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Research Article

Investigation On Improved Thermal Conductivity Of AA6061 By Reinforcing Hybrid Ceramic Particulates Using Stir Casting Method

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ABSTRACT

Aluminium MMCs are replacing conventional aluminium alloys in various domains exclusively in transportation. The basic scientific concept here is to improve the thermal conductivity of the conventional aluminium alloys. Stir casting process is mainly used for manufacturing of particulate reinforced metal matrix composite (PMMC). Manufacturing of aluminium alloy based casting composite by stir casting is one of the most economical methods of processing MMC. Properties of these materials depend upon many processing parameters and selection of matrix and reinforcements. Advancements of manufacturing technology would allow incorporating the Aluminium oxide (Alumina) and Graphite (c) fillers of different/varied and also equal volume with molten aluminium. Scanning Electron Microscopy and EDX are necessary to study the various percentages of particle distribution in Al matrix system. Then temperature distribution along the extended surface (fins) would be determined by pin fin apparatus. This is used to calculate average temperature of fins.

Keywords: *AA6061, Metal Matrix Composites, Stir casting, thermal conductivity, fins*

1. Introduction

A metal matrix composite (MMC) is a composite in which two or more reinforced materials are added to the metal matrix in order to improve the properties of the composite. A hybrid metal matrix composite (HMMC) consists of three or more composites mixed with the matrix. Apart from metal matrix composite, there is polymer matrix composite (PMC) and ceramic matrix composite (CMC). In general, metal matrix is favored over polymer matrices because of its ability to meet the engineering demand. Composites are the most promising material of recent interest. In the modern applied sciences, the concept of mixing two dissimilar materials has gained much attention [3]. The combinations provide unique properties. The composite in Ductry has begun to recognize the commercial application of composites which promise to offer much larger business opportunities in aerospace and automotive sectors [8]. The most commonly used metal matrix is aluminium, magnesium, titanium and their alloys. Aluminium metal matrix composites (AMMC) are the composites in which aluminium is used as the matrix and several reinforced materials are embedded into the matrix. Some of the reinforced materials are silicon carbide, graphite, fly ash, particulate alumina, red mud, cow dung, rice husk etc. AMMC are in demand due to their properties like low density, high specific strength, high damping capacity, high thermal conductivity, high specific modulus and high abrasion and wear resistance [10], low density, good mechanical properties, low thermal coefficient of expansion, better corrosion resistance, high strength to weight ratio and high temperature resistance etc. Aluminium metal matrix composite provides lesser wear resistance when compared to steel and hence it is widely used as a matrix metal.The AMMC can be manufactured by various manufacturing techniques such as stir casting, powder metallurgy, pressure infiltration, squeeze casting [16], chemical vapour deposition etc. Amongst all the processes, stir casting is the most common method used by the researchers

2. Background

Stir casting technique is simple and the most commercial method of production of metal matrix composites. In preparing metal matrix composites by the stir casting method, there are several factors that need to be

considered [8], including, Difficulty in uniform distribution of the reinforcement material, Wet ability between the two main substances, Porosity in the cast metal matrix composites, and Chemical reactions between the reinforcement material and the matrix alloy.
In conventional stir casting method, reinforced particulate is mixed into the aluminium melt by mechanical stirring. Mechanical stirring is the most important element of this process. After the mechanical mixing, the molten metal is directly transferred to a shaped mould prior to complete solidification. The essential thing is to create the good wetting between particulate reinforcement and aluminium melt. The distribution of the reinforcement in the final solid depends on the wetting condition of the reinforcement with the melt, relative density, rate of solidification etc. Distribution of reinforcement depends on the geometry of the stirrer, melt temperature and the position of the stirrer in the melt.
An improvement in conventional stir casting is a double stir casting method or two-step casting process. In the first stage, the matrix material is heated to above its liquidus temperature and then cooled down to a temperature to keep in a semi-solid state. At this stage, the preheated reinforcement materials are added and mixed with a mechanical stirrer. Again the slurry is heated to a liquidus state and mixed thoroughly. Nowadays, this two-step mixing process has used in the fabrication of aluminium because of more uniform microstructure as compared of conventional stirring [17].A recent development in stir casting is three step stir casting for the fabrication of nano particle reinforced composite. In this method, first, the Al particles and reinforcement are mixed using ball milling process to breakdown the initial clustering of nano particles. Then the composite powder is mixed with melt by mechanical stirring [11].

3. "Fabrication of Composite"

Since Stir Casting is the most achievable process of aluminium composites, the method has been preferred. The moulding die needs to be prepared at the appropriate specimen dimensions. By the predefined proportions the particulates can be fed to systems. The composites with varying proportions can be fabricated.
Furnace power cable is connected to the main power supply. Retort, Stirrer blade and stirrer rod, Preheating furnace for heating the alloying material are ensured for cleanliness. The mains power supply is switched ON. Input power will be indicated on the power meter, as well as the RYB indicators will glow. The required temperature has been set on the furnace temperature controller, pre-heating temperature controller and melt temperature controller. The stirrer has been lifted by pressing the UP button. The Al alloy and other materials duly weighed are added in the resort. The L type melt temperature sensor has been inserted into furnace to know the melt temperature in the indicator. Once the temperature is reached, the furnaces will automatically cut off and if the temperature falls down than set limit then the controller will switch ON the furnace to maintain the set temperature.
The composites are added in the preheating furnace, the temperature has been set and the furnace is switched ON. Once aluminium is melted, the stirrer has brought down, so as to immerse the blade into melt. The stirrer is switched ON in the stirrer speed regulator. The required speed has been increased by pressing the push switch in the stirrer speed regulator. The stirrer is stopped to add the alloying metal. The pre-heating valve is opened to introduce the heated alloy metal into the melt. The sufficient time has been given for the alloy to melt and then the stirrer is switched ON. Stirrer speed should be less than 200rpm while adding abrasive alloying metal.
The die is placed below the bottom pouring tube. The bottom pouring toggle switch has kept at pour position. The melt has poured into the die by operating the remote control panel. Once the bottom pouring is complete, the bottom pouring green switch on the remote control panel has released to stop the pouring. Bottom pouring melt switch and Stirrer using the toggle switch has been switched OFF.
The die has been kept under room temperature for curing. After curing, the composite has been removed from the die. The same procedure has been repeated for reinforcing graphite, alumina + graphite particulates. The composites are machined for the testing purposes.

4. Structural Characterization

Structural characterization involves optical microscopic observation, SEM Testing, EDX testing and Pin fin testing. Optical microscopic observation provides the arrangement of particulates and also any defects in the material. A scanning electron microscope (SEM) produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the sample's surface topography and composition. The electron beam is scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image.
Energy-dispersive X-ray spectroscopy (EDX) Analysis is an analytical technique designed to provide more in-depth information about crystalline compounds, including identification and quantification of crystalline phases. In EDX analysis, a focused X-Ray beam is shot at the sample at a specific angle of incidence. The X-Rays diffract in various ways depending on the crystal structure (inter-atomic distances) of the sample. The locations (angles) and intensities of the diffracted X-Rays are measured. Thermal performance of the material will be measured by Pin fin testing.

4.1. Optical Microscope Results – Al_2O_3

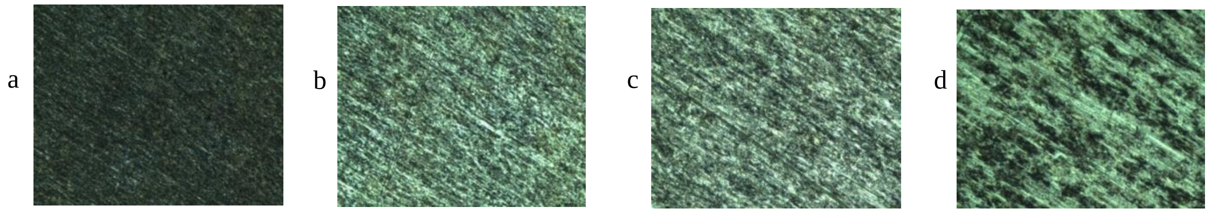


Fig. 1. (a) 5x; (b) 10x; (c) 20x; (d) 50x.

4.2. Optical Microscope Results – Graphite

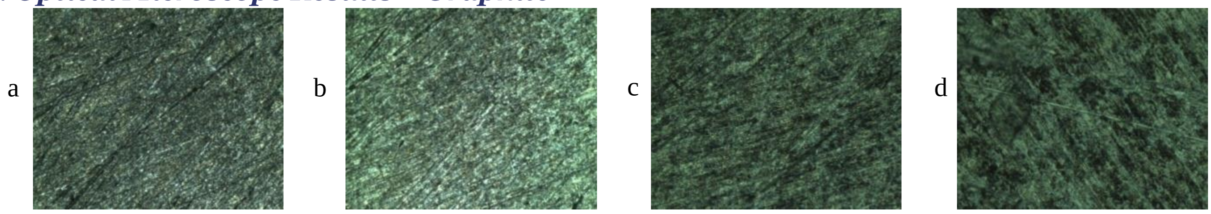


Fig. 2. (a) 5x; (b) 10x; (c) 20x; (d) 50x.

4.3. Optical Microscope Results – Al_2O_3 + Graphite

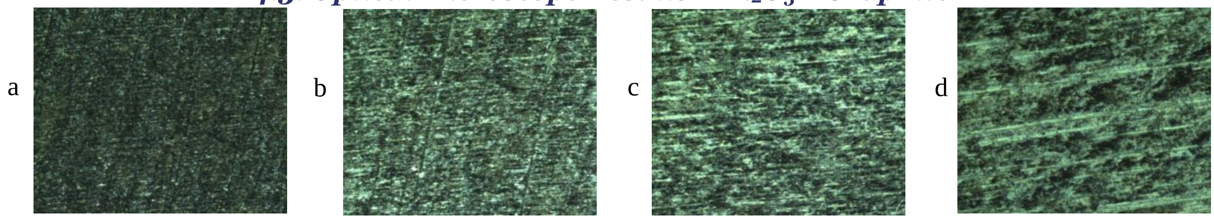


Fig. 3. (a) 5x; (b) 10x; (c) 20x; (d) 50x.

4.4. Scanning Electron Microscope Result - Al_2O_3

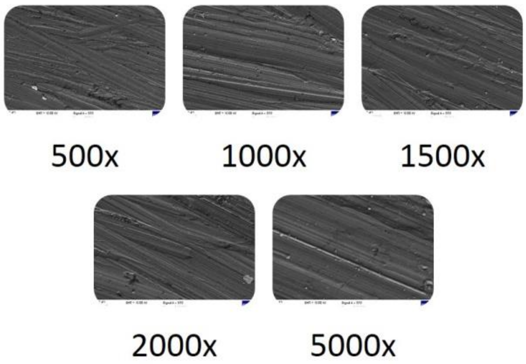


Fig. 4. SEM result - Al_2O_3

4.5. Scanning Electron Microscope Result – Graphite

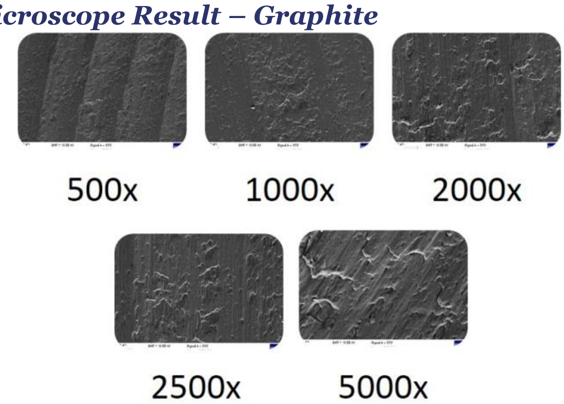


Fig. 5. SEM result – Graphite

4.6. Scanning Electron Microscope Result - Al_2O_3+ Graphite

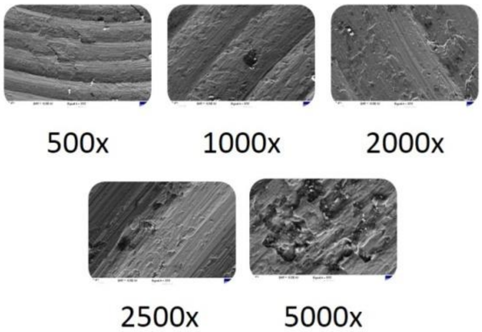
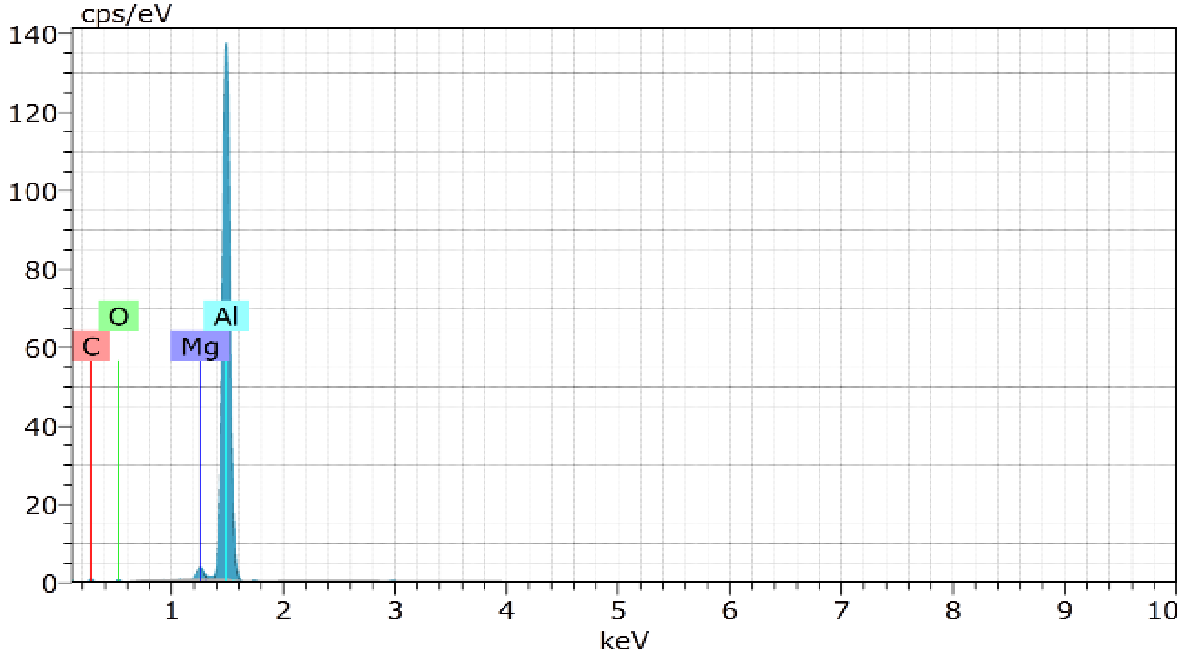


Fig. 6 SEM result - Al_2O_3 + Graphite

4.7. Energy-Dispersive X-Ray Spectroscopy - Al_2O_3

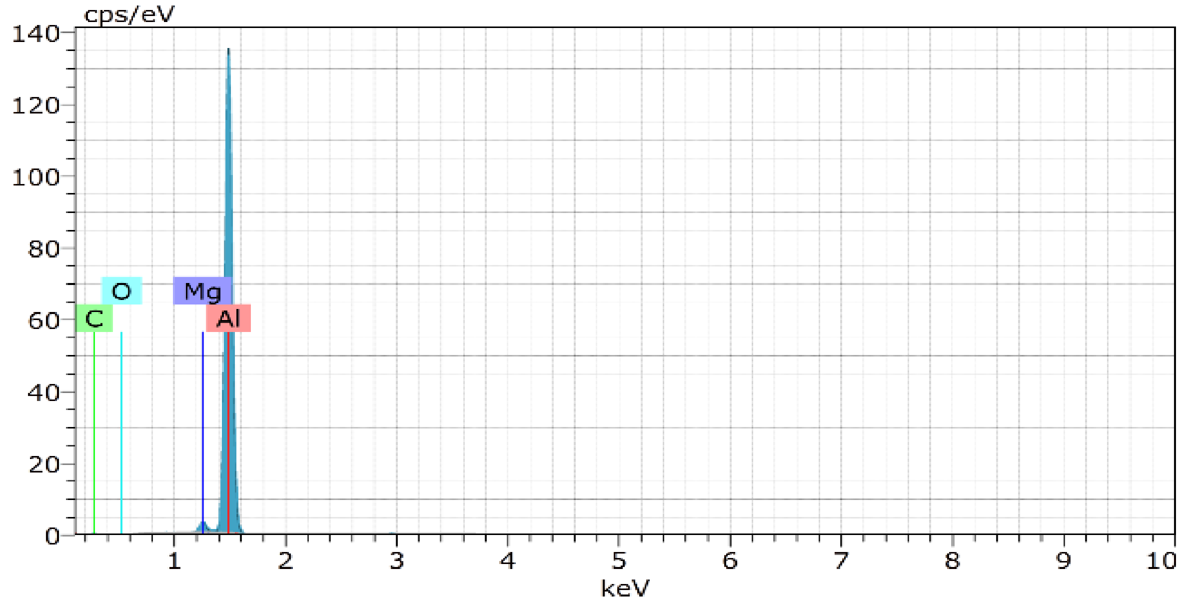


Spectrum: AL203

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (3 Sigma) [wt.%]
Carbon	K-series	13.60	14.03	26.45	9.36
Oxygen	K-series	2.06	2.13	3.01	1.73
Magnesium	K-series	1.83	1.89	1.76	0.40
Aluminium	K-series	79.46	81.95	68.78	11.47
	Total:	96.95	100.00	100.00	

Fig. 7. EDX result - Al_2O_3

4.8. Energy-Dispersive X-Ray Spectroscopy – Graphite

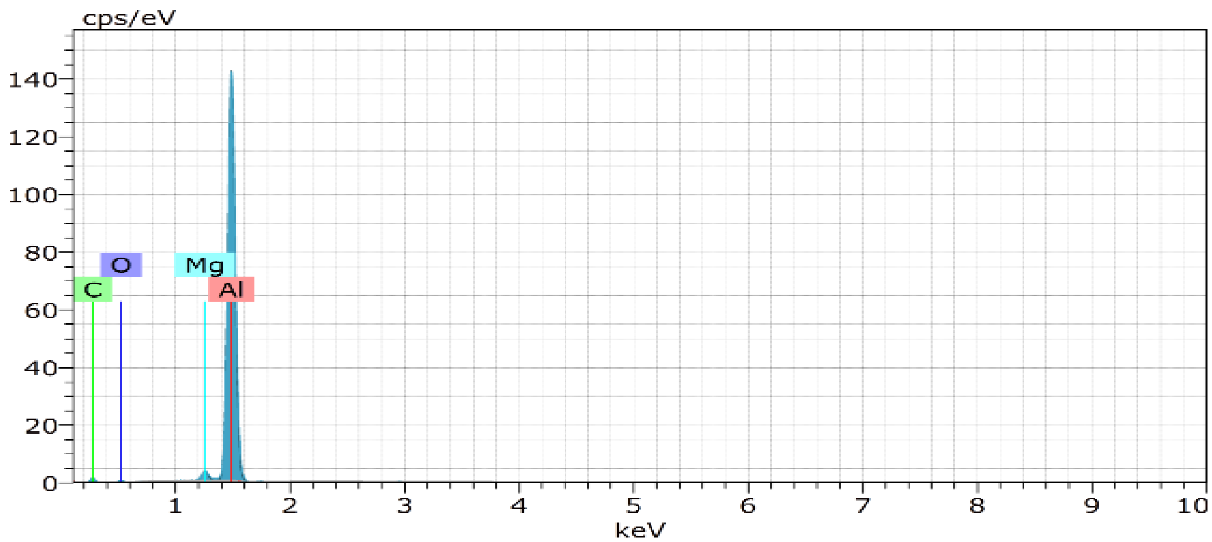


Spectrum: G

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (3 Sigma) [wt.%]
Aluminium	K-series	84.88	88.89	79.84	12.25
Carbon	K-series	8.19	8.58	17.32	6.84
Magnesium	K-series	1.84	1.92	1.92	0.40
Oxygen	K-series	0.58	0.61	0.92	0.81
	Total:	95.49	100.00	100.00	

Fig. 8. EDX result – Graphite

4.9. Energy-Dispersive X-Ray Spectroscopy - Al_2O_3 + Graphite



Spectrum: AL2O3&G

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (3 Sigma) [wt.%]
Aluminium	K-series	76.22	74.34	57.81	11.01
Carbon	K-series	21.88	21.34	37.27	12.86
Oxygen	K-series	2.73	2.67	3.50	2.10
Magnesium	K-series	1.70	1.65	1.43	0.38
	Total:	102.53	100.00	100.00	

Fig. 9. EDX result - Al_2O_3 + Graphite

5. Result

Table 1. Thermal Conductivity of tested samples

Material	Thermal Conductivity (k)
Al_2O_3	239.26 Wm/K
Graphite	233.63 Wm/K
Al_2O_3 + Graphite	233.16 Wm/K

6. Conclusion

Aluminium Metal Matrix Composite has been generated by reinforcing the Alumina, Graphite and Alumina + Graphite particulates in AA6061 using Stir Casting method. The dispersion of the particulates was observed through the structural characterization techniques such as Optical Microscope, Scanned Electron Microscope and Energy-Dispersive X-Ray Spectroscope. The aim of the project is to improve the thermal conductivity of AA6061. The same has been achieved and ensured by testing in Pin-fin apparatus. The results are summarized and concluded that alumina particulates on reinforcing in AA6061 using stir casting technique shows high thermal conductivity of 239.28 W/mk.

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