# Investigation on Mechanical Properties of AA6351/SiC and AA6351/SiC/Gr Composites Fabricated by Stir Casting Method

**M. Vijaya, K. Srinivas**

***Abstract:*** ***Metal matrix composites have many usages in the fields like materials and engineering sectors. In the current scenario castings were prepared by liquid metallurgy route and the mechanical properties of both metal matrix (AA6351/SiC) and Aluminum hybrid composite (AA6351/SiC/Graphite) were estimated. The castings were prepared with liquid metallurgy process through the reinforcement of 2-8 weight percent of SiC (AA6351/SiC) where as in hybrid composite reinforcement ranging with equal composition from 2 – 8% of SiC and Graphite. The reinforcing effect of SiC and Gr is studied where in the investigation went into the intensity of Density, Micro hardness and Tensile strength. The mechanical properties are found to increase at 6% SiC and with the combination of Graphite reinforcement in the AA6351 base matrix alloy. The SEM (scanning electron micrographs) images revealed that uniform distribution of particles without voids occur in castings and X-ray Diffraction Analysis (XRD) observes the phase formation of hybrid composite.***

***Index Terms: Castings, Metal matrix, Metallurgy route, XRD.***

## I. INTRODUCTION

Metal matrix composites (MMC's) offer engineers necessities they are predominantly suitable for many applications due to high strength, good structural stiffness, dimensional strength, and lightweight. Metals and alloys will give strength and stiffness to a structures and combinations particularly in matrix composites (MMCs) [1].Aluminium based Metal matrix composites(AMCs) shows major applications in different areas due to light weight and shows good wear resistance property because of particular reinforcements like SiC, $B_4C$ ,$Al_2O_3$ ,$TiO_2$, Gr ….etc.[2][3].This matrix materials exhibit high wear resistant and then becomes more appropriate for Tribological applications in advanced automotive industry applications [4]. AMCs are presently applied in the field of automobile, aircraft, marine applications and facilities in the sector of defence and sports [5]. In Al-SiC matrix composites, Silicon Carbide is considered as reinforcement because of its inexpensive nature with an elevated elastic modulus [6].

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In current research, a combination of weight fractions of SiC particles are considered for study different properties Al-SiC composite is prepared by liquid metallurgy route because of its effective cast ability, reasonably economical, the melt produced by stir casting process is inexpensive and suitable for bulk production [7]-[9]. SiC particles have good wettability with aluminum alloys consequences in good mechanical properties such as increase in stiffness and strength. In Graphite based Aluminum composites, graphite is used as reinforced material and improves self-lubricating capacity of the system. The wear resistance of hybrid composite (Al/SiC/Gr) enhanced with addition of the percentages of graphite [10]. For better mechanical, machinability and tribological properties Aluminum alloys reinforced with Gr and Si particulates are more preferable. In AMC's Graphite will act as a self-lubricating material for the preferred applications [11]. Aluminum based Graphite reinforced matrix composite exhibits as a self-lubricant material with enhanced wear resistance and machinability [12]. In Aluminum hybrid composites graphite will form as a layer between solid lubricant and the contacting surfaces. With the help of Graphite, friction and wear reduced in aluminum hybrid composites. The formation of this lubricant layer, its thickness and hardness depends mostly on the reinforcement of graphite particles in the composite [13]. Latest works have also acknowledged that with increasing graphite more affluent graphite-lubricating film formed on surface of the material, which reduces the wear rate [14]. Experiments like tensile, yield, compressive strength and stiffness are conducted to study the mechanical and wear performance of hybrid composite like Al/SiC/Gr which has many exclusive properties above Aluminum /SiC-MMC or Aluminum /Gr-MMC [15]

## II. EXPERIMENTATION

### A. Reinforced Matrix Material

The materials chosen for the present research are AA6351 reinforce of SiC particle of 50 μm and Graphite particle of size 30 μm.

### B. Preparation of Aluminium Hybrid Composite

In this method, initially the aluminum metal was heated up to $800^0$c for about 5 hours in an induction-coiled furnace. Reinforcing particles (SiC) are heated at $600^0$ c for a period of two hours and graphite particles at $100^0$ c for two hrs to take away the adsorbed hydroxide and other gases from the surface.

Then the metal is heated up to its liquidous temperature i.e. $750^0$ c, such that the metal is totally liquefied. Magnesium powder was added to the melt to maintain the wettability. The heated reinforced particles are added to the melt sequentially in 3 steps. The reinforcement particles were added to the melt and stirred manually for 10 min. Since the melt is in semi solid state, it was very complicated to mix using automatic substance device. The melt was heated to a liquid state and then spontaneous automatic mixing was carried out for 10 min at 300 rpm. At the final step, the furnace temperature was maintained at $750^0 \pm 100^0$c. Then dies are cleaned up to pour the melt into the die. The heated stirrer was immersed into the melt, is run at a speed of 300 rpm, and then adds liquid melt into the die at $750^0$ - $800^0$ c. After solidification, the castings were taken out from the die as shown in Fig. 1. Mechanical testing was conducted as per ASTM standards. The prepared samples were keenly observed through scanning electron microscope (SEM) resulting uniform distribution of reinforce particles in melt.

**Fig. 1. Prepared Samples**

### C. Porosity measurement

Porosity is calculated by the study of theoretical and experimental density by the rule of mixtures and experiments were performed by the Archimedes principle. The porosity of composite material was calculated by the equation

%porosity=1-(experimentaldensity/theoretical density) x100

### D. Micro Structural Characteristics

Micro structural characteristics were calculated for prepared castings with different percentages of reinforcement with the help of optical microscope. To analyse the microstructure of castings a part of section was polished with different grade of emery papers to develop as a mirror surface. After the clean, the polished surface was kept in cotton to protect from atmosphere. Casting surfaces were examined by using scanning electron microscope at different magnifications. Uniform particle distribution was observed in matrix composite with magnifying microstructures.

### E. X Ray Diffraction Analysis

The prepared castings were analysed with the help of x-ray diffraction technique to ensure formation of compounds in different reinforcements of the hybrid composites.

### F. Mechanical Properties Estimation

Mechanical properties for prepared castings of varied reinforcements were estimated in aspects of hardness and tensile properties. Brinell hardness was calculated at a load of 250N and is carried out for all reinforcement's average of three readings on each casting. Tensile test was carried according to ASTM A370 standards. Percentage of elongation is calculated by using stress-strain curves for all the castings.XRD Analysis conduct for different samples to study compound formation.

## III. RESULTS AND DISCUSSION

### A. X Ray Diffraction Analysis

According to first analysis, the XRD results of base metal (AA 6351) are observed in Fig.2. As a second study, the possible formations and different phases of Al-SiC are observed in Fig.3. As castings were prepared by Al-SiC matrix XRD reveals the peaks and phases of possible combinations of Aluminum and SiC. The presence of silicon carbide was reported earlier as a consequence of the direct reaction among the liquid aluminum and silicon carbide particles at high temperature, in accordance with the following result of all the XRD results. In Final study, the Al/SiC/Gr hybrid matrix shows the possibility of various possible combinations of compounds in graphs and the peaks observed in a form of amorphous scales on SiC and Graphite particles. The phases have observed in Fig.4 and Fig.5 the addition obviously modifies reactions during liquid stir casting since a higher amount of aluminum carbide is present apart from an increasing amount of graphite.

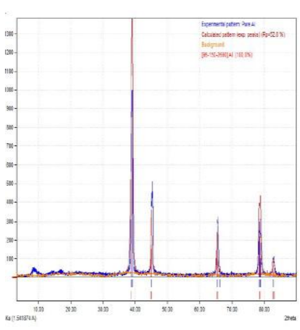


**Fig.2.XRD of AA6351**

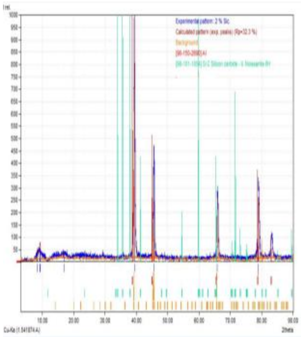


**Fig.3.XRD of 2%SiC**

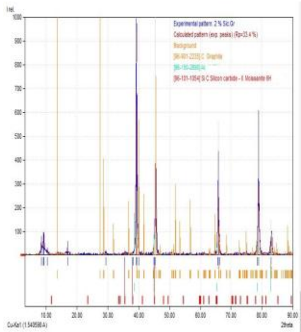


**Fig.4.XRD of 2%SiCGr**

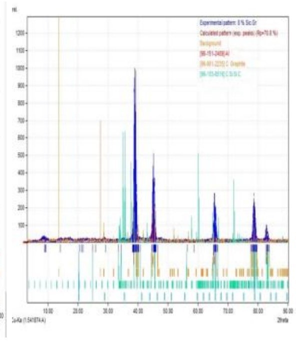


**Fig.5. XRD of 8% SiCGr**

### B. Density and porosity

Generally, the SiC reinforcement increases the density of the composite during manufacturing process. The density of material in aluminium composite is increases gradually up to addition of 10% of SiC as reinforcement Due to addition of graphite the weight of hybrid composite reduced gradually. For calculating theoretical density present study uses rule of mixture.

$\rho$ (composite) = % $\rho$ (matrix metal) +% $\rho$ (reinforcement) ----- [1]

Experimental densities were calculated by Archimedean principle by measuring weight of small piece of composite, in air and then in water with analytical balance of a measurement precision 0.0001 g. For all castings for each percent weight fraction were used for density measurement.

$\rho = w_a / (w_a - w_w) \times \rho_{water}$ --- [2]

Where

$w_a$= weight in air

$w_w$= weight in water

Subsequently, the porosity of the samples was calculated, according to the equation.3

$\%Porosity = 1 - (\rho_e / \rho_t)$ -------- [3]

Where $\rho_e$=experimental density $\rho_t$= theoretical density

By increasing percentage of reinforcements, the porosity increased gradually owing to the occurrence of interstitial voids in clusters and discontinuity throughout stirring and pouring melt into the dies as gasses entrapment.

Table. 1. Density and porosity results of Al-SiC and Al-SiC-Gr material

| Material Density | Theoretical density (gr/cm$^3$) | Experimental Density (gr/cm$^3$) | %Porosity |
|---|---|---|---|
| AA6351 | 2.6 | 2.4 | 7.69 |
| AA6351+2%SiC | 2.61 | 2.56 | 1.91 |
| AA6351+4%SiC | 2.62 | 2.59 | 1.14 |
| AA6351+6%SiC | 2.63 | 2.60 | 1.14 |
| AA6351+8%SiC | 2.64 | 2.61 | 1.13 |
| AA6351+2%SiC+2% Gr | 2.605 | 2.587 | 0.69 |
| AA6351+4%SiC+4% Gr | 2.610 | 2.581 | 1.11 |
| AA6351+6%SiC+6% Gr | 2.615 | 2.571 | 1.68 |
| AA6351+8%SiC+8% Gr | 2.621 | 2.570 | 1.94 |

## IV. MECHANICAL PROPERTIES MATERIAL DENSITY

### A. Hardness

Hardness tests were conducted on different samples reinforced with SiC and both SiC and Graphite, by means of Brinell hardness tester according to ASTM E10 standards. For the evaluation of hardness, 5mm ball indenter and 250N load have been applied for 30 seconds on the castings. The test revealed that the hardness of the composites with silicon carbide as reinforcement is more than that of hybrid composite. The hardness increases because of the existence of hard SiC particles in MMC, leads to load bearing ability in material, which controls the matrix deformation by restraining dislocation movement. The comparing effect of the both Aluminium matrix with percentage of SiC and aluminium hybrid matrix with % of SiC and Graphite are shown in Fig.7. The hardness of the Al-SiC matrix is superior to that of the Al/SiC/Gr. The decline in hardness property in hybrid composite is due to the graphite particles, which was also noticed by earlier researchers. This is because of fragile nature of the graphite particles that are responsible for these effects.

### B. Tensile test

Tensile test of prepared samples were estimated with TUE-C-400 testing machine according to ASTM A370 standards at m/s. The test was led in an advanced metallurgical Laboratory. Capacity of the apparatus is IS 40T and IS-1828-991. Constant strain rate of 0.5 mm/min was assumed during testing of samples. The tested results were observed in Fig.6. and Fig.9 present the comparitive results of both Aluminum matrix and hybrid composites.

**Fig.6.Tensile specimens**

### C. % of Elongation

Fig.8 displays the difference in % of elongation in both Al/SiC and Al/SiC/Gr composites. In Al/SiC matrix, the SiC is focused on in the rolling direction. The orientation of SiC aids in the improved flow of the matrix, than the base alloy. In case of hybrid metal matrix composite with Graphite as reinforcement the percentage of elongation reduced up to 8% of SiC and Graphite. The % of elongation is reduced more in hybrid metal matrix composite than SiC composite.

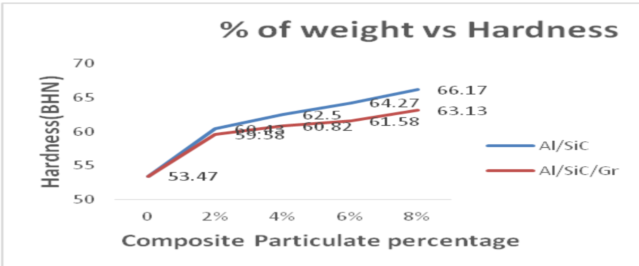



**Fig.7. Hardness7**

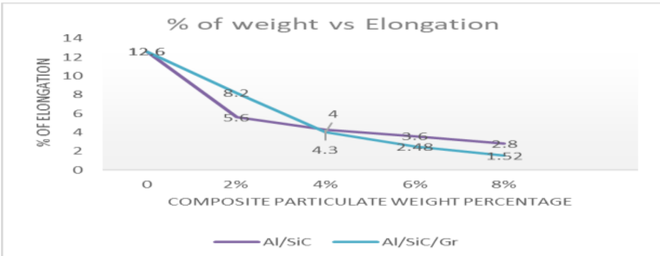



**Fig.8. % of Elongation**

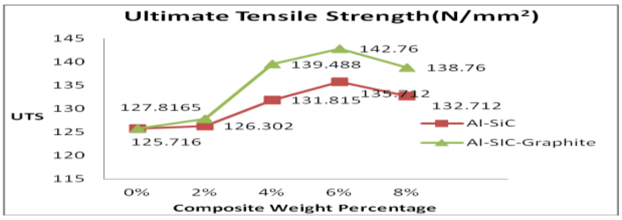
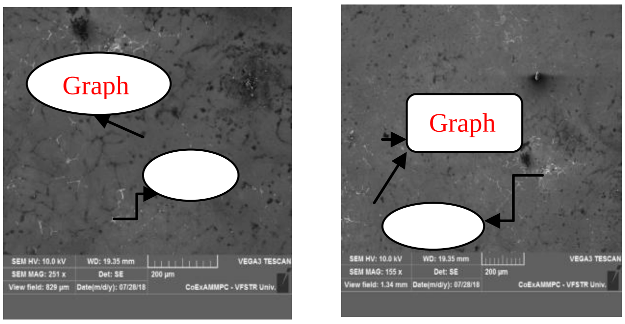



**Fig.9.Tensile Strength**

## V. SEM ANALYSIS

Scanning Electron Microscopy (SEM) of the composites was consequence the morphology of the different combinations of composite. Fig.10 shows the outward composite specimens which shows that the mixture of SiC and graphite with even scattering of particles in the matrix.




**2%SiC & Gr** **6%SiC &Gr**

**Fig.10. SEM images of Composites**

## VI. CONCLUSIONS

- AA 6351/SiC/Gr hybrid composite and AA6351/SiC metal matrix material were effectively prepared by Liquid Metallurgy route (Stir casting technique) with different weight % of reinforcements.
- There is a significant enhanced mechanical property for hybrid composites than metal matrix composites.
- The density of the Al/SiC & Al/SiC/Gr reinforced hybrid composites with different weight fractions, was calculated and the density rises with SiC and lowers with SiC/Gr hybrid particulates, so this Al/SiC/Gr hybrid composites can be considered as a suitable light weight Material for any applications.
- The 6 wt% SiC and Graphite reinforced AA6351 has good mechanical properties than other weight percentages of hybrid and metal matrix composites.
- From the study of SEM and XRD analysis, it reveals that the even scattering of reinforcing particulates and possible combinations of phases.

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## REFERENCES

1. G. Sivakaruna, Dr. P. Suresh Babu, vol:8, Issue 9, 2017, Article ID: IJMET_08_09_012, pp. 112–131.
2. C. Velmurugan et al. ISSN: 1949-4866 terials vol:2, (2011), pp. 49-68.
3. Niranjan K, Shiva raj B,Vol: 04 Issue: 01,2017 ,pp 1036-1040.
4. Macke A, Schultz BF, Rohatgi P, Adv Mater Processes2012; 170: pp 19–23.
5. T. Nithyanandhan, K. Volume 6, Special Issue 7, April 2017, pp 118-126.
6. K Karvanis, D Fasnakis, IOP Conf. Series: Materials Science and Engineering 161 (2016) 012070 doi:10.1088/1757-899X/161/1/012070, pp 1-8.
7. Jeevan V., Rao C.S.P., Sonraj N, 2013 ISSN 2321- 5747, Vol.1, Issue 2, pp34-38.
8. Hosim J, Looney L Hashmi , (1999), pp. 17
9. Devi Neelima, Mahesh.V, Selvaraj. N, 2011 ,Vol: 1 Issue 4, pp 793-799
10. S. O. Adeosun, Vol:8 No: 7, 2014, pp. 731-736.
11. Pradeep Sharma, Dinesh Khandujaa, Satpal Sharmab.2016;5(1), pp:29–36
12. Dr. Rajanna.S, 1(1), 2013, pp 39-44.
13. F. Akhlaghi, A. Zare-Bidaki, Wear 266 (2009), pp 37-45.
14. B. Stojanovica, M. babica, 19, No 1, (2013), pp 83–96.
15. Rohitha Nagabhyrava, Sravan Kota, Volume 8, Issue 5, May 2017, Article ID: IJMET_08_05_028, pp. 265–269.
16. Rajmohan, T. Ranganathan, S. Suryakumari, volume 7, 2014, pp .11–14
17. N. Nanda Kumar et al (IJMER), pp 166-172
18. C. Velmurugan et al. volume 2, (2011), pp. 49-68.
19. B. VijayaRamnath, C.Elanchezhian.Adv. Mater Sci. 38 (2014), pp.55-60.
20. M. Vamsi Krishna, Anthony. Xavier gcmm 2014.procedia Engineering 97 (2014), pp918 – 924.
21. PrashantSN et al, ISSN 2278 – 0149 Vol. 1, No. 3, October 2012pp.106-112.
22. Dr. Rajanna.S, ISSN 2347 – 7393 1(1), 2013, pp39-44.
23. YAnamandalaRaghuram Chowdary, C. Yuvaraj, K. Prahlada Rao, B. Durgaprasad, Vol.2, No.6, Pages: 286-289 (2013) Special Issue J. Singh, vol. 4, 2016. pp. 1-17.
24. Revanasidappa M D et al, (NCAMES-2016) ISSN: 2231-5381, pp.2231-5381.
25. P. Ramakrishna, New Age International Publishers, (2009), pp 377-379.
26. Alaneme KK, Aluko AO, 2012,19:992–6, pp.992-996.
27. P. Karthik, M. S. Srinivasa Rao 2nd National Conference On Developments, Advances & Trends in Engineering Science [NC-DATES2K16] ISSN: 2249-6645, pp.49-52.
28. S. Suresha, B.K. Sridhara. 70 (2010), pp.1652–1659.
29. A. Baradeswaran, Vol.53 No.2 (2011), pp.163- 170.

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