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An Investigation of the Mechanical and Tribological Properties of Aluminium Alloy Series with SiC Metal Matrix Composites: A Review

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Abstract - *For the last few years there has been abrupt increase in usage of aluminium metal matrix composites, especially in automobile, aerospace, marine, agriculture farm machinery due to its high strength, low density, and good wear resistance compared to any other metals. Aluminium alloys with silicon carbide (SiC) as reinforcement is preferred due to its weight ratio, better wear resistance and creep resistance applications. Also efforts have been made to review the different combination of composites to check their effect on properties of the different alloys of aluminium.*

Key Words: Aluminium alloy, Reinforcement, Silicon Carbide, Stir Casting.

1. INTRODUCTION

The combination of two or more constituent materials with significantly different physical and chemical properties produces a material with characteristics different from the individual components. A hybrid metal matrix composite consists of three or more composites mixed with the matrix. Apart from metal matrix composite, there are polymer matrix composite and ceramic matrix composites [1]. Mechanical properties of composites are affected by the size, shape and volume fraction of the reinforcement composite material and reaction at the interface [2].

Silicon carbide particles reinforced metal-matrix composites have been considered as a excellent structural materials in aerospace, aeronautical, automotive industry because of excellent combination of low density and high thermal conductivity [3].

Aluminium metal matrix composites are the composites in which aluminium is used as matrix and various reinforced materials are embedded into the matrix. Aluminium metal matrix composites are in demand due to their properties like high specific strength, low density, high damping capacity, high thermal conductivity, high specific modulus ,high abrasion and wear resistance[4], high strength to weight ratio and high temperature resistance[5], Aluminium metal matrix provides less wear resistance than steel and hence its widely used by researchers[6]. Characterization of aluminium with silicon carbide composites by various techniques is needed to ascertain the proper microstructure, distribution, identification and weight percentage of different elements of aluminium alloy [7].

Table-1: Properties of Al and SiC.[8]

Properties	Aluminium	Silicon Carbide
Density (gm cm^3)	2.70	3.30
Tensile strength (MPa)	185	588.0
Coefficient of thermal expansion ($10^{-6}/^0C$)	23	4.6
Modulus of Elasticity (GPa)	70	345

The aluminium metal matrix composites can be manufactured by different methods like stir casting, powder metallurgy, squeeze casting [9]. Among which stir casting is the most common method used by the researchers [10].

2. LITERATURE REVIEW

1. [11] Rajesh Kumar Bhushan observed the study of fabrication and characterization of 7075 aluminium alloy reinforced with silicon carbide particulates. In his study the SiC was added as dispersed particles by fluid vortex cast technique. The composites of different volume divisions of filler materials were examined by EPMA, XRD, SEM, EMPA and DTA investigation. The evolution of the microstructures during reheating and the mechanical properties of thixoformed products of 7075 Aluminium alloy cast by liquidus semi continuous casting were studied. SEM micro pictures show that the dispersion of filler particles is uniform. The XRD chart sees no rise in aluminium carbide. EPMA investigation shows that aluminium as the essential compound and the particles contained the alloying component of zinc, magnesium, copper.

From the above paper we could infer that alloying of aluminium metal with magnesium and its detachment at the interface has been seen to be amazing in reduction the course of action of the aluminium carbide at the interface during sample planning.

2. [12] Manoj Singla conducted experiments on study of wear properties of aluminium silicon carbide composites by changing the weight percentage of silicon carbide. Silicon carbide is fabricated by liquid metallurgy method. In his

study friction and wear characteristics of aluminium- silicon carbide composites have been investigated under dry sliding conditions. It was inferred from the papers that wear rate decreases linearly with increase in percentage of silicon carbide.

From the above paper we inferred that both pure aluminium and composites, the average coefficient of friction decreases with increasing load but comparatively composites show lower coefficient of friction than pure aluminium.

3. [13] Miss. Laxmi, Mr. Sunil Kumar investigated on fabrication and testing of Al 6061 alloy and silicon carbide MMC by addition of 10%, 15% and 20% by weight composition of silicon carbide by stir casting technique. In these paper efforts has been made to study mechanical properties like hardness. The analysis of microstructure was conducted by SEM to verify the dispersion of reinforcement in the matrix.

From the above paper we can infer that increase in composition of SiC, an increase in hardness has been observed.

4. [14] Z. Hasan conducted studies on wear characteristics in Al-SiC particulate composites. The Al-SiC composites was prepared using liquid metallurgy technique employing 2124 Al alloy with 10% and 20% of SiC particulates by weight. The abrasive wear study was conducted on a pin on disc machine. The characteristics of the worn surface were investigated using scanning electron microscope. From the above research work we can infer that the expansion in wear rate of aluminium alloy is progressively significant because of wrinkle and cutting activities by rough particles.

5. [15] Shivaraj H B, B S Praveen Kumar investigated about the determination and analysis of fracture toughness of MMC. In this study Aluminium alloy 356 MMC is reinforced with zirconium silicate and silicon carbide, which is fabricated using stir casting technique. The outcome of the paper shows higher hardness with the expansion in the particle volume fraction in weight %. The result of the study inferred that there is considerable increase in the fracture toughness in presence of both silicon carbide and zirconium silicate reinforced in metal matrix. The matrix alloy with 2% silicon carbide and 6% zirconium silicate reinforcement has shown high toughness for fracture. It is settled that enormous particles are difficult to break toughness because of their tendency to crack.

6. [16] Niranjan K N, Shivaraj B N, Sunil Kumar M, Deepak A R investigated about the hybrid composite of Aluminium 6061 reinforced with 6% silicon carbide and varying steps of graphite. In these paper mechanical properties like hardness, tensile strength and compressive strength was calculated. From the above paper we can infer that as the percentage of graphite is increased, hardness decreases and tensile and compressive strength increase with the increase in graphite particulates with the influence of silicon carbide particulates.

7. [17] Ajith Bhandakkar investigated about the fracture toughness of aluminium alloy 2024 reinforced with silicon carbide and fly ash. From the above paper we could infer that, as the percentage of filler material increases, the ultimate stress, yield stress and percentage of elongation also increases and we could assume that fracture strength decreases with maximum reinforcement materials and combination of silicon carbide and fly ash is not ideal to get expected results. Uniform distribution of fly ash and silicon carbide particles in the aluminium was obtained by liquid metallurgy route of stir casting followed by hot extrusion.

3. FABRICATION OF Al-SiC COMPOSITES

Al-SiC composites can be fabricated by many different methods like stir casting, powder metallurgy and squeeze casting.

3.1 STIR CASTING

The aluminium metal matrix can be prepared in many ways, one of the best economical way is to produce the composite is by stir casting. By the means of mechanical stirring with the help of electric motor dispersed phase is mixed with molten matrix metal. The mechanical properties and final microstructure of the composites are affected by many process parameters. The advantage of stir casting process lies in producing very large sized components easily. The process parameters which affect the stir casting process are stirring speed, time of stirring, impeller size, blade angle of impeller and impeller position. In the conventional stirring process, the aluminium melt and the reinforced particulate is mixed by mechanical stirring. After the mixing stage, the molten metal is transferred to the mould to allow it to solidify. The main essential distribution in final solid depends on reinforcement wetting condition with the melt, relative density and solidification rate. The reinforcement distribution depends on stirrer geometry, temperature of the melt and stirrer position in the melt. The figure listed below gives the brief of stir casting process

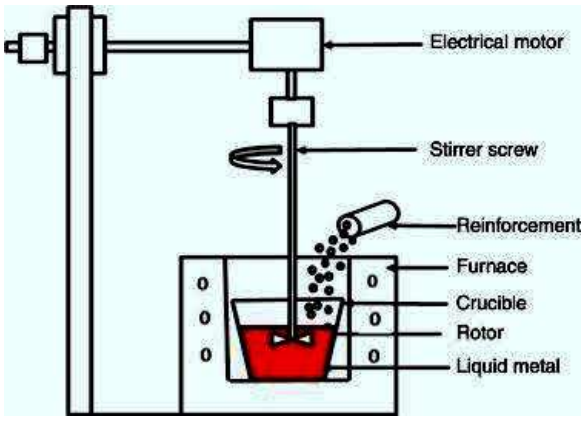

Figure 1: Typical Stir Casting Process.

Double stir casting or two step stir casting process is an improvement over conventional stir casting process. At the first stage, the metal matrix is heated above liquidus

temperature and then it's cooled down to temperature such that a semi solid state is reached. At this stage, the reinforcement is added and mixed using a mechanical stirrer. Subsequently the slurry is heated to the liquidus state and it is mixed thoroughly. The two step mixing process is often used in fabrication of aluminium because of uniform microstructure obtained when compared to conventional stirring process.

Table 2: Composition of samples [7].

Sample No.	Aluminium (grams)	SiC (grams)	Remarks
1.	2000	0	Al-0%SiC
2.	2000	60	Al-3%SiC
3.	2000	120	Al-6%SiC
4.	2000	180	Al-9%SiC

3.2 POWDER METALLURGY

Powder Metallurgy is a process in which the materials are finely powdered and are pressed in a die of required shape.

The different stages in the powder metallurgy are

- Powder production
- Blending or Mixing
- Powder compaction
- Sintering

3.2.1 Powder Production

The first stage in the powder metallurgy process is the powder production. Powder production is the process of converting the solid parts into the fine powders through the process such as atomization, electrolytic and chemical processes.

3.2.2 Blending

Powders of same chemical properties but different particle sizes are intermingled. This is done to reduce the porosity. Blending the coarser fraction with finer fraction ensures that the interstice between the larger particles is filled out. It also ensures to have a homogeneous mass with uniform distribution of particle size and composition.

3.3.3 Powder Compaction

Powder compaction is a process in which the metal powder compacts of desired shape is obtained. The compacting is done in order to consolidate the powder into desired shape close to final dimensions. It decides the porosity level. The work part after pressing is called green part, the term Green means it is not yet full processed. The green strength of the part is adequate for handling but less than after sintering. Powder do not flow like liquids, they are compressed until equal and opposite force is created. This opposite force is created by a combination of resistance of bottom punch and friction between the die surface and particles.

3.4.3 Sintering

Sintering is a heat treatment process required to bond the metallic particles resulting in increasing the strength and hardness between the particles. The process is carried out between 70% and 90% of metal's melting point. The primary driving force for sintering is the reduction of surface energy. It also transforms mechanical bonds into stronger metallic bonds. It also transforms mechanical bonds into stronger metallic bonds.

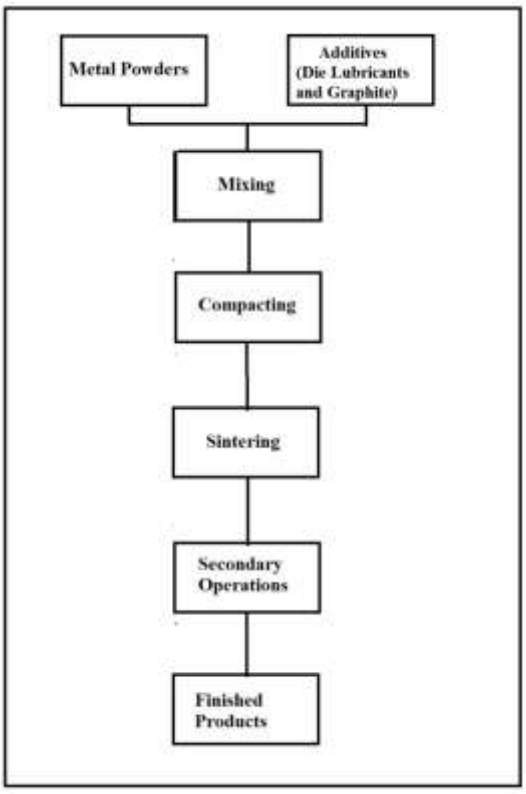

Figure 2: Powder Metallurgy Method.

4. RESULTS OF VARIOUS CASE STUDIES [7].

4.1 Tensile Test

Tensile test was carried on universal testing machine and it has been concluded that the percentage elongation decreases with increase in silicon carbide percentage. But the yield strength and universal tensile strength decreases upto 10% silicon carbide and then increases.

Table 3: Tensile result (Al7075-0% SiC)

TESTS	RESULTS
Initial Area mm^2	64.32
Initial Gauge Length mm	45.00
Final Gauge Length mm	50.36
Yield Strength MPa	199.79
Ultimate Tensile Load KN	15.01
Ultimate Tensile Strength MPa	233.45
% Elongation	11.91

Table 4: Tensile result (Al7075-3% SiC)

TESTS	RESULTS
Initial Area mm²	64.32
Initial Gauge Length mm	45.00
Final Gauge Length mm	50.87
Yield Strength MPa	158.9
Ultimate Tensile Load KN	13.10
Ultimate Tensile Strength MPa	203.08
% Elongation	13.04

Table 5: Tensile results (Al7075-6% SiC)

TESTS	RESULTS
Initial Area mm²	65.71
Initial Gauge Length mm	45.00
Final Gauge Length mm	50.64
Yield Strength MPa	175.1
Ultimate Tensile Load KN	16.47
Ultimate Tensile Strength MPa	245.8
% Elongation	12.53

Table 6: Tensile results (Al7075-9% SiC)

TESTS	RESULTS
Initial Area mm²	65.84
Initial Gauge Length mm	45.00
Final Gauge Length mm	49.67
Yield Strength MPa	250.4
Ultimate Tensile Load KN	19.64
Ultimate Tensile Strength MPa	298.3
% Elongation	10.37

4.2 Hardness Test

Table 7: Hardness Test

Sl No.	Particulars of sample Al7075-SiC	Result 1	Result 2	Result 3	Average
1	3%	67.1	65.3	64.2	65.5
2	6%	74.6	75.8	76.3	75.5
3	9%	87.3	88.4	86.1	87.2

5. CONCLUSION

The purpose of this paper is to have a wider outlook about different grades of aluminium and choosing best combination of the individual parameters. This review paper includes investigations on tribological and mechanical properties of various aluminium metal series reinforced with silicon carbide. It can be inferred that when silicon carbide reinforcement is added to aluminium base alloy it increase its tensile strength up to 60-70% from the aluminium base metal.

Hardness shows the best results when silicon carbide is employed at 25% weight. The main objective of wear test is to provide the information on friction behavior, heat treatment, and load speed. The significant effect of these factors influences tribological properties.

All the research paper concluded that, the reinforcement materials very much affects the physical, mechanical and tribological properties of various aluminium series materials. This inspire other research scholars to investigate various mechanical properties by reinforcing the new materials to aluminium and aspire to get best results of mechanical and tribological properties.

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