



# Synthesis of Aluminium Alloy Based Discontinuous Metal Matrix Composites Reinforced With Ceramic Particles Using Liquid Metallurgy Route

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## ABSTRACT

Aluminum alloy-based metal matrix composites (AMMCs) have been by now established themselves as a suitable wear resistant material especially for sliding wear applications. However, in actual practice engineering components usually encounter combination of wear types. By adopting the liquid metallurgy route on different wear modes like sliding, abrasion, erosion, and combinations of wear modes like cavitations erosion, erosion abrasion, sliding abrasion attempt is to highlight the effect of dispersing ceramic particles in base alloy. Also the distribution of Alumina and Aluminum is examined by microstructure analysis, chemical composition, hardness distribution and the material is tested for its mechanical Properties such as tensile strength and Hardness. Initially, the required properties are identified, after which, the work explores pure aluminum and its importance in the industry along with its limitations. Using these limitations, MMC's were recommended as a possible replacement for aluminum and it is seen that the exact set of properties depend on certain factors.

*Keywords*— Aluminum Alloy, Ceramic Particles, Composites, Discontinuous Metal Matrix composites, Liquid Metallurgy, Synthesis of Aluminum Alloy.

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## I. INTRODUCTION

Material scientists and researchers in this area have been fulfilling the demand of the engineering sector since decades in synthesizing materials to attain the demanded properties to enhance efficiency and cost savings in the manufacturing sector. In fulfilling this demand, a certain trend has been followed, the materials presently been used is tried for improvement through known methods of alloy additions, heat treatment, grain modification, and the like. Metal Matrix Composites (MMC) have a combination of different superior properties to an reinforced matrix which are; increased strength, higher elastic modulus, higher service temperature, improved wear resistance, high electric and thermal conductivity, low coefficient of thermal expansion and high volume 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 Aluminum because of its unique combination of good corrosion resistance, low density and excellent mechanical properties. Aluminum 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 Aluminum matrix with Al<sub>2</sub>O<sub>3</sub> & ceramics reinforcement requiring the light weight in combination of high strength and high stiffness [4]. This is because Aluminum 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 various ceramics in varying proportion.

Metal matrix composites constitute a metallic matrix that is reinforced with another material, usually in the form of fibers, particulates, whiskers etc. The reinforcing material usually carries most of the load and the matrix material, by holding them together, enables load transfer. The advantages of using these materials (with metals as matrices) include high tensile and shear moduli, good fatigue and fracture properties, small thermal expansion coefficient, high melting point, high toughness, high ductility, high thermal and electrical conductivities, good erosion (and/or corrosion) resistance, dimensional stability and good moisture resistance. In addition, MMCs with aluminum as the matrix benefit from good wear resistance, high specific modulus and specific strength.

One such example of MMC is an aluminum matrix composite reinforced with silicon carbide (Al-SiC). The most important property of aluminum-silicon carbide with reference to the aerospace industry is its strength to weight ratio, which is three times more than mild steel. In addition, composites containing SiC (reinforcing material) and Al(matrix) have high modulus, strength values, wear resistance, high thermal stability, less weight and a more effective load carrying capacity compared to many other materials. It is also expected that this composite will exhibit good corrosion/ oxidation properties since silicon carbide forms a protective coating of silicon oxide at 1,200°C and aluminum also displays a similar reaction.

## II. EXPERIMENTAL WORK

The matrix material used for the current study was Al-Si alloy, having composition average values. The Al-Si alloy has an excellent combination of mechanical properties in cast condition. The matrix material was loaded in a graphite crucible and it was placed inside a top loaded resistance furnace at different temperature level (700°C, 750°C, 800°C, 850°C, 900°C). The SiC reinforcement was preheated at 1000°C for two hours before added in the matrix melt. The 10% by volume of preheated SiC powder was added in the liquid melt and the slurry was consciously stirred using a stir- ring. The four blade Stirrer was designed in order to produce the adequate homogenous particle distribution throughout the matrix material. The axial and radial flows are provided to avoid different stagnant zones in the liquid melt by stirrer. Stirring of the mixture is carried out at holding time (10, 20, and 30 minutes) to achieve homogeneity of particulates. The stainless steel stirrer was coated with zirconia to avoid the reaction between stainless steel and Al alloys at higher temperatures. The Argon gas was supplied into the near the crucible during the stirring to avoid the formation of oxide layer on the surface of matrix melt. The Stirring speed 450 rpm was maintained throughout work. The mixture is allowed to solidify in the preheated (300°C) steel die.



Fig.1 Experimental setup.

## III. TYPES OF REINFORCEMENT

Considers two types of SiC reinforcements – fibers and platelets (although the study uses a 6061 alloy, it is argued that these results could be extrapolated to pure aluminum matrix as well since both types of reinforcements in the study have been considered under similar environments). Considering fiber and platelets without any heat treatment from Arsenault's [22] work, it is seen that even though both the composites demonstrate similar proportional limits (121 MPa), the material with the SiC fiber shows greater yield stress and ultimate tensile strength. However because the fiber's strength was higher, its ductility compared to the platelets were lower. The increase in the properties of the fiber-reinforced composites is a result of the void density percentage, which according to Arsenault [15] is 2% ( $\pm 1\%$ ) for the fibers and 5% ( $\pm 2\%$ ) for the platelets.

TABLE I  
VALUES OF PROPERTIES CONTAINING DIFFERENT  
TYPES OF REINFORCEMENTS

Property	Platelets	Fibres
Proportional Limit (Mpa)	121	121
Yeild Stress (MPa)	162.2	258.8
Ultimate Tensile Strength (MPa)	249.1	452
Plastic Strain (Elongation) (%)	8.1	3.5

## IV. DISTRIBUTION OF THE REINFORCEMENT MATERIAL

When fabricating MMCs through casting or similar liquid phase techniques, the distribution of the reinforcement material is an important factor to consider as it affects the properties and the quality of the material. The particle distribution is affected at three stages of the fabrication process i.e., (1) during mixing, (2) after mixing but before solidification (holding) and (3) during solidification. The authors suggest the use of stir casting as it not only helps in the transfer of the particles to the melt but also retains them in a state of suspension. It is also seen that the solidification/cooling rate (of the composite) is important because it influences the distribution of the SiC in the final ingot. When the material is cooled, the SiC particles are rejected at the meniscus and pushed ahead of the

solidification front; they are then trapped by converging dendrite arms in the intercellular regions. When the material is cooled rapidly, there is a more homogenous distribution of SiC particles compared to a more slower rate which results in a more clustered distribution (because of more particle pushing). The distribution of the particles also depends on the wetting (discussed previously). This paper believes that a more homogenous distribution of SiC particles results in less localized damaged (since both the particles and interfaces are more spread out) and also that the clustered particles can result in the formation of stress concentration regions because the load bearing particles are drawn together.

TABLE II  
VALUES OF PROPERTIES WITH DIFFERING SiC  
CONTENT

Property	SiC-5%	SiC-10%	SiC-15%
Density (g/cm <sup>3</sup> )	2.4660	2.3125	N/A
Yield Strength (N/mm <sup>2</sup> )	236	257	N/A
Hardness (BHN)	85.3	87.2	N/A
Tensile strength (N/mm <sup>2</sup> )	248	265	N/A
Elongation (%)	19.0	18.2	N/A
Hardness (BHN)	40.2	41.1	43.7
Impact Strength (N-m)	22	24	N/C

## V. CONCLUSIONS

The following conclusion can be reached based on the present investigation:

- From the microstructure analysis, the particles were distributed uniformly in the processing temperature 750° and 800°. The particles agglomeration were found in the processing temperature of 700°, 850° and 900° due to the changes of viscosity in liquid Al matrix.
- The tension test revealed that ultimate strength increased gradually on addition of SiC up to 800° and start to decrease gradually due to the distribution of the Al matrix.
- The ultimate tensile strength of metal matrix composites decrease with increase holding time. It is revealed that holding time influences the viscosity of liquid metal, particles distribution and also induces some chemical reaction between matrix and reinforcement.

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