Preparation and Mechanical Behaviour of Al6063-SICP MMC by Using Stir Casting Technique

M.Amrutha Pavani,
M.TECH (Machine Design),Narasaraopeta Engineering College.

M.Venkaiah,
Assistant professor,Department of mechanical Engineering,Narasaraopeta Engineering College,Narasaraopet, Andhrapradesh 522601.

Abstract

Metal Matrix Composites (MMC's) have evoked a keen interest in recent times for potential applications. Advance composite materials like Al/SiC metal matrix composite is gradually becoming very important materials in manufacturing industries e.g. aerospace, automotive and automobile industries due to their superior properties such as light weight, low density, high strength to weight ratio, high hardness, high temperature and thermal shock resistance, superior wear and corrosive resistance, high specific modulus, high fatigue strength etc. In this study aluminum (Al-6063)/SiC Silicon carbide reinforced particles metal-matrix composites (MMCs) are fabricated by melt-stirring technique with varying the reinforced particles by weight fraction ranging from 5%, 10%, 15%.The stirring process was carried out at 200 rev/min rotating speed by graphite impeller for 15 min. Different mechanical tests were carried out to find torsion strength, tensile strength, hardness strength & impact strength of fabricated aluminum (Al-6063)/SiC metal-matrix composites material.

Keywords: *metal matrix composites (MMC's), silicon carbide (SiC), stir casting technique*

1. INTRODUCTION

Metal Matrix Composite (MMC) is engineered combination of metal (Matrix) and hard particles (Reinforcement) to tailored properties. Metal Matrix Composites (MMC's) have very light weight, high strength, and stiffness and exhibit greater resistance to corrosion, oxidation and wear. Fatigue resistance is an especially important property of Al-MMC, which is essential for automotive application. These properties are not achievable with lightweight monolithic titanium, magnesium, and aluminium alloys. Particulate metal matrix composites have nearly isotropic properties when compared to long fiber reinforced composite. But the mechanical behavior of the composite depends on the matrix material composition, size, and weight fraction of the reinforcement and method utilized to manufacture the composite. The distribution of the reinforcement particles in the matrix alloy is influenced by several factors such as rheological behavior of the matrix melt, the particle incorporation method, interaction of particles and the matrix before, during, and after mixing [1]. Non homogeneous particle distribution is one of the greatest problems in casting of metal matrix composites [2]. Nai and Gupta [3] reported that the average coefficient of thermal expansion of the high SiCp end was reduced as compared to that of the low SiCp end. Hashim et al. [4] reported that the distribution of the reinforcement material in the matrix must be uniform and the wettability or bonding between these substances should be optimized. Aluminum-silicon carbide metal matrix composite has low density and light weight, high temperature strength, hardness and stiffness, high fatigue strength and wear resistance etc. in comparison to the monolithic materials [5]. However, aluminum alloy with discontinuous ceramic reinforced MMC is rapidly replacing conventional materials in various automotive, aerospace, and automobile industries [6]. Amongst various processing routes stir casting is one of the promising liquid metallurgy technique utilized to fabricate the composites. The process is simple, flexible, and applicable for large quantity production. The liquid metallurgy technique is the most economical of all the available technique in producing of MMC [7]. Aluminum alloy-based composites containing 10wt% alumina (size range: 150-225 mm) were prepared by liquid metallurgy technique using the vortex method [8,9]. The ZnO whiskers 25 vol% reinforced with Al-matrix composites were fabricated by a squeeze casting process [10]. The quartz-silicon dioxide particulates reinforced LM6 alloy matrix composites were fabricated by carbon dioxide sand molding process [11]. Various researchers have utilized conventional stir casting technique for producing MMC [12,13,14,15] but still applied research is needed for successful utilization of the process for manufacturing of MMC.

In this study stir casting is accepted as a particularly promising route, currently can be practiced commercially. Its advantages lie in its simplicity, flexibility and applicability to large quantity production. It is also attractive because, in principle, it allows a conventional metal processing route to be used, and hence minimizes the final cost of the product. This liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production [16], and allows very large sized components to be fabricated. The cost of preparing composites material using a casting method is about one-third to half that of competitive methods, and for high volume production, it is projected that the cost will fall to one-tenth [17]. In general, the solidification synthesis of metal matrix composites involves producing a melt of the selected matrix material followed by the introduction of a reinforcement material into the melt. To obtain a suitable dispersion the stir casting method is used. The solidification of the melt containing suspended SiC particles is done under selected conditions to obtain the desired distribution.

From the past review, it is found that the number of research work on wear behaviour of MMCs have been published, but only few work related to the influence of weight fraction on mechanical properties like tensile strength, hardness, impact strength, percentage of elongation etc., have been reported. In this study, different weight fractions of Silicon Carbide particulates are added with aluminium matrix to fabricate the Al/SiC metal matrix composites. Different samples have been fabricated by melt-stirring casting and their microstructure, hardness, tensile strength, shear strength and impact strength are studied.

2. MATERIALS AND FABRICATED METHOD

2.1. Materials

The base material for the investigation is aluminium alloy (6063), as-received in the form of round bar as shown in fig.1 with a chemical composition (determined by the use of a spectrometric analyzer) as presented in Table 1. silicon carbide (SiC) and graphite are used as reinforcement. 1% by weight of pure magnesium powder is used as wetting agent..fig.2 shows the Silicon carbide powder.

Table 1 Chemical composition of AL-6063 T6

Chemical Element	% Present
Manganese (Mn)	0.0 - 0.10
Iron (Fe)	0.0 - 0.35
Magnesium (Mg)	0.45 - 0.90
Silicon (Si)	0.20 - 0.60
Zinc (Zn)	0.0 - 0.10
Titanium (Ti)	0.0 - 0.10
Chromium (Cr)	0.0 - 0.10
Copper (Cu)	0.0 - 0.10
Other (Each)	0.0 - 0.05
Others (Total)	0.0 - 0.15
Aluminium (Al)	Balance

Fig.1 Aluminum 6063-T6 material

Fig.2. Silicon carbide (SiC) with a particle size of 30 µm

2.2. Method

2.2.1. Stir casting

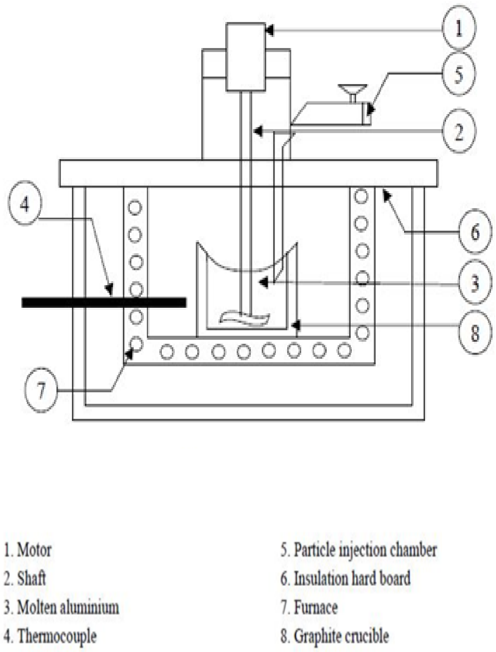

Fig 3. Schematic view of setup for fabrication of composite

Stir casting process starts with placing empty crucible in the muffle. At first heater temperature is set to 500°C and then it is gradually increased up to 900°C. High temperature of the muffle helps to melt aluminium alloy quickly, reduces oxidation level, enhance the wetability of the reinforcement particles in the matrix metal. Aluminium alloy Al6063 is used as Matrix material. Required quantity of aluminium alloy is cut from the raw material which is in the form of round bar. Aluminium alloy is cleaned to remove dust particles, weighed in the crucible for melting as shown in fig 3.During melting nitrogen gas is used as inert gas to create the inert atmosphere around the molten matrix. Aluminium 6063, silicon carbide (SiC) and graphite are used as reinforcement. 1% by weight of pure magnesium powder is used as wetting agent. At a time total 700 gram of molten composite was processed in the crucible. Required quantities of reinforcement powder and magnesium powder are weighed on the weighing machine. Then it is thoroughly mixed with each other with the help of blending machine for 24 hour. This mixture is kept ready 1 day before the test has to carry out. Prior to conducting the test this mixture is kept for heating in another heater.

Reinforcements are heated for half hour and at temperature of 500°C. When matrix was in the fully molten condition, Stirring is started after 2 minutes. Stirrer rpm is gradually increased from 0 to 300 RPM with the help of speed controller. Temperature of the heater is set to 630°C which is below the melting temperature of the matrix. A uniform semisolid stage of the molten matrix was achieved by stirring it at 630°C.Pouring of preheated reinforcements at the semisolid stage of the matrix enhance the wetability of the reinforcement, reduces the particle settling at the bottom of the crucible. Reinforcements are poured manually with the help of conical hopper. The flow rate of reinforcements measured was 0.5 gram per second. Dispersion time was taken as 5 minutes. After stirring 5 minutes at semisolid stage slurry was reheated and hold at a temperature 900°C to make sure slurry was fully liquid. Stirrer RPM was then gradually lowered to the zero. The stir casting apparatus is manually kept side and then molten composite slurry is poured in the metallic mould as shown in fig 3(a). Mould is preheated at temperature 500°C before pouring of the molten slurry in the mould. This makes sure that slurry is in molten condition throughout the pouring.

While pouring the slurry in the mould the flow of the slurry is kept uniform to avoid trapping of gas. Then it is quick quenched with the help of air to reduce the settling time of the particles in the matrix as shown in fig 3(b).

Fig3(a).Pattern making for test specimen

Fig 3(b).Pouring of molten metal into mould

3.RESULTS AND DISCUSSION

3.1 Microstructure

Metallographic samples were sectioned from the cylindrical cast bars. A 0.5 % HF solution was used to etch the samples wherever required. To see the difference in distribution of SiC particles in the aluminum matrix, microstructure of samples were developed on Inverted type Metallurgical Microscope (Make: Nikon, Range-X50 to X1500). Fig4 show Micrograph of Al/Sic-MMC's samples for different weight fraction (5%, 10%, 15%) of SiC particles. Optical micrographs showed reasonably uniform distribution of SiC particles. In this Al matrix SiC particles are clearly labeled.

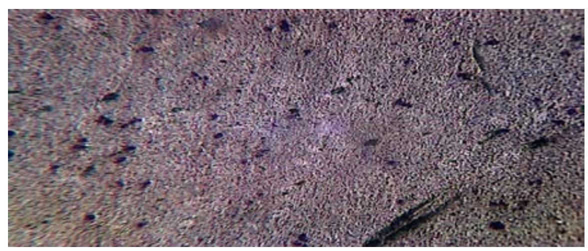

Fig 4(a). Al6063-Sicp 5%

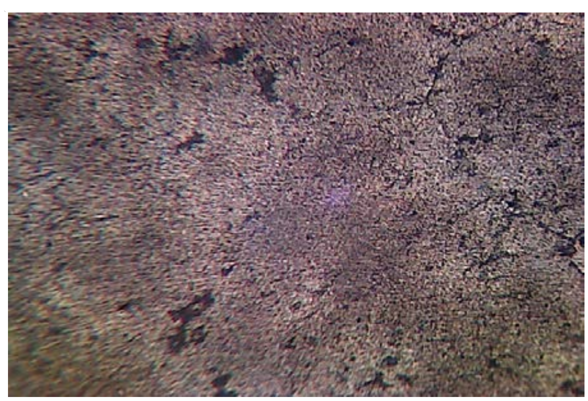

Fig 4(b). Al6063-Sic_p 10%

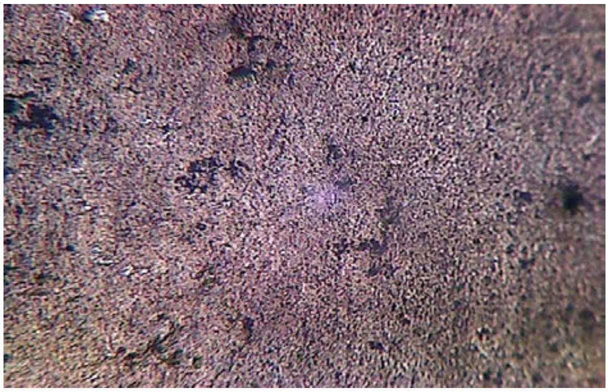

Fig 4(c). Al6063-Sic$_p$ 15%

Micrograph of Al/Sic-MMC's samples for different weight fraction (5%, 10%, 15%) of SiC particles

3.2 Tensile test

A tensile test, also known as tension test, is probably the most fundamental type of mechanical test you can perform on material. Tensile tests are simple, relatively inexpensive, and fully standardized. By pulling on something, you will very quickly determine how the material will react to forces being applied in tension. As the material is being pulled, you will find its strength along with how much it will elongate. The following specifications with Universal Testing Machine Model-UTN-20,Max. Capacity-400KN, Make: Blue Star Ltd was used for testing purpose. Yield & ultimate strength values were shown graphically in fig.5. Test specimens of different Sic compositions are also shown in

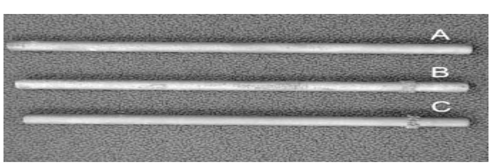

Fig.6 Tensile test specimens

	5%	10%	15%
Yield	79.6	90.1	101.7
Ultimate	104.1	122.8	143.5

Table 2. Yield & ultimate results

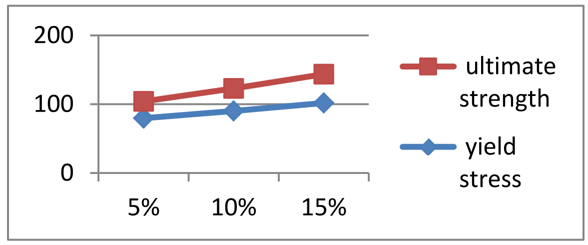

Fig.5 ultimate strength & yield stress Vs wt % of SIC$_p$

3.3 Hardness

Hardness is another measure of the ability of a material to be deformed. There are many different tests for this, but all measure the resistance of a material to indentation, applying a known force to a tool of defined radius which is very much harder than the material being tested. Empirical hardness numbers are calculated from measurements of the dimensions of the indentation.

3.3.1 BHN

The brinell test consists of indenting the surface of the metal by a hardened steel ball under a load. The load is applied by lever system and the specimen is placed on stage with its ground face upwards. The height of the specimen can be raised by hand wheel so that the specimen is brought into contact with the indenter which is forced into the specimen by the specified load.

ISSN 2348 – 7968

3.3.2 Rockwell

In the Rockwell hardness test, the hardness is determined by the depth of penetration of a indenter, rather than by surface area of the indentation. the specimen placed on stage is brought into contact with the penetrator , the penetrator is then slowly forced into the specimens surface by weights acting through a system of levers. Model RAB from SEU Pvt. Ltd type equipment was used tomeasure the two types of harness at load=150kgf, ball=2.5mm. Yield & ultimate strength values were shown graphically in fig.8 and test specimens of different Sic compositions are also shown in fig7(a,b,c).

Formula for hardness

$$B.H.N = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})} \quad \text{--(1)}$$

Fig 7(a) Al - 5% of sic_p hardness test specimen

Fig7(b) Al - 10% of sic_p hardness test specimen

Fig7 (c) Al - 15% of sic_p hardness test specimen

Table 3. Brinell & Rockwell hardness results in BHN & RCN

% of sic_p	5%	10%	15%
BRINELL	86	96	97.5
ROCKWELL	16	26	27.5

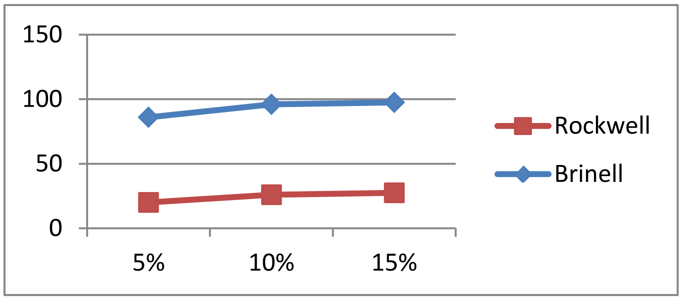

Fig 8. Brinell & Rockwell Vs Wt % Of Sic_p

From the above results, we can observe that the hardness of composite material increasing by varying the amount % of sic_p.

3.4 Impact strength

The charpy impact testing and the means of supporting the specimen. The charpy testing machine is available in variety of sizes. A usual size is one having a capacity of about 30 kilojoules for testing metals. A notched specimen is mounted as simple supported beam and heavy pendulum is allowed to strike the specimen from a fixed height. The charpy testing machine with following specifications Maximum capacity: 30joules,Minimum capacity: 2joules,Distance between supports: 40mm±0.2mm is used for impact test. Impact test specimens at different Sic compositions are as shown in fig8.

Fig 8 Impact & torsion test specimens

Impact is a high force or shock applied over a short time period when two or more bodies collide. Such a force or acceleration usually has a greater effect than a lower force applied over a proportionally longer time period of time. The effect depends critically on the relative velocity of the bodies to one another. The test results are shown in fig 9 graphically.

Table 4. Impact test results in joules

% of sic_p	5%	10%	15%
Charpy	7.4	11	18

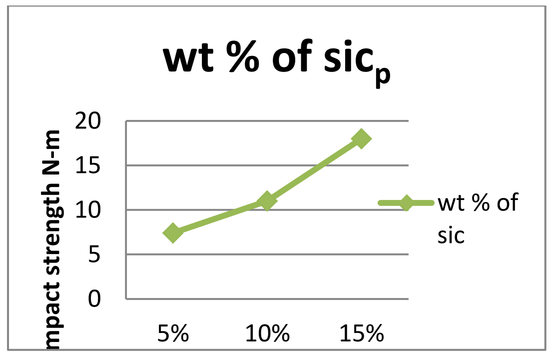

Fig .9 Impact strength Vs Wt % of sic_p

From the above results, we can observe that the composition of 15% sic_p has the high impact strength comparing to the compositions of about 5%sic_p, 10%sic_p.

3.5 Torsion test

A torsion test measures the strength of any material against maximum twisting forces. It is an extremely common test used in material mechanics to measure how much of a twist a certain material can withstand before cracking or breaking. This applied pressure is referred to as torque. Materials typically used in the manufacturing industry, such as metal fasteners and beams, are often subject to torsion testing to determine their strength under duress.

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 8, August 2015.
www.ijiset.com
ISSN 2348 – 7968

There are three broad categories under which a torsion test can take place: failure testing, proof testing and operational testing. Failure testing involves twisting the material until it breaks. Proof testing observes whether a material can bear a certain amount of torque load over a given period of time. Operational testing tests specific products to confirm their elastic limit before going on the market.

It is critical for the results of each torsion test to be recorded. Recording is done through creating a stress-strain diagram with the angle of twist values on the X-axis and the torque values on the Y-axis. Using a torsion testing apparatus, twisting is performed at quarter-degree increments with the torque that it can withstand recorded. The strain corresponds to the twist angle, and the stress corresponds to the the torque measured.

The elastic limit of any material is the point at which it can no longer return to its original shape or size. The elastic limit determined by a torsion test is equal to the slope of the line from the start of testing to the proportional limit. This relationship was first measured by Sir Robert Hooke in 1678. Hooke's Law states that stress is directly proportional to strain until the proportional limit is reached, at which point the object tested will begin to show signs of stress.

After testing, metal materials are categorized as being either ductile or brittle. Ductile metals such as steel or aluminum have high elastic limits and can withstand a great deal of strain before breaking. Brittle materials such as cast iron and concrete have low elastic limits and do not require much strain before rupturing.

Without performing a torsion test, materials would not be properly vetted before being released for industrial use. It is of paramount importance that the ability for a material to bear a certain amount of twisting is accurately measured. Otherwise, structures and machines that depend on such materials could break down causing instability, work flow interruption or even significant damage and injury. TT6 model from Fuel instruments & engg. private limited type shear test was conducted with Maximum capacity :60N-m,Torque ranges: 30-60N-m to measure the the torque,results are shown in table 5 and also graphically shown in fig10.

formulae for maximum shear stress

$$_{max} = T/abt^2 \text{ ---------------------(2)}$$

b= length of the long side

t = thickness, or width of short side

α ,β = parameters

b/t	1.0	1.5	1.75	2.0	2.5	3.0	4	6	8	10	∞
α	.208	.231	.239	.246	.258	.267	.282	.299	.307	.313	.333
β	.141	.198	.214	.229	.249	.263	.281	.299	.307	.313	.333

Table 5. Torque results from torsion test in N-m

ANGLE OF TWIST in °	5%	10%	15%
0-5	3.5	8.5	10
5-10	6.5	17	15.5
10-15	11.5	20.8	18.2
15-20	15	23	19.5
20-25	16.6	25.5	20.8
25-30	17	26.5	21.4

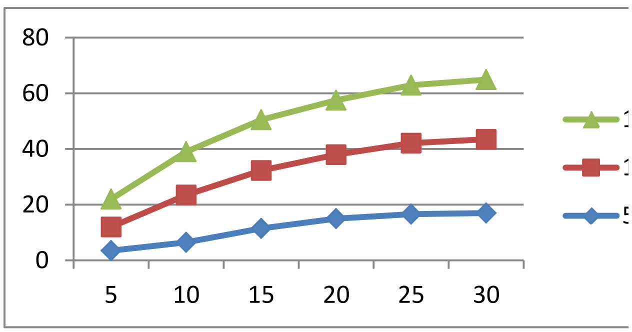

Fig 10. Torque (N-m) Vs Angle Of Twist In degrees

From the above results we can observe that composition of the 15%-sic_p have the more shear strength compared to the other compositions of 5%-sic_p, 10%-sicp

3.6 Maximum Shear Test

When Yielding occurs in any material, the maximum shear stress at the point of failure equals or exceeds the maximum shear stress when yielding occurs in the tension test specimen.from equation 2 Maximum Shear Results are calculated and tabulated as ashown in table 6 and graphically shown in fig11.

Table 6.Maximum Shear Results In KN/mm^2

Angle Of Twist In °	5%	10%	15%
0-5	22.26	54.07	63.61
5-10	41.35	108.15	98.61
10-15	73.16	132.32	115.78
15-20	95.42	146.32	124.05
20-25	105.6	162.23	132.32
25-30	108.15	168.59	136.14

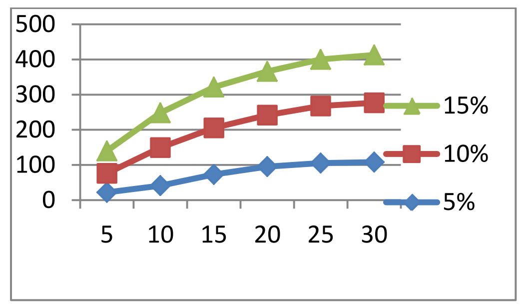

Fig 11 Shear Stress Vs Angle Of Twist In degrees

From the results, we can observe that the composition of 15% sicp have more shear stress results under different angle of the twists.

CONCLUSION

The composition of aluminum with the increased weight fraction of silicon carbide increases the mechanical properties. The maximum mechanical properties like impact, hardness, and shear, tensile attained maximum at 15% of SiC. At the composition of Al-Sic from 5% to 10%

there is a drastic change in mechanical properties and at 10% to 15% the small vary in mechanical properties. Due to the extensive applications of aluminum metal matrix it is used in manufacturing industries, structural designs, automotive parts (hydro dynamic tube chassis)

References

[1] Hashim, J., Looney, L. and Hashmi, M.S.J., "Particle Distribution in Metal Matrix Composites," Part-I, *Journal of Materials Processing Technology*, 123: 251-257. 2002.

[2] Nather, S., Brabazon, D. and Looney, L., "Simulation of the Stir Casting Process," *Journal of Materials Processing Technology*, 143-144: 567-571. 2003.

[3] Nai, S.M.L. and Gupta, M. ,"Synthesis and Characterization of Free Standing, Bulk Al/Sicp Functionally Gradient Materials: Effects of Different Stirrer Geometries," *Material Research Bulletin*, 38: 1573-1589. 2003.

[4] Hashim, J., Looney, L. and Hashmi, M.S.J., "Metal Matrix Composites: Production by the Stir Casting Method," *Journal of Materials Processing Technology*, 92-93: 1-7. 1999.

[5] Manna, A. and Bhattacharyya, B., "Study on Different Tooling Systems during Turning for Effective Machining of Al/SiC-MMC," The Institution of Engineers (India) *Journal-Production*, 83: 46-50. 2003

[6] Allison, J.E. and Cole, G.S., "Metal Matrix Composite in Automotive Industry: Opportunities and Challenges," *Journal of Mechanical Science*, 19-24. 1993.

[7] Surappa, M.K., "Microstructure Evolution during Solidification of DRMMCs: State of the Art," *Journal of Materials Processing Technology*, 63: 325-333. 3078 A. MANNA ET AL.1997.

[8] Yang, J., Pickard, S.M., Ctedy, C., Evans, A.G. and Mehrabian, T.,"The Stress/Strain Behavior of Aluminium Matrix Composites with Discontinuous Reinforcements," *Acta Metallurgica Materialia*, 39: 1863-1870. 1997.

[9] Lloyd, D.J., Lagace, H., Mcleod, A. and Morris, P.L. (1989). Micro Structural Aspect of Aluminium Silicon Carbide Particulate Composites Produced by a Casting Method, Materials Science and Engineering, A107: 73-79.

[10] Guo, Z., Xiong, J., Yang, M. and Li, W., "Microstructure and Properties of Tetrapod-like ZnO Whiskers Reinforced Al Matrix Composite," *Journal of Alloy and Compounds*, 461: 342-345. 2008.

[11] Sulaiman, S., Sayuti, M. and Samin, R., "Mechanical Properties of the As-Cast Quartz Particulate Reinforced LM6 Alloy Matrix Composites," *Journal of Material Processing Technology*, 201: 731-735. 2008.

[12] Zhou, W. and Xu, Z.M., "Casting of SiC Reinforced Metal Matrix Composites,"

Journal of Materials Processing Technology, 63: 358-363. 1997.

[13] Gupta, M., Lai, M.O. and Lim, C.Y.H., "Development of a Novel Hybrid Aluminium Based Composite with Enhanced Properties," *Journal of Materials Processing Technology*, 176: 191-199. 2006.

[14] Ourdjini, A., Chew, K.C. and Khoo, B.T., "Settling of Silicon Carbide Particles in Cast Metal Matrix Composites," *Journal of Materials Processing Technology*, 116: 72-76. 2001.

[15] Srivatsan, T.S., Sudarshan, T.S. and Lavernia, E.J., "Processing of Discontinuously-Reinforced Metal Matrix Composites," *by Rapid Solidification, Progress in Material Science*, 39: 317-409. 1995.

[16] M.K. Surappa. J. Mater., "Fabrication of Al-Al2O3/Grp Metal Matrix Composites 3079 ," in *Proc. Tech.* 63, 325-333.1997.

[17] D.M. Skibo, D.M. Schuster, L. Jolla, "Process for preparation of composite materials Containing nonmetallic particles in a metallic matrix, and composite materials made by," *US Patent No*. 4 786 467, 1988.

[18] Alaneme, K.K. and Aluko, A.O. ''Production and age-hardening behaviour of borax pre-mixed SiC reinforced Al–Mg-Si alloy composites developed by double stir casting technique'', West Indian J. Eng., 34(1–2), pp. 80–85 (2012).

[19] Singla, M., Chawla, V., Dwivedi, D.D. and Lakhvit, S. ''Development of aluminium based SiC particulate metal matrix composite'', J. Miner. Matls Charac. Eng., 8(6), pp. 455–467 (2009). f composites