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Development of Aluminium(6063), Silicon Carbide Based Metal Matrix Composite by using Stir Casting Method

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ABSTRACT

Metal Matrix Composites(MMCS) have raised scope in the present modern sector for potential application in aero scope, automobile & automotive engineering aerospace, transportation, defence, marine , piston cylinder and sports because it being their higher-up the properties such as thermal shock resistance, high strength, low density, light weight, high hardness, high fatigue, corrosive resistance etc. At present various attempts have been made to develop Aluminium Silicon Carbide (ALSIC) Metal Matrix Composites with target to build up a low cost conventional method of producing Metal Matrix Composites. There are several fabrication techniques are available for production of MMCs but to attain these objective stir casting method has been adopted. Preparation of metal matrix composite i.e. AL 6063, is the base matrix metal in the experiment for fabrication of the composites of silicon carbide which has been reinforced with weight age of 2%,3%, 5%, 7%, 9%. Four samples of varying percentage of compositions of SIC are taken and to be tested under the hardness test, microstructure test and tensile test are conducted.

Keyword: - Metal Matrix Composite, Silicon Carbide, Stir Casting.

INTRODUCTION

As we know that the Metal Matrix Composites have gained a very expressive attention in recent year because they having light weight, high strength, high strength and low density and also having some mechanical property such as ultimate stress , yield stress, heat treatable & weld able and hardness. Material Matrix Composite is the continuous phase of combination two or more materials to form a new material and it helps to improve the property by converting it into composite with introduction/addition of reinforcements (hard materials) [1-2]. Presently, Aluminium and its alloys have gained attention as a base metal in metal matrix composites [3]. The aluminium metal matrix composite (AMMCs) reinforced with ceramic particles has gained extensive applications in automotive and aerospace industries due to their better mechanical properties [4]. The particle distribution plays an important role in the properties of MMC and also improved intensive shearing. Stir casting is generally accepted because it's cost of fabrications low as compare to others[5]. The advantages of Stir Casting lies in its simplicity, applicability to large volume production and flexibility. This process is most economically as compared to all other MMCs production techniques and it allows fabricating big components. However, the following consideration is achieving via stir casting. The addition of Silicon Carbide (alloying metal) helps to improve the matrix by making a transient layer between particles and liquid. This layer has a low wetting angle. The low wetting angle helps to decreases the surface tension of the liquid, and surrounds the particles with a structure that are similar to both the particle and the matrix alloy (at various compositions). In this micron sized silicon carbide particle (400 mesh) is used as a reinforcement material and magnesium particle (0.5% of total weight) is added for improve wet ability of the particles between Aluminium and Silicon carbide, by reducing the $SiO2$ layer on the surface of the Sic.

Main objective of paper:-

The purpose of this paper is to improve the mechanical property of aluminium by mixing of silicon carbide. The objective is:-

- **To increase in yield strength and tensile strength**
- **To Increase fatigue strength**
- **To improve of thermal shock resistance**
- **To make light weight and low density**
- **To improve of corrosion resistance**
- **To increase in Young's modulus**
- **To reduce of thermal elongation**

Materials:-

1. **Metal Matrix**:**-** The metal matrix used in this experiments is Aluminium 6063. It has good mechanical property and having a low melting point is 710°C. 6063 has a density of 2.68g/cm^3. Al 6063 is an Aluminium alloy, with magnesium and silicon as the alloying elements.

   The various compositions of element:**-**

Component	Weight age (in %)
Silicon	Min. 0.2%, Max.0.6%
Manganese	Max. 0.10%
Iron	0.35% Max
Zinc	Max. 0.10%
Titanium	Max. 0.01%
Chromium	Max. 0.10%
Copper	Max. 0.10%
Aluminium	98.7%

2. **Reinforcement Material:-**

   Silicon Carbide:**-** Silicon Carbide(400 mesh) is highly wear resistant and having good mechanical properties with low density, high temperature strength and thermal shock resistance Silicon carbide is mainly composed of tetrahedral of carbon and silicon atoms with strong bonds in the crystal lattice. It produces a very hard and strong material because of the presence of carbon atoms [6]. The melting point of Sic is 2700 °C. It is generally made by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive property and use to make grinding wheels. It is used in abrasives, refractories, ceramics, and numerous high-performance applications.

Method of preparation of Al/Sic metal matrix composite

There are several techniques for preparation of metal matrix composite in engineering field, but stir casting has been adopted because it has a low cost fabrication technique.

Stir Casting:-

Stir Casting is the process for fabrication of generally particulate reinforced metal matrix composite. It is a main process of composite production in which the reinforcement material is integrated into the molten metal by stirring process. In stir casting, the particles are often tends to liquid form which can be easily dissolved by stirring with high temperature. The reinforcing phases are propagated into molten by stirring. Mechanical stirring in this furnace is a key element of this process. The next step is to solidify the molten melt which containing suspended dispersoids and are solidify under selected conditions to obtain the desired effect of distribution of the dispersed phase in the cast matrix. The resultant product with ceramic particles can be used for die casting, permanent mould casting.

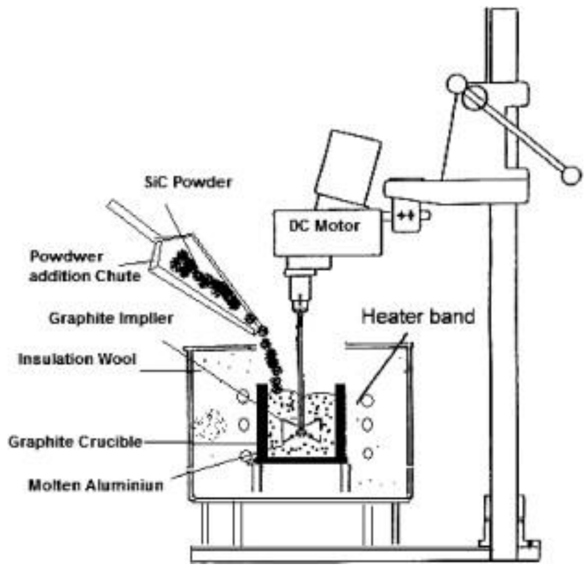


Fig. 1: Stir Casting Process

The final distributions of the particles are depending upon material properties and process parameters are:

1. Speed of rotation: The speed of rotation of sterrier is a very important factor in production of casting material. Rotational speed tempts the structure; increase of speed tends to refinement and very low speed tends to unstableness of the liquid mass. Thus, it is important to avoid the highest speed.
2. Stirring temperature: The viscosity of the matrix is determined by the processing temperature. The change of viscosity is subjective by particle distribution in the matrix. When the processing temperature is increased and also with increasing holding time of stirring process, there is a decrease in the viscosity of liquid. There is also accelerated in the chemical reaction between matrix and reinforcement.
3. Reinforcement pre-heat temperature: Pre heat temperature is given to remove moisture or any other gases which are present in reinforcement, the reinforcement was preheated at a specified temperature of 500 °C for 30 minutes. The wettability of reinforcement with matrix is promoted by preheating.
4. Stirring time: Uniform distribution of the particles in the liquid and perfect interface bond between reinforcement and matrix is promoted by stirring process. In the processing of composite, the stirring time between matrix and reinforcement is considered as an important factor.
5. Pouring temperature: pouring temperature is plays a major role in the solidification and determines relation partly to the required structure type. Low temperature is associated with maximum grain refinement and equated structure while higher temperature associated with columned growth in many alloys. To ensure the satisfactory metal flow and freedom from collapse whilst avoiding coarse structures, the pouring temperature must be sufficiently high.
6. Mould temperature: Its principle significantly lies in the degree of expansion of the die with preheating. The risk of tearing in casting is diminished by expansion. The mould temperature should neither be too low nor be too high in the non-ferrous casting. The mould should be at least 25 mm thick with this thickness increasing with size and weight of casting.
7. Blade design of strirrer:- Number of blades and angle of the strirrer are main factor which decides the flow pattern of the liquid metal at the time of stirring process. The blade angle is 45° & 60° gives it uniform distribution. The number of blades should be 4 and width 20mm above the bottom of the crucible. Blade pattern drastically affects the flow pattern. Stirrer blades play an important role in creating vortex of the molten matrix. This vortex formation ensures boding characteristic of matrix and reinforcement.
8. Powder Feed Rate:- The feed rate of powder particles is uniform to produce a good quality casting. If it is non-uniform, then it elevated the clustering of particles at some places which increase the porosity defect so that the feed rate of particles must be uniform.

Apparatus: - there are many necessary apparatus required for manufacturing the material are:-

1. Muffle furnace
2. Stirrer Blade
3. Dimmer for speed regulation
4. Crucible

1. **Furnace: -** Electrical muffle furnace is used for preparation of the homogenous metal matrix. Furnace dimension are 16cm x 16cm x 37cm.

Fig. 2 Muffle Furnace

Fig. 3 Sterring frame

2. **Frame for sterring system: -** Frame is prepared for holding motor up to height of furnace. Mild steel dimension 3cm x 3cm square rod is used for manufactured. Height of frame is 72cm from the ground and its length and breadth is 72cm in each side.

3. **Sterrier specification: -** stirrer is made up stainless steel (310 grades). The length of stirrer is 95cm and blade having X shape.

Fig. 4 Sterrier Blade

Fig. 5 Motor Dimmer

4. **Motor-Dimmer**: - motor is used for mixing purpose of having 4000RPM speed. A special attachment is attached to motor to fix the stirrer to the motor. Dimmer is used for controlling rate of speed.
5. **Crucible**: - crucible is made up of graphite because melting point of graphite is high.

Fig. 6 Graphite Crucible

Experimentation and Testings:-

The composite has been manufactured via Stir Casting.

1. Aluminium strip are cut into small pieces because of easily pour into crucible.
2. Aluminum were kept into crucible and pre heated in a muffle furnace(30-35 min.) at 450-500°C and silicon carbide pre heated at 1100°C.
3. After preheating silicon carbide magnesium is also added (1%wt.) for improving wet ability with matrix and removes moisture.
4. The AL6063 matrix alloy was melted at 750°C in a graphite crucible by using muffle furnace.
5. After melting Al6063 material the silicon carbide is mixed with stirrer at 900RPM and mixture are also heated again upto 800°C.
6. After complete process the slurry has been poured into the mild steel cavity within 30 sec. and finally allowed to solidify.
7. After solidified the material is cut into small parts for performing different experiments like hardness test, tensile test, compressive test, micro structure test.
   The experiment should be conducted by repeatedly varying the composition of the composite powder of Sic (2%, 3%, 5%, 7%, and 9%) weight of Aluminium strips and Silicon Carbide is:-

Mechanical properties observations:-

1. **Microstructure Characterization:** Microstructure studies are conducted on the reinforced samples and is achieved by using optical microscope. The objective to see the microstructure is to check the distribution of the reinforcement whether uniformly distributed or not. To see the microstructure of the samples the sample must be polished properly.
2. **Tensile Test:-** In this type of test a sample is subjected to control tension upto failure. The results are commonly used to select a material for various applications. To foretell how a material will react under other various types of forces which are applied on it in various conditions. The properties that are measured Via tensile test are ultimate strength, yield strength, elongation, passion's ratio, young's modulus, displacement, reduction in area.
3. **Hardness Test:-** Hardness is the resistance of a material to under deformation. There are three types of hardness measurements are:-
4.
   - Scratch
   - Indentation
   - Rebound

   Hardness is dependent on ductility, elastic, stiffness, plasticity, strain, toughness and viscosity.

Table 1: Percentage of SiC in Aluminium

Percentage	Al6063(in Gm)	Silicon Carbide(in Gm)
0	1000	00

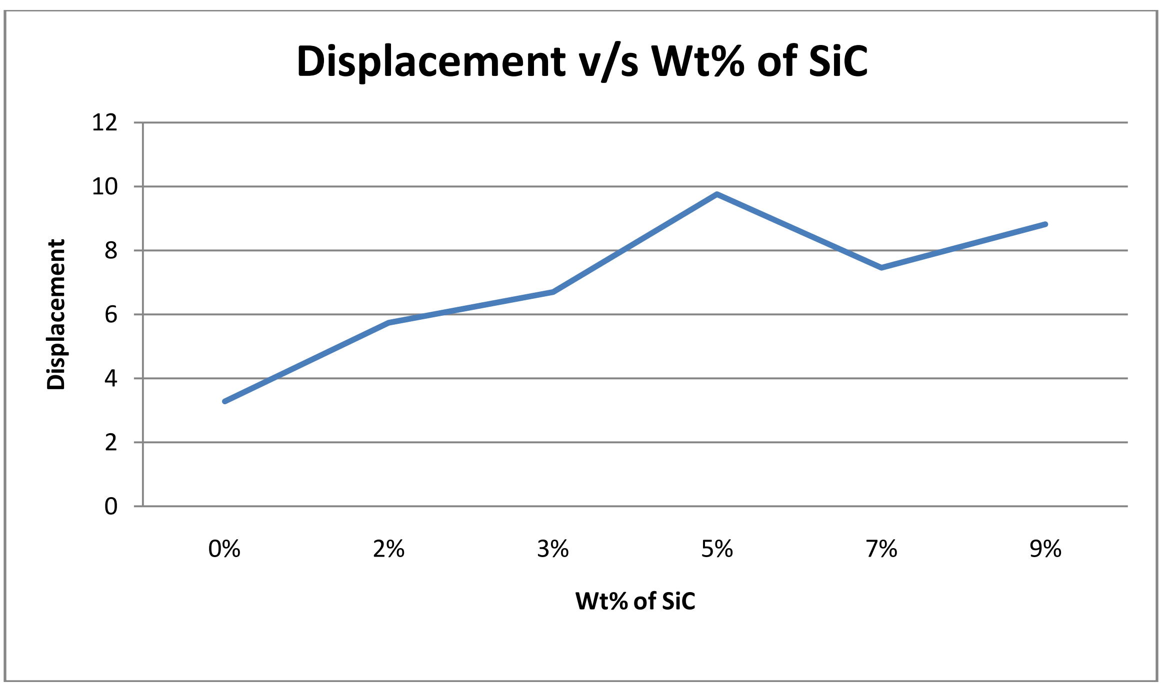
2%	980	20
3%	970	30
5%	950	50
7%	930	70
9%	910	90

The six samples are prepared by varying composition of the silicon carbide.

Result and Discussion: - The major aim of this paper is to fabricate a metal matrix composite of aluminium based silicon carbide by which we find the low cost fabrication method for producing Metal Matrix Composites and got homogenous dispersion of ceramic material. To prepare Metal Matrix Composite of Aluminium Silicon Carbide, stir casting technique has been adopted. Small sized Sic particles are integrated into a molten aluminum and Mg is also added as a wetting agent to fabricate aluminum matrix composite. After getting varying composition MMCs of ALSic (2%, 3%, 5%, 6%, and 7%) samples are ready for testing. It is found that with the increase of percentage of Silicon Carbide, hardness and tensile strength of the ALMMC is also increased.

Table 2: Tensile Strength of various compositions

S.NO.	%SiC	Force(KN)	Elongation (%)	Tensile Strength(KN/mm2)	Displacement(mm)
1	0	6.520	12.118	109	3.270
2	2	7.755	9.687	129	5.720
3	3	8.300	9.063	138	6.680
4	5	8.615	18.438	144	9.750
5	7	9.120	22.188	152	8.450
6	9	9.250	26.82	159	8.810



Graph 1: Displacement v/s Weight percentage of SiC (Silicon Carbide)

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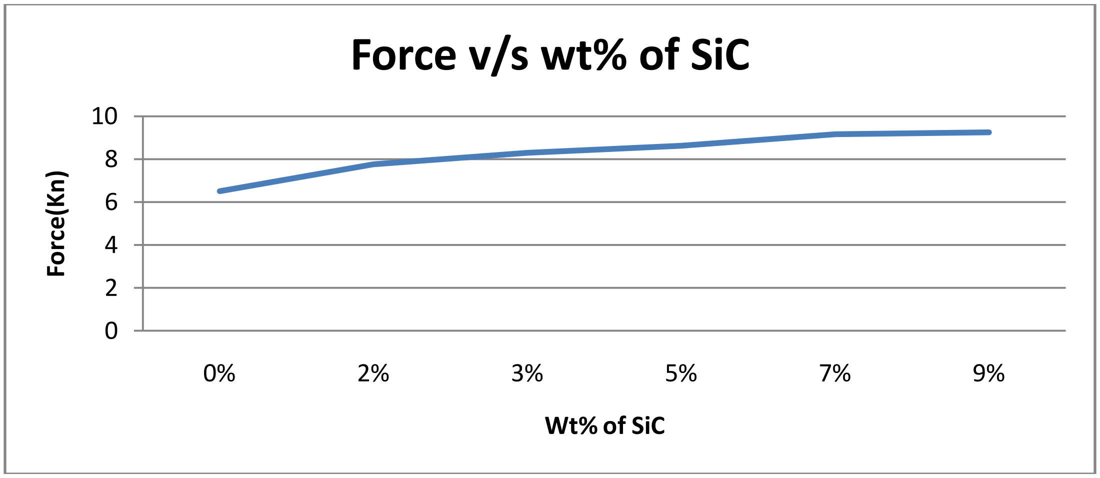
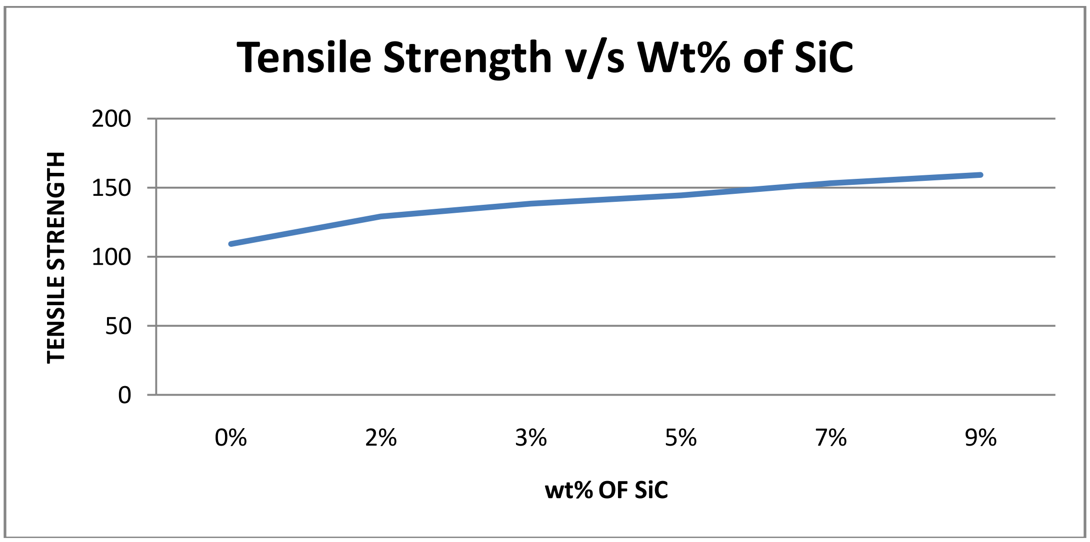
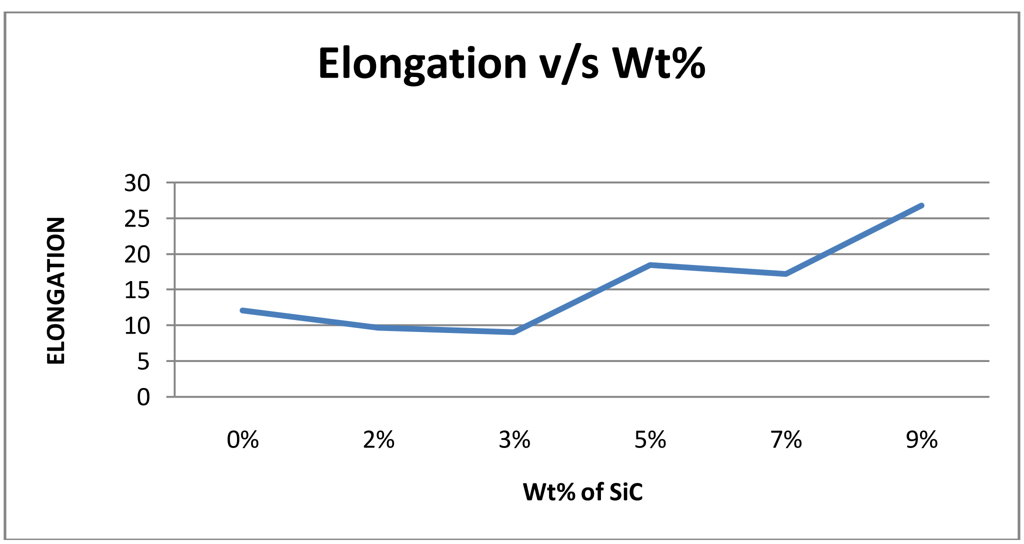


Graph 2: Force v/s weight percentage of SiC



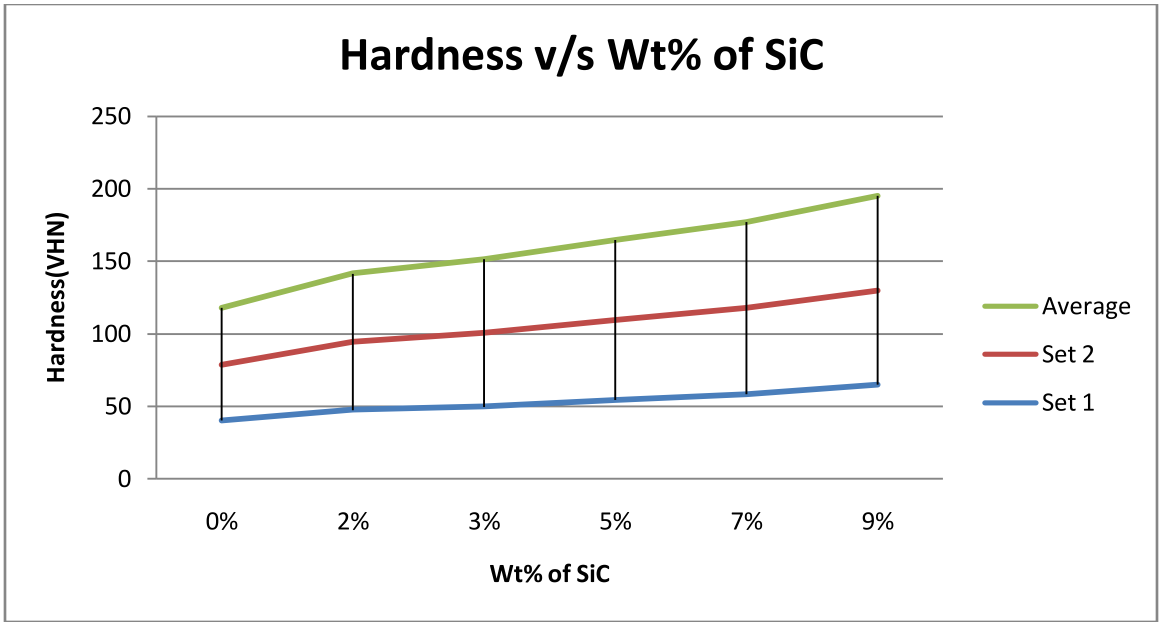
Graph 3: Tensile Strength v/s Weight percentage of SiC



Graph 4 : Elongation v/s Weight percentage of Sic

Table 3: Hardness of Various Samples

S.NO.	Weight %	Hardness(VHN) Set 1	Hardness (VHN) Set 2	Hardness (VHN) Average
1.	0%	40.2	38.5	39.35
2.	2%	47.6	46.8	47.2
3.	3%	49.8	51.2	50.5
4.	5%	54.5	55.2	54.85
5.	7%	58.5	59.6	59.05
6.	9%	65.2	64.8	65



Graph 5: Hardness v/s weight Percentage of SiC

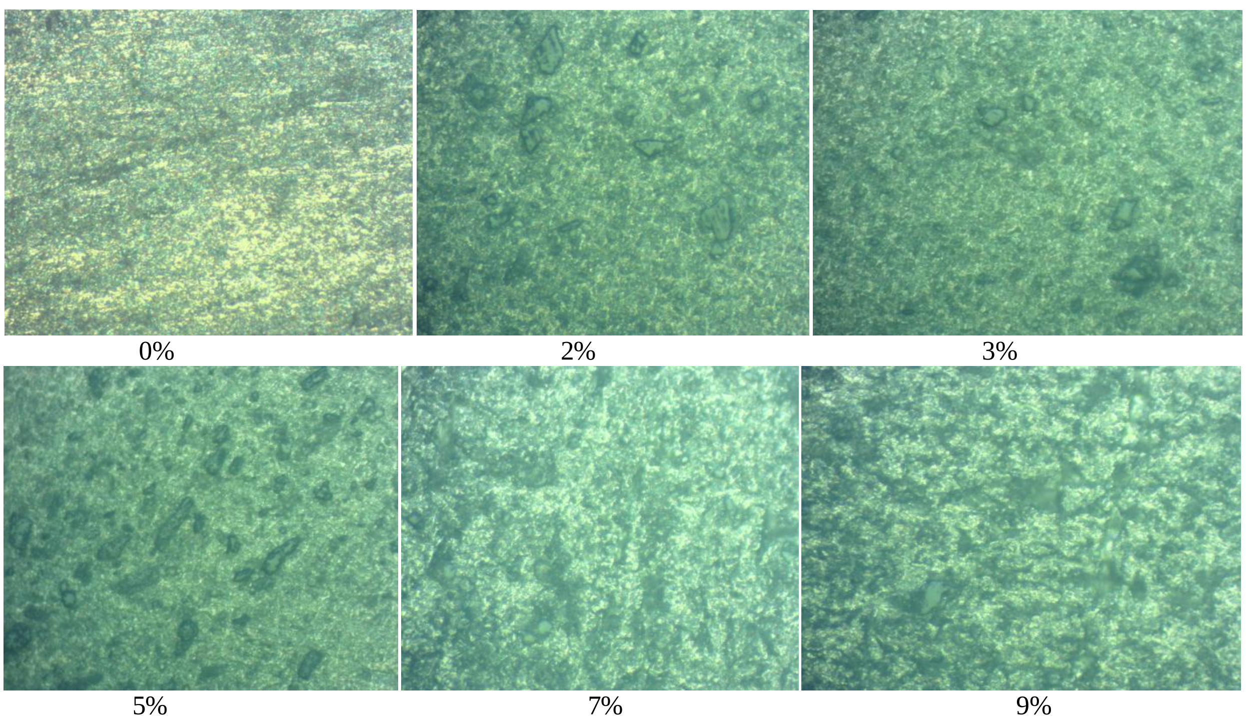


Fig. 1: Images of Microstructure test of AMCs Samples according to Wt% of Sic

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