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Fabrication and Mechanical Testing of MMC Formed by Reinforcement of SIO_2, Graphite& Fly Ash in Aluminium LM06

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Abstract**—** Metal Matrix Composites (MMCs) have evoked a keen interest in recent times for potential applications in aerospace and automotive industries owing to their superior strength to weight ratio and high temperature resistance. In the present study a modest attempt has been made to develop aluminium 6061 alloy reinforced with aluminium – matrix titanium aluminide composite formed in situ from aluminium, titanium dioxide and sodium hexafluoroaluminate with an objective to develop a conventional low cost method of producing MMCs and to obtain homogenous dispersion of ceramic material. An aluminium-matrix SiO2, graphite, Fly Ash -Particle composite exhibiting high high hardness was made by a new in situ method involving reactions between Al Lm6, Sio2 and Fly ash , which were subjected to stir casting at 900^0c. Experiments have been conducted by varying weight fraction of Al Lm6, Sio2 and Fly ash, while keeping all other parameters constant.

Index Terms**— Al Lm6, Fly Ash, silicon dioxide,Graphite, in situ method, Stir casting.**

I. Introduction

A material composite can be defined as a material consisting of two or more physically and chemically distinct parts, suitably arranged, having different properties respect to those of the each constituent parts.This is a very large family of materials whose purpose is to obtain certain property resulting by the combination of the two constituents (matrix and reinforcement), in order to obtain the mechanical characteristics (and sometimes thermal) higher than that it is possible to have with their corresponding matrices. For this reason, about the wide range of new developed materials, composites are certainly those able to comply better the needs of most technologically advanced industries.

In a material composite, when the matrix is a metal or an its alloy, we have a "Metal Matrix Composite (MMC = Metal Matrix Composite). In general we can say that metal matrix composites utilize at the same time the properties of the matrix (light weight, good thermal conductivity, ductility) and of the reinforcement, usually ceramic (high stiffness, high wear resistance, low coefficient of thermal expansion). By this way it is possible to obtain a material characterized, if compared to the basic metal component, by high values of specific strength, stiffness, wear resistance, fatigue resistance and creep, corrosion resistance incertain aggressive environments.

A basic classification, about the technological methods for MMCs, takes account of the state where the constituents during the primary cycle of production:

- Solid state processing
- Liquid metal processing
- Vapor state processing
- Plasma/spray deposition
- "In situ" processing

II.SELECTION OF MATERIALS

Base metals : Aluminium Lm6 is the base metal of our metal matrix composite.

Ceramics : silicon dioxide(SIO_2),Graphite, Fly Ash are the selected ceramics for reinforcement in metal matrix.

Aluminium LM6

- Aluminium alloy LM6 is one of the most extensively used of the LM6 series aluminium alloys.
- It is a versatile heat treatable extruded alloy with medium to high strength capabilities.
- LM6 is a precipitation hardening aluminium alloy, containing magnesium and silicon as its major alloying elements.

TABLE.1

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Chemical Composition (%)	Amount (wt. %)
Copper	0.1max
Zinc	0.1max
Magnesium	0.1max
Lead	0.1max
Ssilicon	0.1max
Tin	0.05 max
Iron	0.6 max
Titanium	0.6 max
Maganese	0.5 max
Aluminium	remainder

Typical properties of aluminium alloy Lm 6 include

- Medium to high strength
- Good toughness & surface finish
- Excellent corrosion resistance to atmospheric conditions
- Good corrosion resistance to sea water Can be anodized

Mechanical Properties LM6-M

- 0.2% Proof Stress (N/mm2) 60-70
- Tensile Strength (N/mm2) 160-190
- Wear (%) 5
- Impact Resistance Izod (Nm) 6.0
- Brinell Hardness 50-55 BHN

Physical Properties

- Density: 2.67 g/cm3
- Melting Point: Approx 580°C
- Modulus of Elasticity: 70-80 GPa
- Poissons Ratio: 0.33

Thermal Properties

- Co-Efficient of Thermal Expansion (20-100°C): 23.5×10^{-6} m/m °C
- Thermal Conductivity: 173 W/m K

Electrical Properties

- Electrical Resistivity: $3.7 – 4.0 \times 10^{-6}$ Ω.cm

Application

Having high resistance to corrosion and excellent castability, aluminium LM6 is suitable for most marine 'on deck' castings, water-cooled manifolds and jackets, motor car and road transport fittings etc.. LM6 is equally adaptable for sand casting and aluminium die casting (gravity die casting and pressure die casting). It has excellent resistance to corrosion in marine environments, possesses excellent ductility, but is of medium strength and is not heat treated.

Ceramics

Ceramics are generally compounds between metallic and nonmetallic elements and include such compounds as oxides, nitrides, and carbides. Typically they are insulating and resistant to high temperatures and harsh environments. Ceramics exhibit good strength under compression and virtually no ductility under tension.

GRAPHITE: The effect of graphite powder with respect to the performance of final Plastic Metallurgy parts is not fully understood yet. The same is valid for the interaction of graphite with other additives, especially lubricants, which plays a major role for flow ability and agglomeration. For the latter, the selection of raw materials and the many processing options available, result in a wide range of property variation.

Fly Ash

Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash.

III.METHODOLOGY

In situ method is selected of our metal matrix composite.

“In situ” Method:

The in situ production route of metal matrix composites is highly interesting because it avoids the need for intermediate formation of the reinforcement. Indeed, in this process the reinforcements are formed by reaction in situ in the metal matrix in a single step. A further advantage is that the interfaces between the reinforcement and the matrix are very clean, enabling better wetting and bonding between them and the matrix (no gas adsorption, no oxidation, and no other detrimental interface reactions). Also costs are reduced, as the handling of the fine particle reinforcement phases are eliminated.

Ingot Metallurgy (IM)

This production technique consists of two consequential steps: the first consists of a dispersion process, during which the element that forms the reinforcement ceramic is incorporated, at random and not in default, in the molten metal matrix. Usually the system is mixed to facilitate the dispersion of particles. The second step consists of a conventional casting process of liquid enriched with reinforcement, derived from the aforesaid first step. The cast produced by this way is then usually subjected to mechanical processing. This system is now less expensive to produce in situ composites with titanium matrix and generally discontinuously reinforced MMCs, leading, among other things, to produce a wealth of different materials.

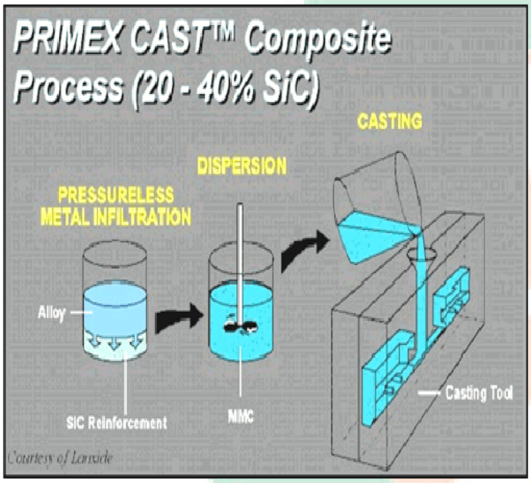

Figure1.1 IM (Ingot Metallurgy) Technology

Synthesis by chemical reaction

In the case of composites obtained by in situ reaction between a liquid and other phases, as a gas or **Synthesis by chemical reaction** solid, the basic mechanisms are the same chemical reaction. By the production in situ techniques that provide a chemical reaction, are obtained within the matrix metal, ceramic reinforcing phases very fine and stable in thermodynamic terms. One of the most important production technologies that are based on the principle of synthesis through chemical reactions regard the process for “exothermic dispersion” (XD).

The process, patented by Martin Marietta Corporation, provides high temperatures heating of various mixtures so as to activate an exothermic reaction, that diffuse by independent and very fast way, allowing to create very fine dispersion of some pottery stable phases. In particular, mixtures of metal and ceramic powders are heated to a temperature of reaction (that is usually above the melting point of the considered metal) so as to generate a new ceramic phase into the matrix metal form.

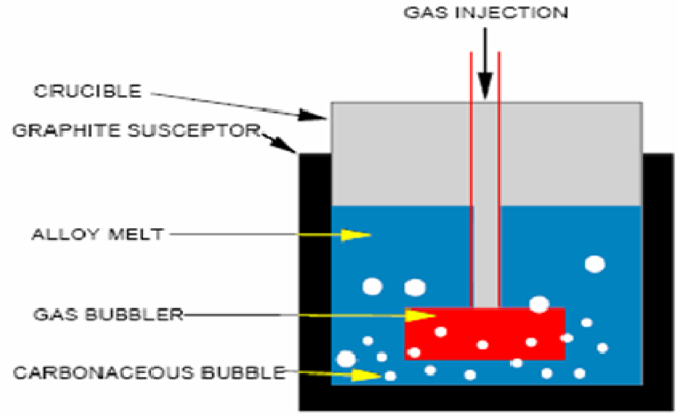

Figure 1.2 Technology of synthesis by chemical reaction

Stir Casting

This is a primary process of composite production whereby the reinforcement ingredient is incorporated into the molten metal by stirring. A variant very applied of the Stir Casting is called "Compocasting" (or "Rheocasting), in which the metal is semi-solid. In particular the reinforcing ingredient are incorporated into vigorously agitated partially solid metal slurries. The discontinuous ceramic phase is mechanically entrapped between the pro-eutectic phase present in the alloy, which is held between its liquidus and solidus temperatures. This semi solid process allows near net shape fabrication since deformation resistance is considerably reduced due to the semi- fused state of the composite slurry.Techniques is adopted such as processes involving infiltration by centrifuge, ultrasound and magnetic electromagnetic even having all the essential purpose of obtaining a composite reinforced by the distribution of more homogeneous as possible.

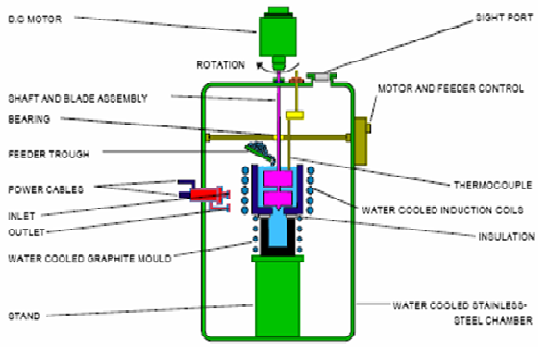

Figure 1.3 Compo-casting technology

IV.FABRICATION

STIR CASTING

Most of the methods used for the manufacture of metal matrix composites are expensive and require skilled complicated operations. The liquid phase routes are more similar to conventional casting process and are economical for the manufacture of metal matrix composites. In addition, these casting processes enable to fabricate large complex near net

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shaped components. Hence liquid phase route (Stir casting) is chosen in this work.

Calculation for stir casting process

Diameter of the work piece, d = 25mm

Length of the work piece, L = 110mm

$$\text{Die volume} = \frac{\pi}{4} * d^2 * L = \frac{\pi}{4} * 25^2 * 110$$

$$V = 53968.75 mm^3$$

Density of aluminium Lm 6 = $2.65 * 10^{-6}$ Kg/mm^3

Die capacity = Die volume * Density of aluminium Lm 6

$= 53968.75 * 2.6 * 10^{-6}$

= .0.1403 Kg = 140.31 grams

TABLE.4 Orthogonal L9 array

No of level = 3 No of parameter = 3

Experiment	Graphite	Fly ash	SiO2
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Hybrid ratio of the reinforcement with Aluminium casting alloy Lm 6

TABLE.5

		LEVELS		
	Material	**Level 1**	**Level 2**	**Level 3**
FACTORS	Graphite(%)	15	30	45
	Fly Ash(%)	15	30	45
	SiO_2(grams)	15	30	45

V. PREPARATION OF SAMPLES

In the present study, an electrical stir casting furnace has been used. The crucible material was graphite. A electrical sources was used as the input of the system. Scraps of aluminium were preheated up to a temperature of 900^{0}C and particles of graphite , SiO2, fly ash up to a temperature of 500^{0}C in muffle furnace. Crucible used for pouring of composite slurry in the mold was also heated up to 400 ^{0}C.

Taguchi L9 orthogonal array method was used for nine iteration corresponding to various weight ratio combinations of materials.

In this method, graphite , SiO2 particles were mixed with Fly Ash particles in various weight ratio and then heated at 500 °C for 2 h. The mixture was then slowly added to the surface of the liquid aluminium at 900 °C. After this, the slurry was stirred inter-mittantly at 900°C for a period of about 10 min in order to allow the reactions to occur. All of the graphite was reacted, so that no SiO2 particle remained on the surface of the liquid aluminium.

In this methods, immediately after stirring the slurry and subsequently allowing the slurry to sit for 5-10 min, the slurry was poured into a cylindrical steel mould of diameter 28 mm and height 250 mm and cooled at room temperature.

Nine different materials are formed from the nine iterations. Each material is tested for its tensile strength. The material with the highest tensile strength is tested to find its mechanical properties.

VI.RESULT

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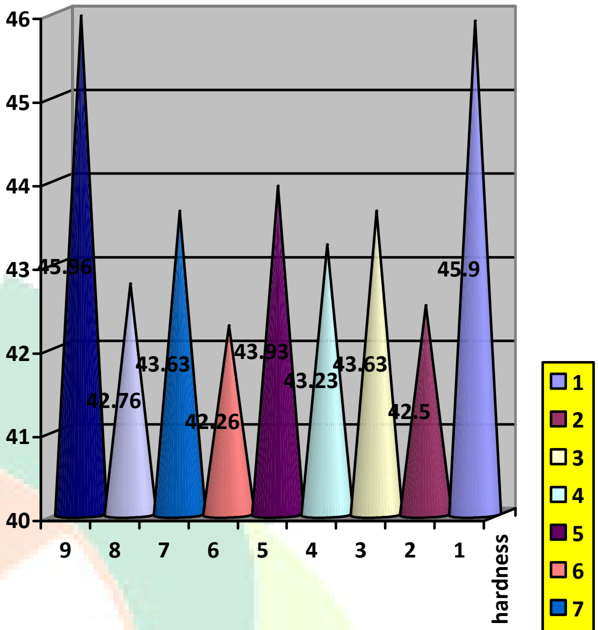
HARDNESS

Hardness is the characteristic of a solid material expressing its resistance to permanent deformation. The hardness test was conducted according to ASTM E92-82(2003). The hardness tests were conducted on cast specimens. 10 mm Ball indenter was used and 500 kg was the applied force. Three tests were conducted and average value is taken as the hardness of the specimen.



	hardness
1	45.9
2	42.5
3	43.63
4	43.23
5	43.93
6	42.26
7	43.63
8	42.76
9	45.96

TABLE.5Hardness of the hybrid composite Al casting alloy in various composition

TABLE.6 ANOVA for HARDNESS

L9 orthogonal array with data for hardness

8.2 ANOVA for HARDNESS

Table 8.3 L9 orthogonal array with data for hardness

Experiment	Graphite (grams)	Fly Ash (grams)	SiO_2 (grams)	HARDNESS (BHN)
1	15	15	15	45.9
2	15	30	30	42.5
3	15	45	45	43.63
4	30	15	30	43.23
5	30	30	45	43.93
6	30	45	15	42.26
7	45	15	45	43.63
8	45	30	15	42.76
9	45	45	30	45.96

VII.CONCLUSIONS

A stir casting setup was fabricated and metal matrix composites of Aluminium Lm 6 reinforced with Graphite and Fly Ash , SiO2 was cast. The influences of change in volume fraction and size of Fly Ash on the mechanical properties of the cast Aluminium Lm 6 reinforced with Graphite and Fly Ash composites were studied..

Based on the analysis the following points may be concluded:

1. The hardness of the cast composites were studied using Brinell Hardness Testing Machine hence it is found that hardness is improved with addition of fly ash.

2. The addition of SiO2 particles and their increase in volume fraction results in decrease in wear loss of the composites.

3. The multi response optimization using Grey relational analysis was carried out and the best

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specimen was founded to be 9th component which is the composition of 45grams graphite , 45 grams Fly ash , 30 gram SiO2.

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