we imply that the solution is to be made using the weight-in-volume (w/v) method. As with w/w, weight-in-volume is a simple type of formula for describing the preparation of a solution of solid material in a liquid solvent. This method can be used to describe any solution, but is commonly used for simple saline solutions and when the formula weight of the solute is unknown, variable, or irrelevant, which is often the case with complex dyes, enzymes or other proteins. Solutions that require materials from natural sources are often prepared w/v because the molecular formula of the substance is unknown and/or because the substance cannot be described by a single formula. Total Volume of the Composite: 16cm X 4cm X 3cm =192 cm^2

Table 1 Constituents of Metal Matrix Composite (Al 6061 +TiB_2 + Ni + Fly ash) mass calculations.

S. No	Composition of Material	% by Vol.	Vol. Occupied (cm^3)	Density (gm/cm^3)	Mass (gm)
1	Al 6061	77%	147.84	2.7	399.17
2	TiB_2	8%	15.36	4.52	69.43
3	Ni	2%	3.84	8.908	34.21
4	Flyash	4%	7.68	0.99	7.60
5	Al_2O_3	3%	5.76	3.97	22.87
6	Mg	2%	3.84	1.47	5.64
7	Hexa Chloro methene	4%	7.68	1.2	9.22

Table 2 Constituents of Metal Matrix Composite (Al 2021 + TiB2 + Ni + Husk) mass calculations.

S. No	Composition of Material	% by Vol.	Vol. Occupied (cm^3)	Density (gm/cm^3)	Mass (gm)
1	Al 2021	74%	142.08	2.74	389.30
2	TiB_2	6%	11.52	4.52	52.07
3	Ni	4%	7.68	8.908	68.41
4	Husk	7%	13.44	1.02	13.71
5	Al_2O_3	3%	5.76	3.97	22.87
6	Mg	2%	3.84	1.47	5.64
7	Hexa Chloro methene	4%	7.68	1.2	9.22

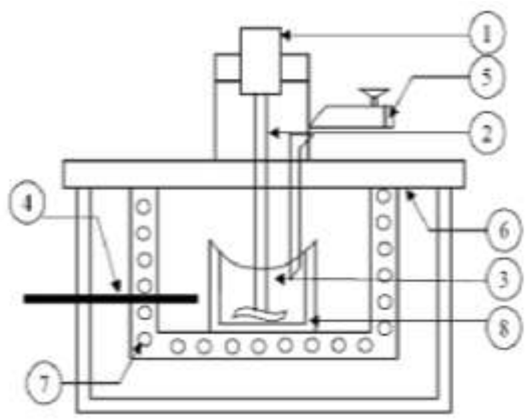
Table 3 Constituents of Metal Matrix Composite (Al 6062 + TiB2 + Ni) mass calculations.

S. No	Composition of Material	% by Vol.	Vol. Occupied (cm^3)	Density (gm/cm^3)	Mass (gm)
1	Al 6062	73%	140.16	2.71	379.83
2	TiB_2	12%	23.04	4.52	104.14
3	Ni	6%	11.52	8.908	102.62
4	Al_2O_3	3%	5.76	3.97	22.87
5	Mg	2%	3.84	1.47	5.64
6	Hexa Chloro methene	4%	7.68	1.2	9.22

VII. STIR CASTING PROCESS

The systematic procedure involved on the stir casting technique is as below:

1. Heat the 3 kg of Al6061 alloy pieces in the furnace and it will get melt at 750^{0}C. and care is taken to achieve 100% melting.
2. Slag is removed using scum powder to avoid the bad quality of casting.
3. Measure the 8% of TiB_2 has been added and is pre heated to 650^{0}C-700^{0}C and maintained at the same temperature for about 20 minutes to remove the moisture content.
4. Measure the 3% of alumina (Al_2O_3) by weight and is also preheated.
5. Take less than 5% weight of solid dry hexachloroethane tablets to degas the molten metal at a temperature of 780°C.
6. Measure approx. 250grams of nickel by weight and pre heated up to liquid form at temparature1450°C.
7. Now start stirring the molten metal to create a vortex. Add slowly pre heated TiB2 and alumina to the molten metal with temperature maintained at more than740°C.
8. After first matrix got stirred then the nickel liquid poured in to the liquid state of before matrix.
9. Add magnesium about more than 2% of weight to ensure good wettability with continuous stirring at a speed of 350-500 rpm to a time of 6-8 minutes.
10. At the same time preheat the mould to avoid shrinkage of casting material.
11. Then the melted matrix with the reinforced particles is poured into the preheated moulds 160x40x30 mm size and the pouring temperature should be maintained at 680°C.
12. Finally withdraw the specimens from the mould after 3 to 4 hours. And confirm the solidification of casting before removing from the mould.



1. Motor 2. Shaft 3. Molten aluminium 4. Thermocouple 5. Particle injection chamber 6. Insulation hard board 7. Furnace 8. Graphite crucible

Fig 3. Stir casting equipment

VIII. RESULTS AND DISCUSSIONS

The figure Nos. 4, 5, and 6 are shows the three different types of Metal matrix composites fabricated by stir casting process.

Fig 4 Raw material of Metal Matrix Composite: Al 6061 +TiB_2 + Ni + Fly ash material

Fig 5 Raw material of Metal Matrix Composite: Al 6062 +TiB_2 + Ni material

Fig 6 Raw material of Metal Matrix Composite: Al 2021 +TiB_2 + Ni + Husk material

The figure Nos. 7 to 12 shows scanning electron microscope (SEM) images of three different samples are analysed at different magnification

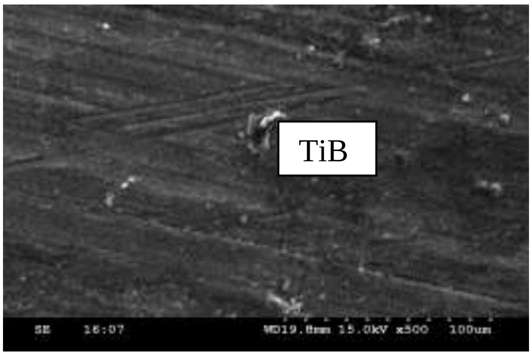


Fig 7 shows the sample 1 at Magnification=500

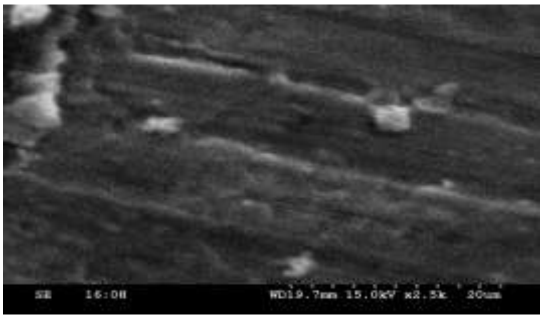


Fig 8 shows the sample 1 at Magnification=2500

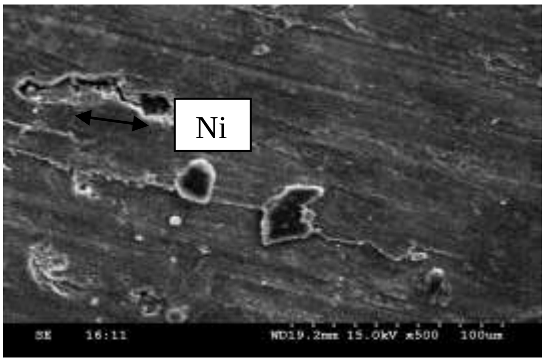


Fig 9 shows the sample 2 at Magnification=500

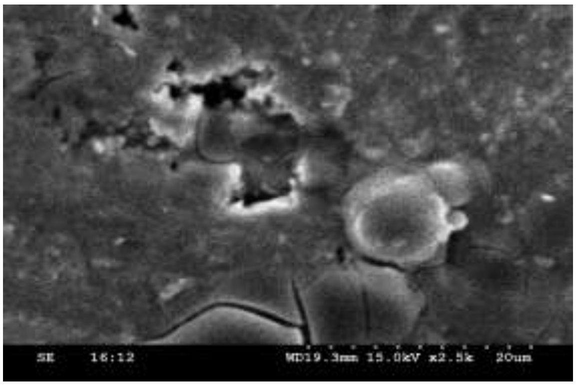


Fig 10 shows the sample 2 at Magnification=2500

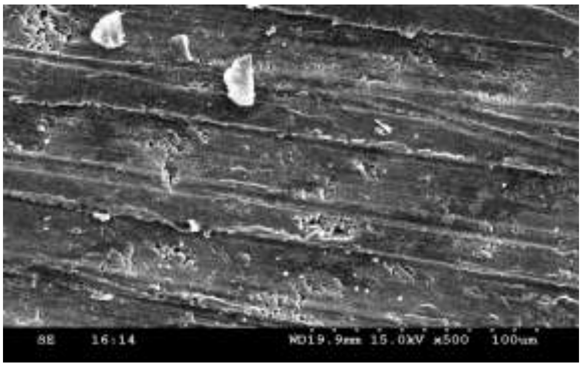


Fig 11 shows the sample 3 at Magnification=500

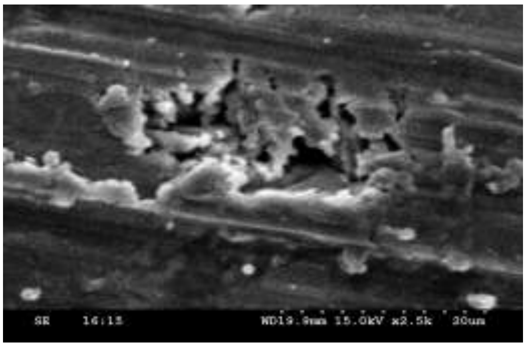


Fig 12 shows the sample 3 at Magnification=2500

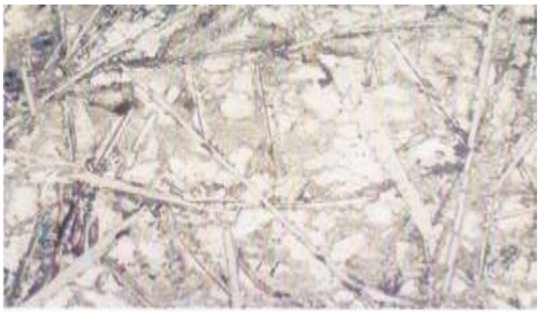


Fig 13 Sample 1 surface image layers at 300x

Fig 14 : Sample 2 surface image layers at 300x

Fig 15 Sample 3 surface image layers at 300x

IX. CONCLUSIONS

The present critical review substantiates that numerous investigations have focused promising future can be envisioned. Within the framework of the objectives established for this review, the relevant conclusions were drawn. The structure, properties and purity of obtained from Nickel are quite sensitive to the chosen extraction methods. Depending on the selected temperature or chemical treatments, the products can range from amorphous to different crystalline phases. The metallic elements Mg, Ca, Al at comparatively lower temperatures and form mixtures of condensed phase products.

1. Strength increased with the increased amount of nickel added sample.
2. Machining become hard with samples 2 & 3 because of medium ratio of TiB_2 and Ni.
3. Nickel added as layers because of high melting point when compared to TiB_2.
4. Less percentage of Nickel given strength and machinability to the matrix.

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