A STUDY ON MICROSTRUCTURE AND CHARACTERIZATION OF ALUMINUM 7075 METAL MATRIX REINFORCED WITH SILICON CARBIDE PARTICLES USING STIR CASTING METHOD

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Abstract

In the advances of application software and available digital computer technology, having more practical challenging field for Designers, Engineers and Academicians for seeking superior composite materials with their mechanical properties. In this study, Aluminum 7075 based metal matrix reinforced with Silicon Carbide particles used to manufacture required composite materials by using Stir casting method. During casting process care is taken with respect to degasifying, proper vertex speed to have thoroughly mixing of reinforcements and to reduce the formation of oxygen in molten material by adding Hexachloro-Ethane tablets. The influence of reinforced ratio 0,1,2,3 and 4 weight percentages of Silicon carbide particles with Aluminum 7075 metal matrix was determined. The distribution of reinforced particles in metal matrix material was studied by using Scanning electron microscope with energy dispersion Spectroscopy analysis. The importance of adding reinforced particles with Aluminum 7075 is to study Microstructure characterization, Chemical compositions, mechanical and tribological properties. Tribological properties of these composite materials were investigated by wear test using pin on disc for different loads at constant speed. In this work, it has been observed that, the reinforcement particles are uniformly distributed in metal matrix composites. The mechanical properties such as hardness, yield and ultimate tensile strength increases with increasing weight percentage of reinforcement in metal matrix composites. It was also observed that, the wear rate decreases with increase in weight percentage of reinforcement.

***Keywords**: Aluminum 7075, Silicon Carbide, Stir Casting, Mechanical properties, Tribological properties*

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1. INTRODUCTION

There have been various studies in engineering materials since 1950. Several super alloys and heat resistant materials have been developed for various industrial applications such as aerospace, space craft, automotive and submarine structures. The advances in engineering materials have lead to new generation materials particularly having low density, light weight, high strength, hardness and high stiffness. One of the most important of these advanced materials is composite. Metal matrix composite (MMC) materials are one of the widely used composites because of their excellent properties such as high strength to weight ratio, hardness, stiffness, wear and corrosion resistant. Silicon carbide particle (SiC-p) reinforced aluminum based MMC are most commonly used Composites and commercially available due to their economical production. The metal matrix composites are gaining popularity in the sectors like automobile industries, aerospace applications and biomedical applications. The increase in the use of metal matrix composites particularly Aluminum MMC also increases the need for developing an appropriate technology for the cost effective methods of production of composites. In the advances of application software and available digital computer technology will have more practical challenging field for designers, engineers and academicians for seeking superior composite materials with their mechanical and thermal properties.

2. LITERATURE SURVEY

K. Madheswaran, S. Sugumar, et.al [1] has studied **"**Mechanical characterization of Aluminum-Boron Carbide composites with influence of Calcium Carbide particles". The objective of this work is to Fabricate and Testing the Mechanical properties of Aluminum metal matrix composites with Boron Carbide and Calcium Carbide reinforcements at different volume fractions. Mechanical properties like Tensile strength, Shear strength and Toughness of newly developed MMCs is improved significantly by incorporating Boron Carbide and Calcium Carbide particles. The Toughness of material is considerably reduced if the percentage of Calcium Carbide addition is increases. From this study, it was conclude that the Ultimate Tensile strength of Aluminum metal matrix composite with 2% of Calcium Carbide and 8% Boron Carbide reinforcements compared with 1% Calcium Carbide and 9% Boron Carbide reinforcements is increased by 8%.

Ehsan Ghasali, Masoud Alizadeh, et.al [2] worked on "Investigation of Microstructure and Mechanical properties of B_4C-Aluminum matrix composites prepared by

Microwave sintering". The B_4C reinforced Aluminum composites were fabricated by Microwave heating of the mixture of B_4C (10, 15 and 20 wt. %) and Aluminum powder at 650,750,850 and 950^0c.The effect of different amounts of B_4C on the Microstructure and Mechanical properties of Aluminum matrix was examined. The maximum bending (238MPa) and Compressive strength (330MPa) values were measured for composites sintered at 950 and 750^0c respectively.

Poovazhagan.L, Kalaichelvan.K, et.al [3] has investigated on "Characterization of Hybrid Silicon Carbide and Boron Carbide nanoparticles reinforced with Aluminum alloy composites". Hybrid nanocomposites based on Aluminum alloy 6061 reinforced with different hybrid ratios of SiC (0.5, 1.0 and 1.5 vol. %) and B_4C (fixed 0.5 vol. %) nanoparticles were successfully fabricated using Ultrasonic Cavitation based solidification process. The fabricated cast specimens were characterized using SEM study with EDS analysis, Hardness test, Tension test and Impact test.

Pankaj Sharma, Amit kumar Bindal [4] has studied "The Development of Mechanical and Metallurgical behavior of Al-SiC reinforced metal matrix composite". Aluminum based metal matrix composite containing up to 5, 10 and 15 weight percentage of Silicon Carbide particles along with 5% Fly Ash are synthesized using Stir Casting method.

Tamer ozben, Erol Kilickap, et.al [5] has worked on "Investigation of Mechanical and Machinablity properties of SiC particles reinforced with Aluminum MMC". The influence of reinforced ratios of 5, 10 and 15wt. % of SiC-p on Mechanical properties was examined. It was observed that increase of reinforcement element addition produced better Mechanical properties such as Impact strength, Toughness and Hardness but the Tensile strength showed different trend of increased up to 10 wt. % of SiC-p reinforced and then decreased when 15wt. % of SiC-p reinforcement addition.

3. OBJECTIVES OF STUDY

1. To manufacture composite material by using Stir Casting method for Aluminum 7075 metal matrix reinforced with Silicon carbide (SiC) particles of size 400mesh.
2. To fabricate the tensile test specimens as per ASTM standard E8 and wear test specimens as per ASTM standard G99.
3. To study the microstructure of metal matrix composites by using SEM interfaced with EDS.
4. To evaluate the mechanical properties such as hardness, yield and ultimate tensile strength of composites.
5. To evaluate tribological properties of Metal matrix composites by using computer interfaced pin on disc test rig.

4. METHODOLOGY

The detailed methodology used for the manufacturing of composite materials as shown in figure 1.1

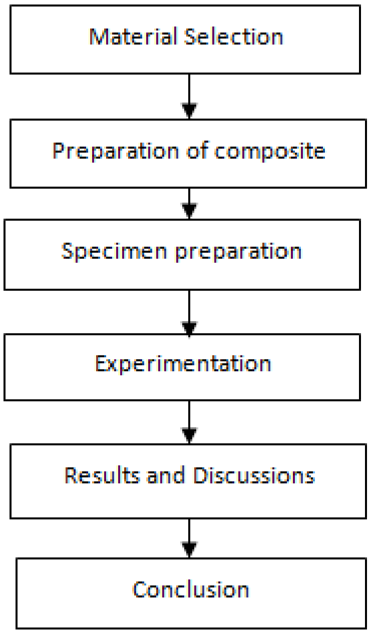

Fig- 1.1: Detailed experimental procedure

5. EXPERIMENTAL PROCEDURE

5.1 Selection of Materials

5.1.1 Aluminum 7075 Metal Matrix

Aluminum 7075 has an excellent machinability property. It exhibits well resistant to corrosion under both ordinary atmosphere and marine conditions. The figure 1.2 shows Aluminum 7075 ingots available in different shapes.

Fig-1.2: Aluminum 7075 ingots

5.1.2 Silicon Carbide Particles

Silicon Carbide is a compound of Silicon and Carbon. Grains of Silicon Carbide are bonded together by sintering to obtain hard ceramics. They are widely used in applications requiring high endurance limit in Car brakes, clutches and ceramic plates in bulletproof vests. Its chemical formula is SiC. Figure 1.3 shows preheated Silicon Carbide particles of size 40μm to 70μm (400 grit size). The melting point temperature of Silicon Carbide is 2700^0C.

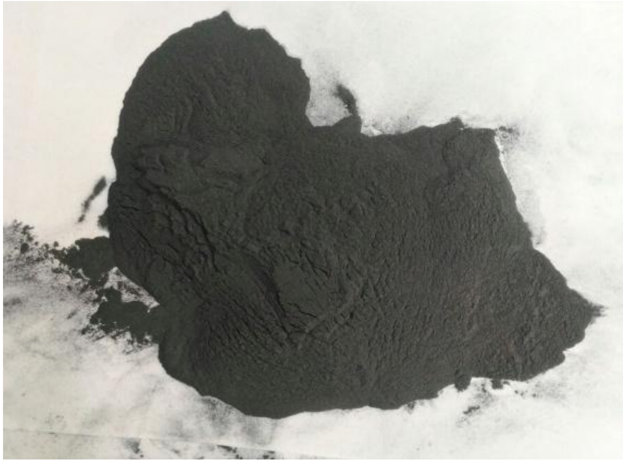

Fig-1.3: Preheated Silicon Carbide particles

5.2 Manufacturing of Composite Materials

Composites are prepared by stir casting method. The base metal aluminum 7075 was heated and melted in a crucible at temperature of 750^0c in the induction resistance furnace. The stirrer was immersed into the molten metal bath and stirrer rotates at a speed of 100 to 300 rpm to create vortex in the liquid metal. Preheated silicon carbide particles (SiC-p) is added to the molten metal through the side of the vortex. After completion of addition of silicon carbide particles (SiC-p), the stirrer was continued to rotate for 5 minutes and pore molten metal mixture into the required mould cavity as shown in Figure 1.4.

Fig-1.4: Prepared mould cavity for casting process

After casting process of Aluminum 7075 metal matrix with Silicon carbide (Sic) particle composite materials was obtained as shown in figure 1.5.

Fig-1.5: Manufactured cast product

5.3 Specimen Preparation

Test specimens were prepared for microstructure analysis, chemical composition analysis, hardness, tensile test and pin on disc wear test by using conventional engine lathe machine. Figure 1.6 shows test specimens for Microstructure analysis, EDS analysis and Hardness test. Figure 1.7 shows tensile test specimens prepared as per ASTM E8 standard with various wt. % of Silicon Carbide particles. Figure 1.8 shows pin on disc wear test specimens prepared as per ASTM G99 standard with various wt. % of Silicon Carbide particles.

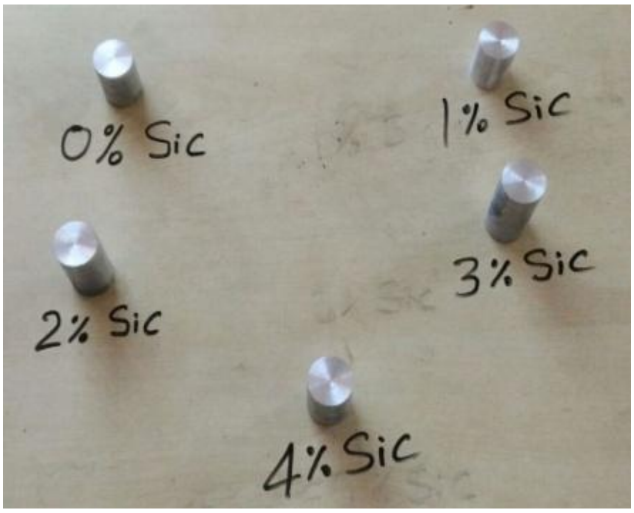

Fig-1.6: Test specimens for Microstructure analysis, EDS analysis and Hardness test

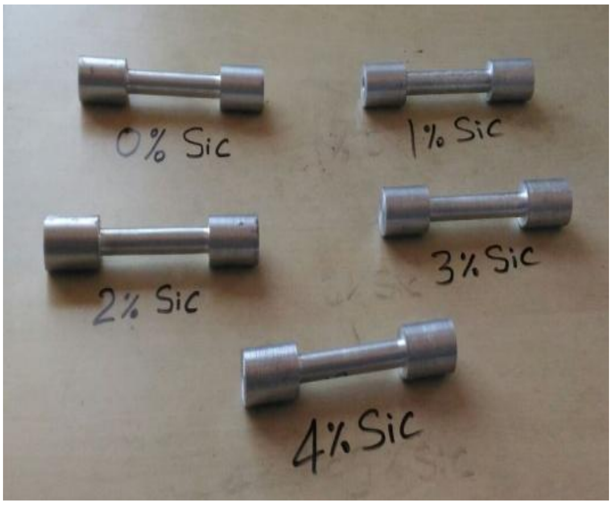

Fig-1.7: Tensile test specimens with various wt. % of Silicon Carbide particles

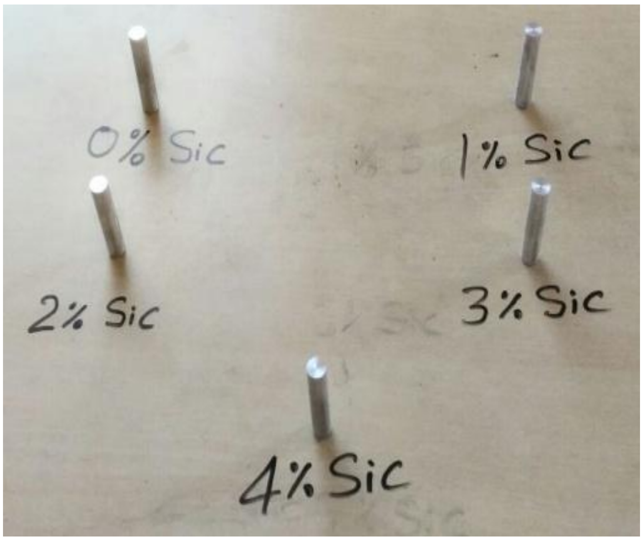

Fig-1.8: Pin on disc wear test specimens with various wt. % of Silicon Carbide particles

5.4 Experimentation

5.4.1 Microstructure Analysis

The Scanning electron microscope (SEM) is used to analyze the distribution of Silicon Carbide particles in the matrix material Aluminum 7075. SEM produces images of a sample by scanning with a focused beam of electrons. The electrons interact with atoms in the sample to produce various signals that contain information about the sample surface composition. The electron beam is generally scanned in a raster scan pattern and the beam's position is combined with the detected signal to produce an image. The uniform and non-uniform distribution of reinforcement particles are verified by using SEM analysis.

5.4.2 Chemical Composition Analysis

Energy dispersive spectroscopy (EDS) is an analytical technique used for the chemical characterization of the specimens. The EDS technique detects x-rays emitted from the sample during bombardment by an electron beam to characterize the elemental composition of the analyzed volume. Features or phases as small as 1 µm or less can be analyzed.

5.4.3 Hardness Test

The Hardness of the composite materials was determined by using Brinell hardness testing machine. By selecting the ball indenter diameter 5mm and major load 250kgs, test was conducted for the composites with different weight percentage of reinforcements.

5.4.4 Computer Interface Tensile Test

As per ASTM E8 standard, composite specimens for various reinforcements such as 0,1,2,3 and 4% by weight were conducted a tensile test with computer interface to obtain required mechanical properties. The obtained trend of stress-strain results of required yield stress and ultimate tensile strength were presented in results and discussion.

5.4.5 Computer Interface Pin on Disc Wear Test

As per ASTM G99 standard, composite specimens for various reinforcements such as 0,1,2,3 and 4% by weight were conducted wear test with computer interface to obtain required tribological properties. The obtained results of required wear rate and coefficient of friction were presented in results and discussion.

5.5 RESULTS AND DISCUSSIONS

5.5.1 Microstructure Analysis

The microstructure of specimens (different weight percentage of reinforcement) was examined by using Scanning electron microscope (SEM). Figure 1.9 to 1.13 shows SEM images with different weight percentage of Silicon Carbide particles of mesh 400 under the magnification factor of 1500X. It was observed that reinforcement particles are uniformly distributed on the metal matrix.

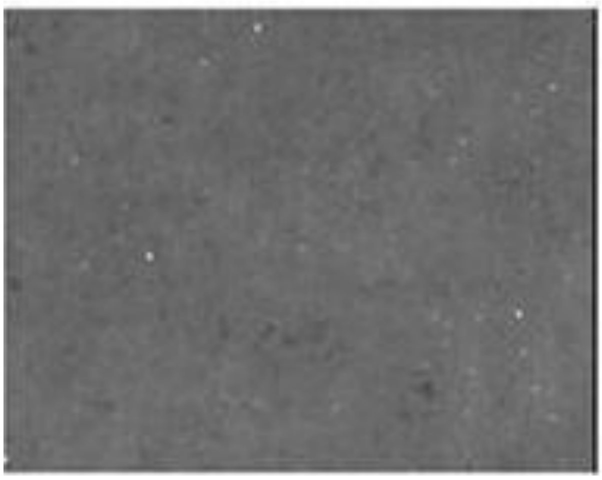

Fig-1.9: Pure Al 7075

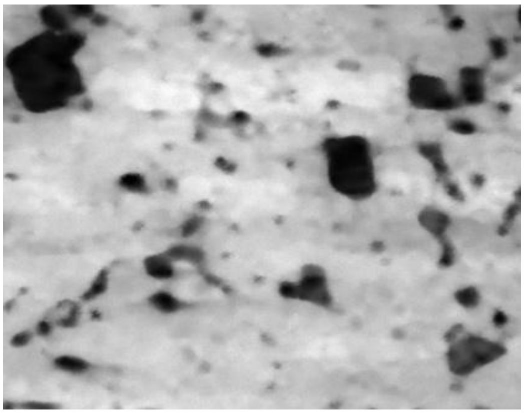

Fig-1.10: Al 7075 with 1% SiC-p

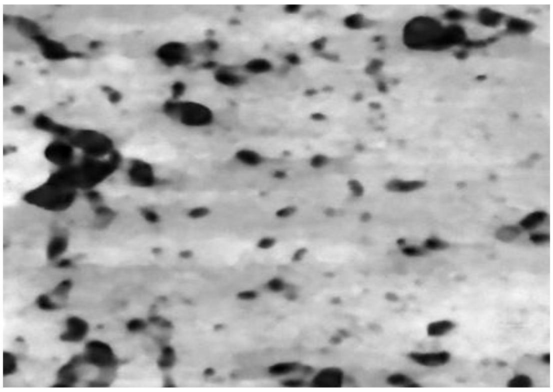

Fig-1.11: Al 7075 with 2% SiC-p

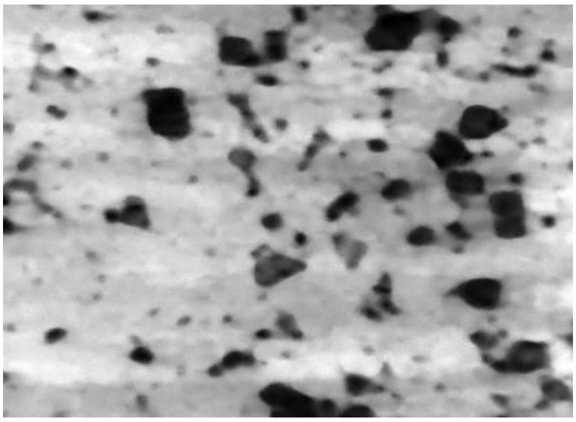

Fig-1.12: Al 7075 with 3% SiC-p

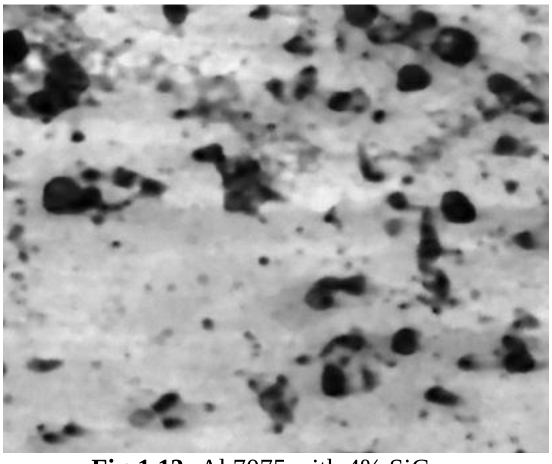

Fig-1.13: Al 7075 with 4% SiC-p

5.5.2 Hardness Test

Hardness of composites was determined by using Brinell hardness testing machine of ball indenter 5mm diameter and major load of 250kgs. Hardness of composite material increases by increasing weight percentage of SiC-p. Table 1.1 shows hardness of composites with different weight percentages SiC-p.

Table-1.1: Hardness of composites with different weight percentages SiC-p

Sl.N	Reinforcements	Hardness value (BHN)
1	Nil	54.5
2	1%SiC	59.3
3	2%SiC	78.34
4	3%SiC	82.3
5	4%SiC	87.58

5.5.3 Tensile Test

The obtained results for tensile test have been presented in Table1.2. The result shows yield strength and ultimate tensile strength for different weight percentage of SiC-p. The result of experiment shows that, yield and ultimate tensile strength increases by increasing weight percentage of reinforcement.

Table-1.2: Details of Tensile test results obtain for different weight percentage of SiC-p

Weight % of SiC-p	Yield strength N/mm^2	Ultimate Tensile strength N/mm^2
Nil	15	126
1	17	136
2	18	137
3	20	140
4	22	145

The results of experiment clearly shows that, without reinforcement (0% by weight) of aluminum 7075, the yield strength is 15 N/mm^2 and ultimate tensile strength 126 N/mm^2 and 1% of reinforcement with aluminum 7075, the yield strength is 17 N/mm^2 and ultimate tensile strength 136 N/mm^2. It clearly shows that, the mechanical properties are enhanced with increase in weight percentage of SiC-p in composites. Figure 1.14 and 1.15 shows variation of yield strength and ultimate tensile strength with different weight percentage of silicon carbide particles respectively.

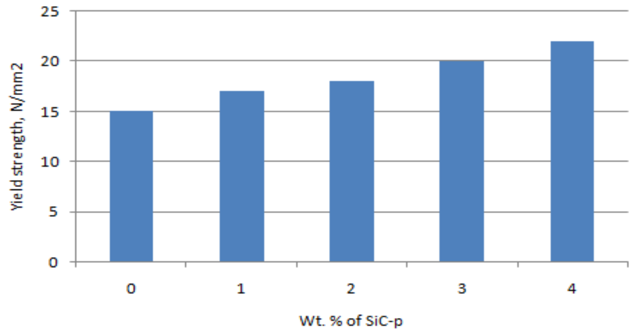

Fig-1.14: Variation of Yield strength with Wt.% of SiC-P

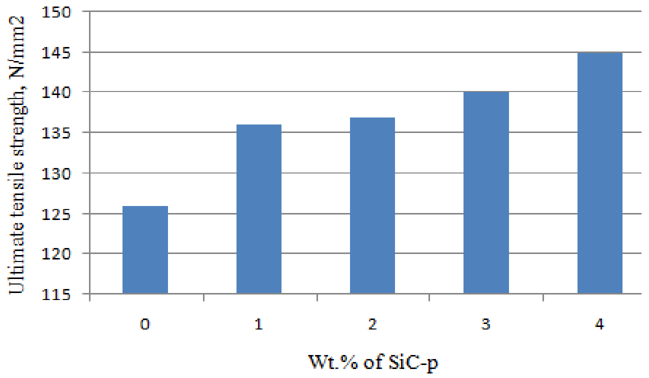

Fig-1.15: Variation of Ultimate tensile strength with Wt. % of SiC-P

5.5.4 Wear Test

The obtained wear test results have been presented in Table 1.3. Wear rate and coefficient of friction was calculated for different weight percentage of silicon carbide particles. The result of experiment clearly shows that, the weight percentage of reinforcement (SiC-p) increases, the wear rate decreases and coefficient of friction increases in tribological properties. Figure 1.16 shows the effect of coefficient of friction on composites by the influence of reinforced particles on composites. Figure 1.17 shows the effect of coefficient of friction by the weight load on composites. Figure 1.18 shows the effect of wear rate by increasing weight percentage of silicon carbide particles in composites.

Table-1.3: Details of wear test results obtained for different weight percentage of SiC-p

Wt.% of SiC	Speed (rpm)	Weight load (kgs)	Wear Rate $\times 10^{-3}$(mm^3/N-m)	Coeff. of friction
0	250	2	0.989	0.013
		2.5	1.137	0.016
		3	1.523	0.018
1	250	2	0.982	0.019
		2.5	1.125	0.027
		3	1.506	0.043
2	250	2	0.971	0.019
		2.5	1.117	0.022
		3	1.498	0.030
3	250	2	0.912	0.014
		2.5	1.105	0.020
		3	1.365	0.025
4	250	2	0.834	0.013
		2.5	1.035	0.019
		3	1.267	0.023

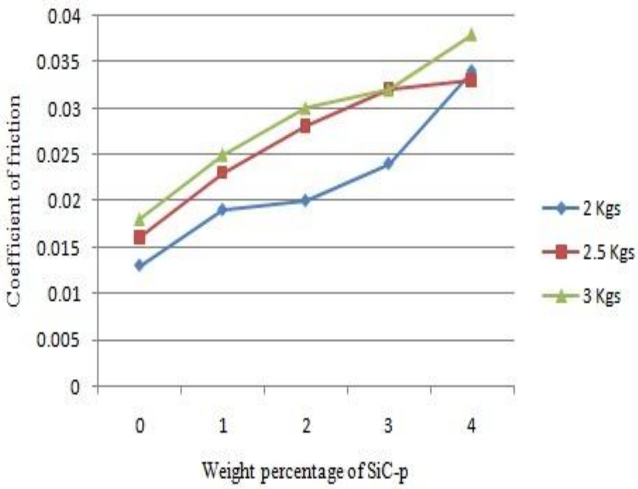

Fig-1.16: Details of coefficient of friction v/s weight percentage of SiC-p

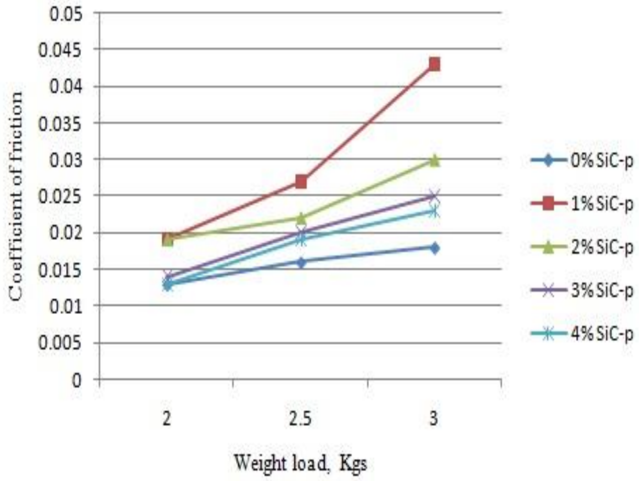

Fig-1.17: Details of coefficient of friction v/s weight load on composites

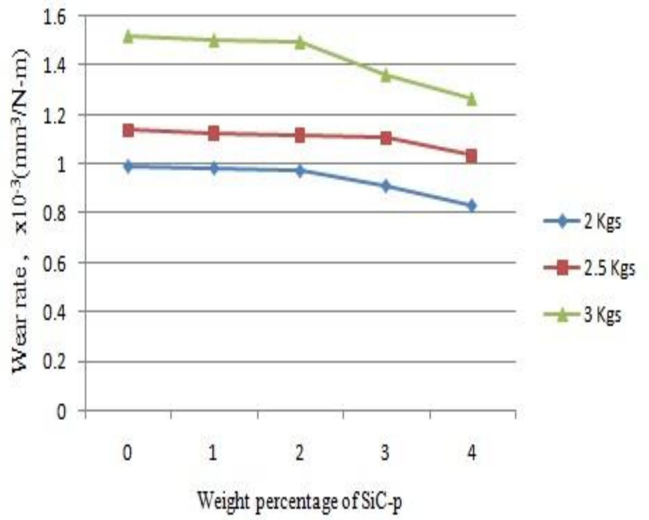

Fig-1.18: Details of Wear rate v/s weight percentage of SiC-p

6. CONCLUSION

In this study, the microstructure analysis, analysis of chemical compositions, mechanical and tribological properties of aluminum 7075 metal matrix with SiC-p reinforcement of different weight percentage of 0,1,2,3 and 4 were examined.

1. Aluminum 7075 metal matrix with reinforced silicon carbide were successfully fabricated through stir casting method for 0%, 1%, 2%, 3% and 4% of reinforcement.

2.It was observed that reinforced particles are uniformly distributed on matrix material by SEM analysis

3. Hardness of composites was increases by increasing weight percentage of silicon carbide particles.

4. It was observed that Yield strength and Ultimate tensile strength increases by increasing weight percentage of silicon carbide particle.

5. It was also observed that the wear rate decreases as the weight percentage of silicon carbide increases and coefficient of friction increases as weight load increases.

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