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Property Evaluation of Aluminium Metal Matrix Composite for Disc Brake Application

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***Abstract* - Metal matrix composites are the class of composite materials finding vast applications in automotives, aircraft, defense, sports and appliance industries. The disc brake is mostly fabricated using Aluminium based metal matrix composite. The aim of the present work is synthesis Aluminium (Al) – Silicon Carbide (SiC) composite. Composites of Al with 5 to 40wt. % of SiC were fabricated by powder metallurgy techniques. The influence of Silicon Carbide particles and its amount on both physical and mechanical properties of Aluminium composite were investigated. The fabricated composite properties are investigated such as relative density, hardness, compression strength and porosity using various techniques. The phase composition and microstructure were analyzed by X-Ray Diffraction and Scanning Electron Microscope. XRD studies conformed that the dominant components were Al and SiC. Densification and compressive strength of the composites is found to increase with increase in the amount of SiC. The porosity of the composite samples has been decreased with increase in amount of SiC. Increasing the amount of SiC leads to higher hardness. XRD studies confirmed that the dominant components are Al and SiC present in the composite. SEM studies showed that the distribution of the reinforced particle was uniform.**

Keywords—composite, powder metallugy, Al-SiC, properties, characterization

I INTRODUCTION

The disc brake friction materials play an important role in braking system. They convert the kinetic energy of a moving machine to thermal energy by friction during braking process. There are two types of braking systems used in vehicles, which are drum brake system and disc brake system. Although both systems look very similar, disc braking system is much effective than the drum brake system. Since, brake disc (or) rotor is a crucial component from safety point of view. Materials used for brake systems, should have stable and reliable frictional and wear properties under varying conditions of load, velocity, temperature, environment and high durability.

In addition, these advanced materials should have better performance under severe service conditions like higher speed, higher load etc. which are increasingly being encountered in aerospace and modern automobiles. The latest disc brake is made up composite materials only because of their less density, stiffness, strength and resistance to fracture compare to the metal or alloy used alone. They also provide lot of benefits about the safety and the performance. Besides these advantages, there are certain disadvantages encountered during their service conditions. The cast iron disc brake is unsuccessful due to its heavy weight, aluminium failed due to lower wear resistance and titanium exhibits low wear and low load capacity and ceramics are brittle. Comparing the above materials the carbon-carbon composite is good but its cost is high.

Aluminium is used in a variety of applications due to its high strength to weight ratio but the major drawback is due to its poor wear resistance. This has been rectified by the addition of SiC like hard constituents as reinforcing element. Addition of SiC ceramic particles in aluminium has improved the strength, hardness, electrical conductivity and both wear and corrosion resistance.

Among other techniques, Powder Metallurgy (PM) has been considered as one of the potential techniques for producing metal matrix composites. The advantage of this method is its low processing temperature compared to melting procedures. Good reinforcement, uniform distribution of particles and near net shape module can be achieved in this technique. This method involves three major stages: blending of the metal and ceramic powders, pressing or compaction, and sintering. These last two steps are often combined during hot pressing.

In this present investigation, Al-SiC composites have been fabricated using PM process. Eight compositions of Al-SiC composites were prepared by varying the concentration of SiC as 5, 10, 15, 20, 25, 30, 35 and 40 wt. %. The composites were fabricated using a uni-axial hydraulic press and the compacted pellets were subsequently sintered in an electrical furnace. The physic-chemical properties of the individual powders and the composites were determined using different analytical techniques such as particle size analysis, density, porosity Thermo Gravimetric measurements and Differential Scanning Calorimetry (TGA/DSC), XRD and SEM. The mechanical properties of the Al-SiC composites were evaluated such as hardness and compression strength.

II EXPERIMENTAL WORK

The flow chart for the preparation of Al-SiC composite is shown in Fig.1

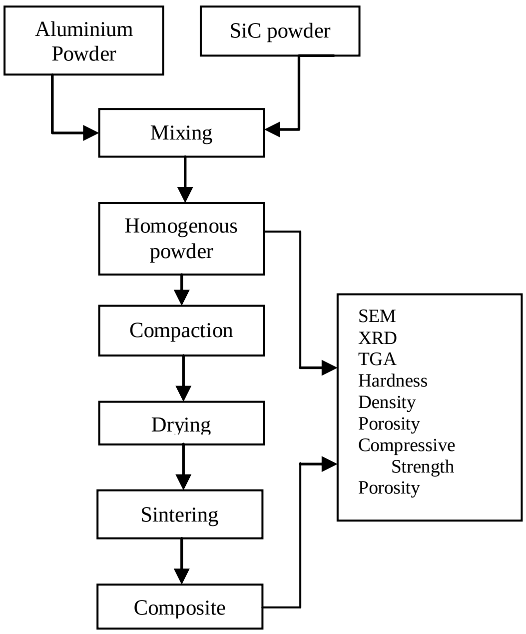

Fig. 1. PROCESS FLOW CHART

A. *Raw material*

Aluminium (43.81μm, 99.7% Purity, Kemphasol, India) and Silicon Carbide powders (70.79μm, 99% Purity, Kemphasol, India) are used as the constituents for the compostite preparation. Poly Vinyl Alcohol (PVA) is added as a binding agent in a gel form.

B. *Mixing of powder*

Pure Al and SiC powders were taken in the various compositions (5 to 40wt. % SiC) namely T1, T2, T3, T4, T5, T6, T7, T8 and T9 and subjected to dry mixing. The homogenous mixing of powders was done by using mortar and pest. The grinding was done for about two hours to obtain a uniform composition of the mix. Then PVA is added to the blended powder and filled in suitable die.

TABLE I. POWDER COMPOSITIONS

Sample Name	T1	T2	T3	T4	T5	T6	T7	T8	T9
Composition (% SiC)	0	5	10	15	20	25	30	35	40

C. *Sample Preparation*

The prepared powder was compacted by means of uni axial press. The die diameter was 15mm. About 2 grams of powder was poured into the die, and then the load of 11.48 KN was applied followed by ejection of samples from the die. Then, all the samples were dried in a hot air oven at 110°C for 2 hours.

D. *Sintering*

The dried samples were kept in the closed container and subjected to sintering by using a muffle furnace. The sintering was performed at different temperature regions ranging from 250°C to 800°C with variong durations.

E. *Characterization*

The particle sizes of the powders are determined by ultrasonic method using La-950 particle size analyzer. X-ray diffraction of the powders as well as composites is examined using (Rigaku) Cu-Ka radiation with wavelength 1.5418 Å at a scan rate of 5°/min. Thermo gravimetric analysis and differential scanning calorimetry of the aluminium and aluminium silicon carbide powders were performed using a thermal analyzer (NETZCH STA 449F3 STA449F3A-0929-M) in the Al_2O_3 crucible at N_2 atmosphere up to (28°C/20.0 K/min) 700°C to compare the thermal decomposition and the enthalpy behavior of the powder sample. The microstructure features of the samples were carried out using scanning electron microscopy (TESCAN, VEGA-SBH) of both back scattered and secondary electron imaging technique.

F. *Testing of Properties*

In order to evaluate the properties of the Al-SiC composite hardness, porosity, density and compressive strength were determined.

l. Density of the sample was determined using the weight and volume of the specimens. The volume was determined by measuring the accurate dimension of the composite samples.

$$\rho_s = \frac{m}{v} \text{ ---------------------------- (1)}$$

Where,
ρ_s= Density of sintered specimen (g/cm^3)
m= Weight of sample (g)
v = Volume of the sample (cm^3)

2. Porosity of the sintered sample was calculated from the following relation

$$\rho = 1 - \frac{\rho_p}{\rho_s} \text{----------------------- (2)}$$

Where,
ρ is the fractional porosity
ρ_P is the density of the sintered sample
ρ_S is the density of the green (solid) sample

3. Hardness of the sample has been found by the use of Vickers hardness instrument. The pyramid type ball indenter is used and the various loads are applied like 25g, 50g, 100g and 200g for 10 seconds. The required values are calculated from the following formula.

$$HV = 1.854 * \frac{p}{d^2} \text{----------------- (3)}$$

Where,
P = load in Kg
d = average length of diagonal in mm

4. Compressive Strength was performed on Al-SiC composite specimens on UTM. The sample was compressed between two flat planes and the maximum failure load was recorded.

III RESULTS AND DISCUSSIONS

G. Characterization

l. Particle size

The particle size and distribution of Al and SiC powder is determined by laser particle size analyzer and the results are presented in Fig. 2 and 3.

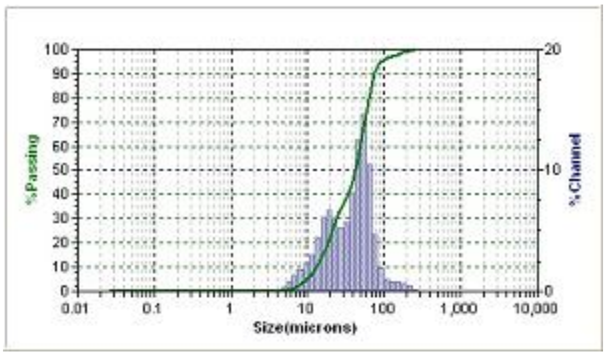

Fig. 2. PARTICLE SIZE OF Al POWDER

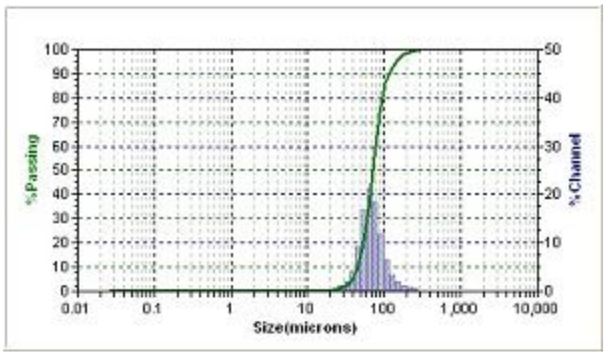

Fig. 3. PARTICLE SIZE OF SiC POWDER

It has been noted that the average particle size of the Al powders is Al 43.81μm (d 50) and that of SiC 70.79μm (d 50). It shows that the average particle size of SiC is little higher than the Al powder which may influence in the mechanical properties of the composite.

2. *X-ray Diffraction*

Fig. 4 shows the X-ray pattern of Al. The spectrum exemplifies the presence of Al in the pure form and the data is in good agreement with this standard JCPDS file no: 0787.

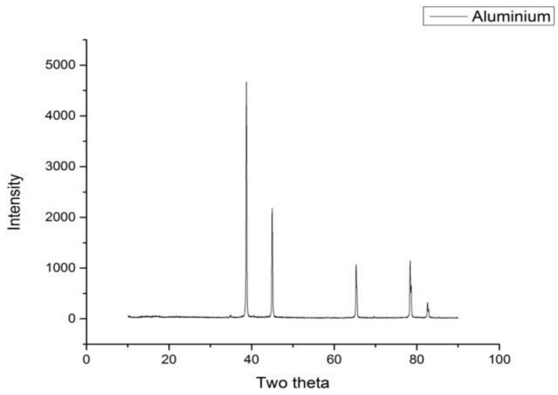

Fig. 4. X-RAY DIFFRACTION PATTERN FOR Al POWDER

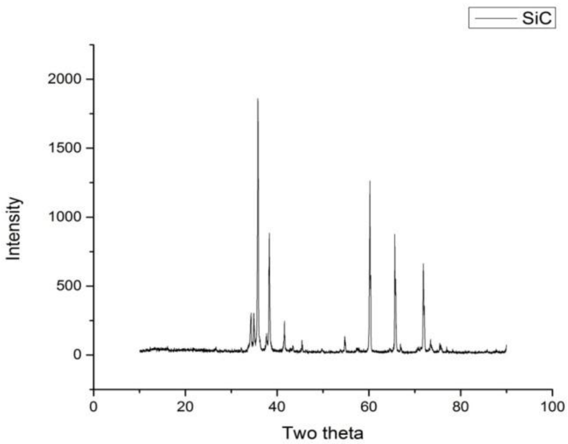

Fig. 5. X-RAY DIFFRACTION PATTERN FOR SiC

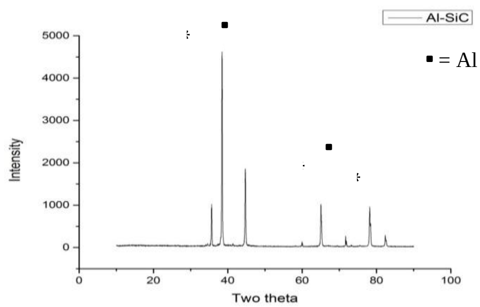

Fig. 6. X-RAY DIFFRACTION PATTERN FOR Al – SiC COMPOSITE

Fig. 5 shows the XRD Spectrum for SiC which reviles the pure form of SiC and matches with the JCPDS file no: 1129. The XRD spectrum of Al-SiC composite is shown in Fig.6. The spectrum indicated the presence of SiC with miner a peak which is dispersed in the Al matrix. The Al-SiC composite also exhibits the absence of secondary phases which has been noted from the XRD spectrum.

3. TGA/DSC

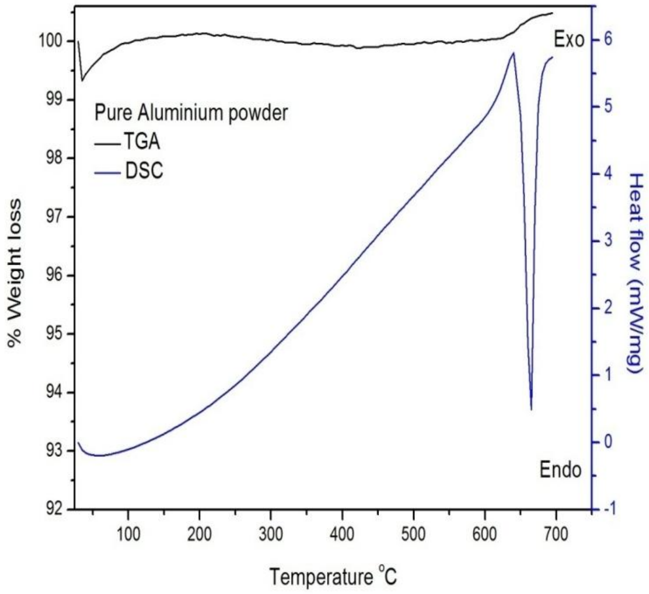

Fig. 7. TGA/DSC CURVE FOR PURE Al

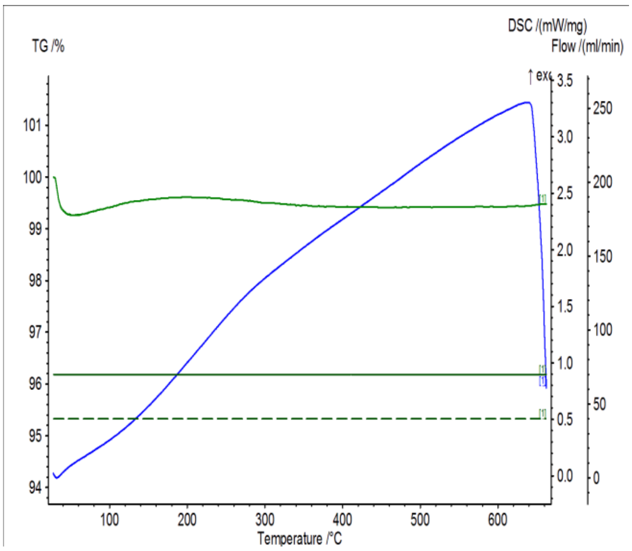

Fig. 8. TGA/DSC CURVE FOR Al – SiC COMPOSITE

Fig. 7 shows the TGA/DTA curve for th pure Al which reviles that, there wont be any dissociation and decomposition of aluminium are occurred during the melting process. The DTA curve clearly indicates the the endothermic peak at 660^{o}C which is responsible for the melting point of the Al. Fig. 8 revils the TGA/DTA curve of Al-SiC composite on progressive melting process its clearly indicates that shift in the melting temprerature of Al by the presents of high temperature SiC dispersoids in the metal matrix.

4. Scanning Electron Microscope

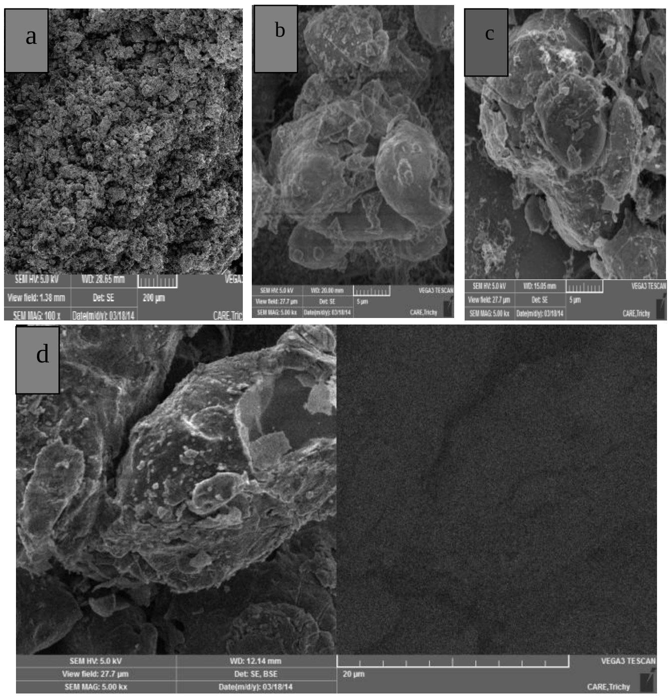

Fig. 9. SEM IMAGE OF VARIOUS COMPOSITION OF Al – SiC COMPOSITE (a) T1 (b) T3 (c) T6 (d) T9

The morphological features of Al-SiC composites are shown in Fig.9, which is prepared by compaction technique. The micrographs reviles that the strong adhesion of SiC particles on the Al matrix by high temperature sintering process. Miner pores have been randomly observed in the prepared composite surface it may be due to non-uniform distribution of SiC particulates on the Al matrix and solidification of al matrix. The non-uniform particulate in the matrix leads to the agglomeration of particles.

H. Property Evaluation

1. Density

Both the green and sintered densities are measured for each composition of the Al-SiC composites and the average values are plotted in a graph which is shown Fig. 10. It is found that the densification of the Al-SiC composite is increase with increase in the concentration of SiC, which is resulted in the densification of the composite. The sintered density is higher than the green density of the pellets, as seen in many of the MMC composite. The sintered density may be due to the evaporation of the organic binder and also the densification and collisions of particles resulting in the higher densification process.

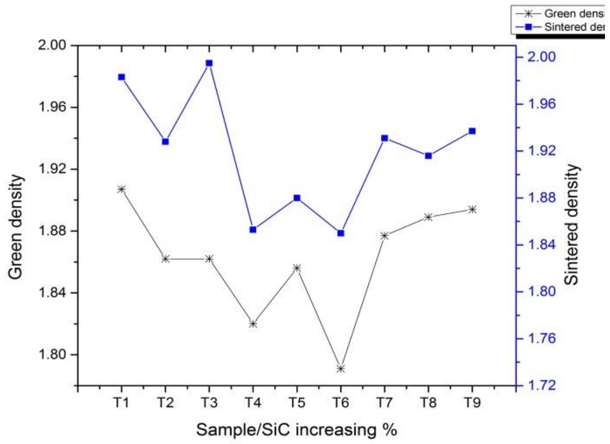

Fig. 10. GREEN DENSITY VS SINTERED DENSITY

2. Porosity

Fig. 11 shows the porosity of the Al-SiC composites. The porosity of the composite samples has been decreased with increase in wt. % of SiC up to 40% wt. %, which may be due to the increase in percentage of coarser reinforcement and melting of aluminum tends to close the pores in the composite.

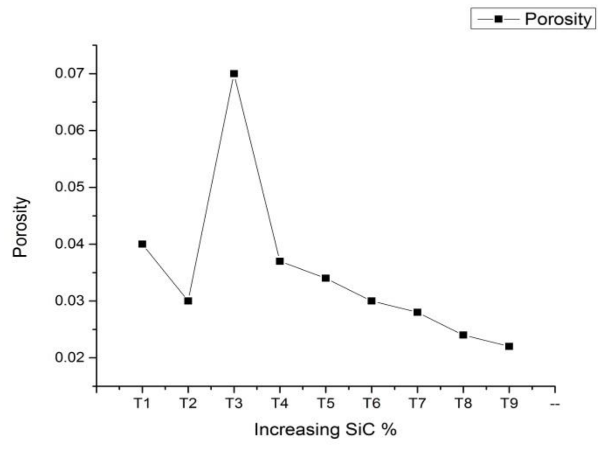

Fig. 11. THE EFFECT OF SiC PARTICLES AND THE AMOUNT OF POROSITY

3. Hardness

The average hardness value of Al-SiC composite measured on the surfaces using diamond pyramid ball indenter at various lo[illegible] 50g, 100g and 200g. Inc[illegible]ing the amount of SiC

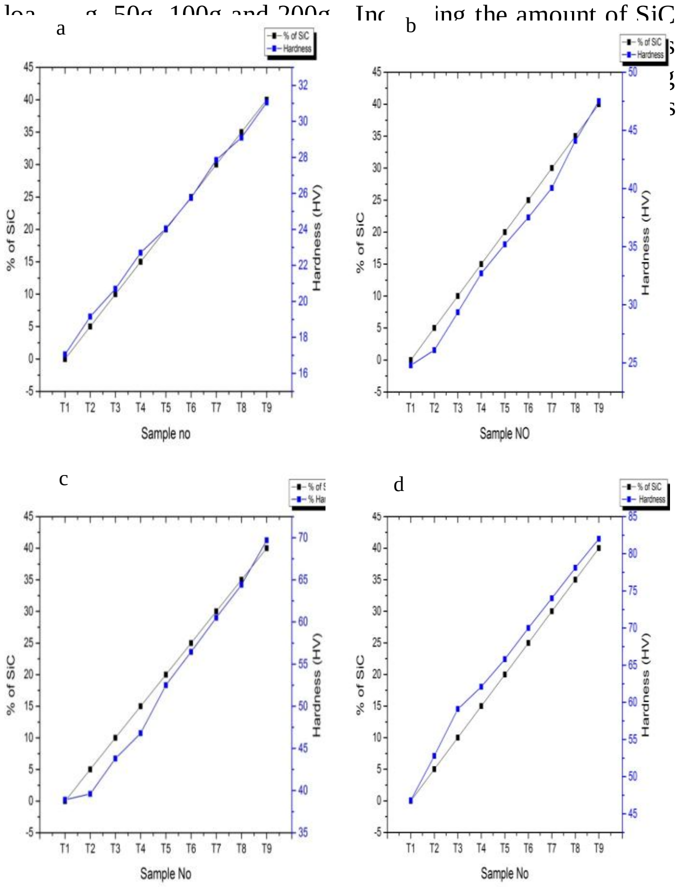

Fig. 12. THE EFFECT OF SiC PARTICLES AND THE HARDNESS VALUE
Various load a) 25g b) 50g c) 100g d) 200g

4. Compressive Strength

The compressive strength is determined for all compositions of Al-SiC composites and the values of the compressive strength for PM samples were plotted in the graphs with weight % of SiC. Fig. 13 shows the compressive strength of the composites fabricated through PM route. The compressive strength of the Al-SiC composites increases with increasing weight % of SiC from 5 to 40 wt. % of SiC. The maximum strength of 19.22 MN is obtained at 40% SiC sample. This was attributed to the uniform dispersion and mechanical interlocking of SiC particles in the aluminium matrix obtained during the sintering process, which strengthened the specimens.

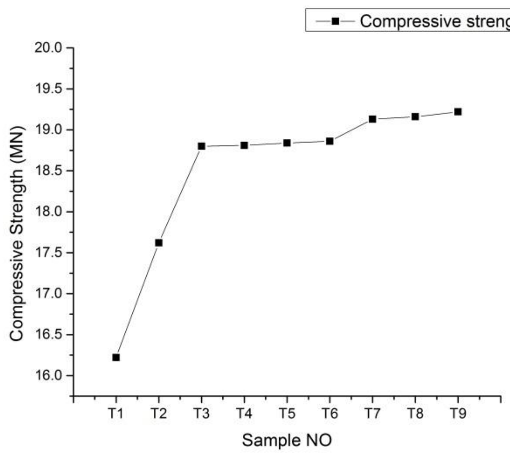

Fig. 13. COMPRESSIVE STRENGTH OF THE Al-SiC COMPOSITE

IV CONCLUSIONS

The effect of addition of Silicon Carbide particles and its amount on both physical and mechanical properties of Al-SiC composites are investigated.

1) The presence of Al and SiC are verified by XRD technique
2) Particle size of the powder are identified by laser method and they are in micro level
3) The density, hardness and compressive strength of the aluminium metal martix composite increases with increase in reinforcement content from 5 to 40 weight percent of SiC.
4) Porosity of the composite is decreased with the increasing wt. % of SiC in to the aluminium matrix.
5) The X-ray diffraction shows absence of secondary phase in the composite and also its well agreement with the JCPDS No.
6) The morphology of the composites exhibits the agglomerated particles intermingled with hard SiC dispersoids.

V FUTURE WORK

Fabrication of Al-SiC metal matrix composite with the addition of MgO and graphite as a reinforcement will be investigated.

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