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Processing and Synthesis of Metal Matrix Al 6063/Al_2o_3 Metal Matrix Composite by Stir Casting Process

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ABSTRACT
Aluminum-Alumina composites have increasingly widened their use due to merits of processing, high specific strength and modulus of elasticity while carrying good deformability and conductivity comparable to metals. In addition to its use in structural components for high performance application, such as aerospace vehicles and racing automobiles, hence this composite requires a good processing method so that the quality of the Al6063/Al_2O_3 composite is not affected. Hence stir casting method of casting is adopted and Al 6063 plate is casted with varying mass of Al_2O_3 (3%, 6%, 9%). Also the distribution of Alumina and Aluminium is examined by microstructure analysis, hardness distribution and the material is tested for its mechanical Properties such as tensile strength and Hardness.

KEYWORDS : Aluminium, aluminium oxide, composite materials, stir casting process, tensile test, hardness test.

I. INTRODUCTION

MMC materials have a combination of different, superior properties to an unreinforced matrix which are; increased strength, higher elastic modulus, higher service temperature, improved wear resistance, high electrical and thermal conductivity, low coefficient of thermal expansion and high vacuum environmental resistance. These properties can be attained with the proper choice of matrix and reinforcement [1]

Composite materials consist of matrix and reinforcement. Its main purpose is to transfer and distribute the load to the reinforcement or fibers. This transfer of load depends on the bonding which depends on the type of matrix and reinforcement and the fabrication technique.[2] The matrix can be selected on the basis of oxidation and corrosion resistance or other properties. Generally Al, Ti, Mg, Ni, Cu, Pb, Fe, Ag, Zn, Sn and Si are used as the matrix material, but Al, Ti, Mg are used widely.[3]

Nowadays researchers all over the world are focusing mainly on Aluminium because of its unique combination of good corrosion resistance, low density and excellent mechanical properties. The unique thermal properties of Aluminium composites such as metallic conductivity with coefficient of expansion that can be tailored down to zero, add to their prospects in aerospace and avionics. [4] The choice of Alumina as the reinforcement in Aluminium composite is primarily meant to use the composite as very good electrical insulation ($1x10^{14}$ to $1x10^{15}$ Ωcm) , Moderate to extremely high mechanical strength (300 to 630 MPa), Very high compressive strength (2,000 to 4,000 MPa) ,High hardness (15 to 19 GPa), Moderate thermal conductivity (20 to 30 W/mK), High corrosion and wear resistance, Good gliding properties, Low density (3.75 to 3.95 g/cm^3).

Aluminium based metal matrix composites have been one of the key research areas in materials processing field in the last few decades. Most of the research work has been dealing with aluminium matrix with Al_2O_3 & SiC rein-forcement requiring the light weight in combination of high strength and high stiffness[5]. This is because aluminium is lighter weight which is first requirement in most of the industries. In addition, impressive strength improvement and the thermal expansion coefficient of Al matrix composites can be adjusted by using Alumina in varying proportion. Al 6063 plate is casted with varying mass of Al_2O_3 (3%, 6%, 9%). [6].

Chemical composition of Al6063

Sl.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Element	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
Composition	0.6	**0.35**	**0.1**	**0.1**	**0.9**	**0.1**	**0.1**	**0.1**	Balance

Mechanical properties of Al6063

Sl.No.	Mechanical properties	Value
1	Minimum proof stress (0.2) %	50
2	Minimum tensile strength(MPa)	100
3	Shear strength(MPa)	70
4	Hardness Vickers(HV)	25

Applications of 6063 Aluminium

Aluminium alloy 6063 is typically used in: Aircraft application, Architectural applications, Extrusions, Window frames, Doors, Shop, fittings, Irrigation tubing

II. PROCESSING METHOD

A. Preparation of the MMC by STIR CASTING and its Mechanical properties

The material used in the present investigation consists of Aluminium alloy (Al6063) as the base matrix alloy. Its Chemical composition (%) is Mg = 0.45-0.9, Si=0.2-0.6,Fe=0.35max, Cu=0.1max, Mn=0.1max, Zn=0.1max, Ti=0.1max,Cr=0.1max,Al=balance. It posses high heat dissipation capacity and is suitable for high strength and high temperature applications.**[7].** The aluminium matrix was reinforced with Al2O3 of 46 microns in varying percentage of 3%, 6% and 9%. The composite were cast using stir casting process as it ensures uniform distribution of the reinforcement and secondary processing like rolling is possible.

Stir casting process is a special type of casting in which stirring action is carried out in the furnace itself. This process is explained in the flow chart in figure 1. It consists of two muffle furnace, one is a big furnace with stirrer setup and another is a small one, shown in figure 2 and 3 respectively.

- Step1: Aluminium alloy is melted at 800^0C in muffle furnace for two hours
- Step2:Alumina is melted at 100^0 C in another muffle furnace for same time period
- Step3:Melted Aluminium & Alumina are mixed in the graphite crucible and 5gm of coverall, nucleant & degasser are added in the melt
  - Coverall: It is a complex of $KCl+HNO_{3,}$ avoids oxidation
  - Nucleant: salt tablets. It enhances good grain structure
  - Degasser:Hexa-chloroethane tablets, it removes the gases present in molten metal
- Step4:After adding all these, the crucible is kept inside the furnace
- Step5:The molten metal are stirred at speed of 200rpm for 10minutes
- Step6:At the same time, dies are preheated at 300^0 C in another muffle furnace for 2 hours
- Step7:Finally the molten metal poured into the preheated die and then the metal is allowed to solidify

(Aluminium 6063 heated)
Fig 1 Muffle furnace 1 with stirrer setup

(Alumina heated)
Fig 2 Muffle furnace 2

Fig 3 Picture of Composite plates

Fig 3.1 Aluminium+3% Al_2O_3

Fig 3.2 Aluminium+6% Al_2O_3

Fig 3.1 Aluminium+9% $Al_2\ O_3$

III. Testing & Results:

For the safe design and usage of these composite plates, it is essential that their ultimate strength and mechanical properties need to be determined. Hence various tests are conducted using the fabricated plates.

3.1 Tensile Test:

The important properties which come into play when a component is subjected to tensile loads are strength, Elasticity & Ductility. The graph below explains detaily about the above parameters. From the cast MMC the standard tensile specimen were prepared by machining as per dimensions of ASTM E8. To obtain mechanical properties, specimens with overall length 100mm, thickness of 6mm and a gauge length of 25mm were tested in UNITEX-94100 Universal Testing machine.

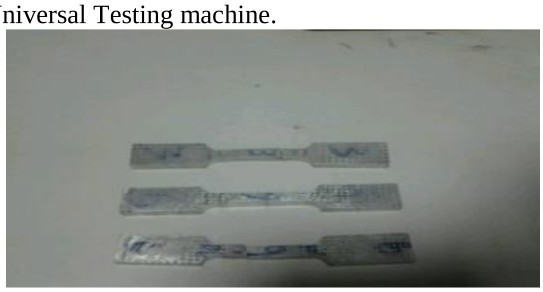

Fig.4. Tensile tested specimen

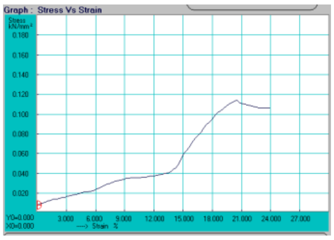

Fig 5: Stress–Strain curve for 3 % Al_2O_3 Tensile strength: 112 N/mm² % Elongation: 8.571%

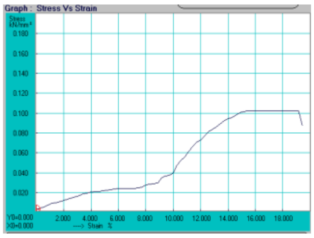

Fig 6: Stress–Strain curve for 6 % Al_2O_3 Tensile strength: 102 N/mm² % Elongation: 8.143%

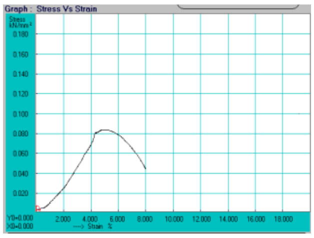

Fig 7: Stress–Strain curve for 9 % Al_2O_3 Tensile: 882 N/mm² % Elongation: 4.543%

The ultimate tensile strength of a composite is affected not only by the particle and matrix fraction but also by the particle and matrix fraction but also the micro geometry of the composite components.[8].

3.2 Micro Hardness:

Hardness: Hardness is often a function of the particle size, porosity, and binder material. Hardness is very important to the success of machining operations. The hardness of the samples was measured using UHL Vickers micro hardness measuring machine by applying a load of 0.5Kg and this load was applied for 20 seconds. In order to eliminate the possibility of error a minimum of five hardness readings were taken for each sample.

Sample	H.V @ 0.5 Kg Load				
Al6063+3% Al_2O_3	45.1	44.2	42.9	43.2	36.7
Al6063+6% Al_2O_3	55.7	57.4	56.3	58.8	55.5
Al6063+9% Al_2O_3	52.8	44.5	60.3	46.1	55.7

3.3 Microstructure Analysis

Microstructure is defined as the structure of a prepared surface or thin foil of material as revealed by a microscope above 25× magnification. The microstructure of a material (which can be broadly classified into metallic, polymeric, ceramic and composite) can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high /low temperature behavior, wear resistance, and so on, which in turn govern the application of these materials in industrial practice.

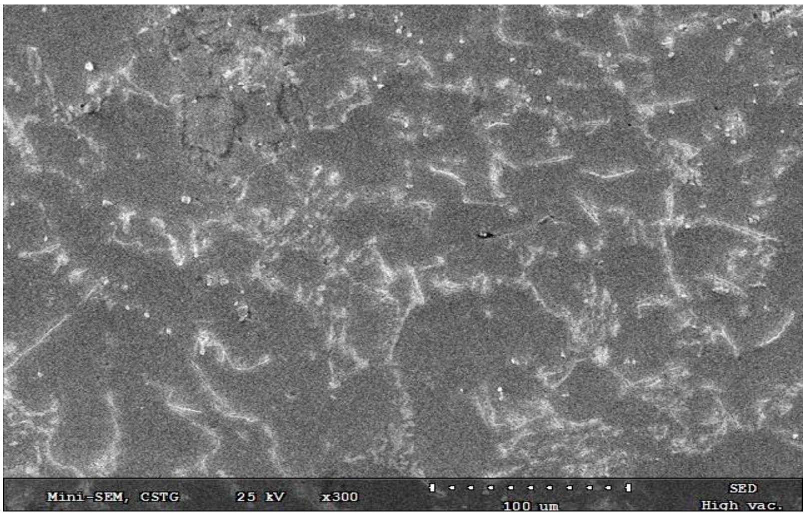

Fig.5.1 SEM Image of Al6063+9% Al_2O_3

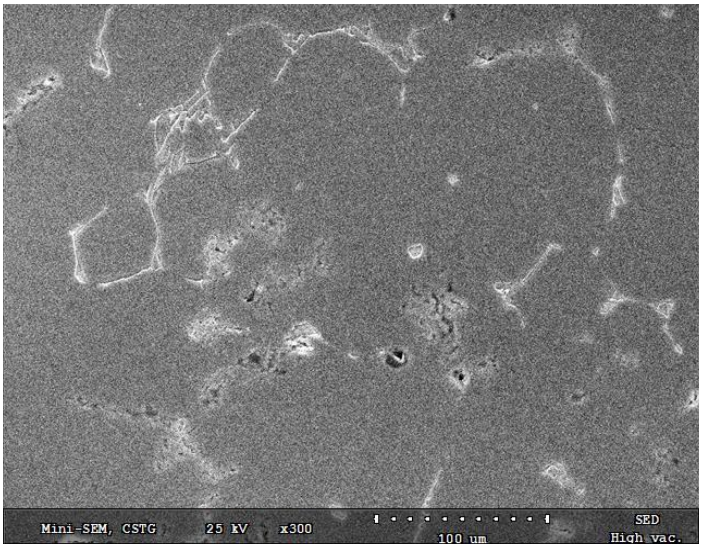

Fig 5.2 SEM Image of Al6063+3% Al_2O_3

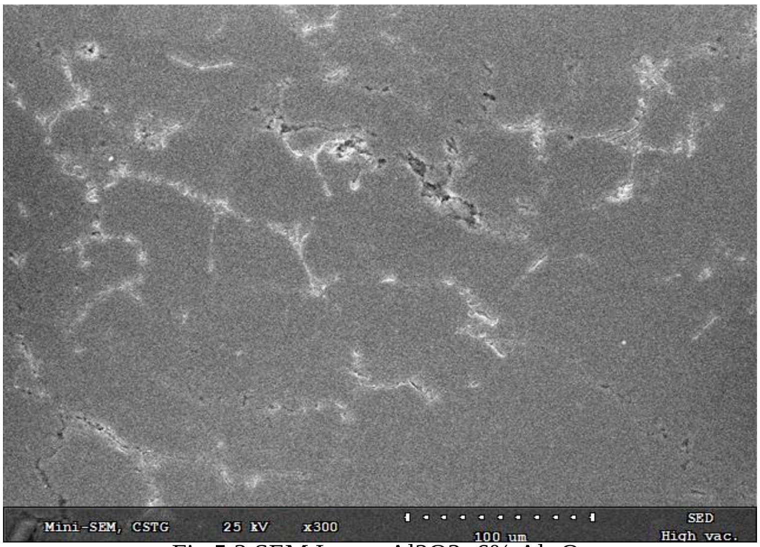

Fig 5.3 SEM Image Al2O3+6% Al $_2O_3$

The above SEM images shows formation of grain boundaries the structures show loosely formed grains with Unmodified Vermicular. Silicon segregation in arranged manner of dendrites leading to a “shrinkage prone site”. This happen due to poorgrain refinement as well aspoor modification. Thus the casting has all the following defects like shrinkage, gas holes & inclusions. Also the formation of porosity and its effects on mechanical properties of composite have been the matter of several studies. It is generally accepted that tensile properties decrase with an increase in porosity content. The effects of parameters, such as porosity were characterized by scanning electron microscope.Similar results are reported by [9,10].

IV. Conclusion

In the research work, a newly formulated composites (Al- Al_2O_3) is prepared by the stir casting process. In this stir casting method of casting Al 6063 plate is casted with varying mass of Al_2O_3 (3%, 6%, 9%). Also the distribution of Alumina and Aluminium is examined by microstructure analysis, hardness distribution and the material is tested for its mechanical Properties such as tensile strength and hardness.

1. The results confirmed that stir casted Al alloy 6063 with Al_2O_3 reinforced composite is clearly superior to base alloy Al6063 in the comparison of tensile strength as well as hardness.
2. Tensile strength of Al composite were improved by the addition of the Al_2O_3 patticles. The tensile strength and porosity of 6% Vol. Al_2O_3 /Al composite decreased with increasing reinforcement.
3. The Percentage elongation of the composite decreased with increase in Al_2O_3 content,which confirms that alumina addition increases brittleness.
4. Increasing of hardness with increasing weight percentage of Al_2O_3 particles ismainly due to

grain refinement and particle strengthening effects.

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