Annals of R.S.C.B., ISSN:1583-6258, Vol. 22, Issue 2, 2018, Pages. 60 - 76
Received 24 June 2018; Accepted 20 August 2018.

Mechanical and Corrosion Behaviours of Aluminum Metal Matrix Composite (Al 7075, Sic, & Zn)

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Abstract

The aluminum based composites are increasingly being used in the transport, aerospace, marine, automobile and mineral processing industries, owing to their improved strength, stiffness and wear resistance properties. The mechanical properties of aluminum alloy based composites were investigated and analyzed. In this project, we have manufactured aluminum metal matrix composites in which Zinc used as an alloying element and Silicon carbide is the reinforcement materials. The aluminum metal matrix composites were manufactured by using stir casting method. The cast aluminum metal matrix composites were machined to required dimensions for testing. After that, mechanical tests were conducted on the composites prepared. The tests carried out are tensile test, Impact test, corrosion test and micro structure. The test results were studied and analyzed. The mechanical properties were determined and corrosion test was carried out.

Key words: Aluminum- Zinc alloy, Composite, Silicon Carbide, and Stir Casting.

INTRODUCTION

A composite material (also called a composition material or shortened to composite) is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials. More recently, researchers have also begun to actively include sensing, actuation, computation and communication into composites, which are known as Robotic Materials. Composite materials are generally used for buildings, bridges, and structures such as boat hulls, swimming pool panels, race car bodies, shower stalls, bathtubs, storage tanks, imitation granite

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and cultured marble sinks and countertops. The most advanced examples perform routinely on spacecraft and aircraft in demanding environment. Polymer Matrix Composites(PMCS) is also known as fiber reinforced polymers (FRPs), or resin-based composites (RBCs). For the matrix, it uses a polymer-based resin and fibers as the reinforcement. Metal Matrix Composites (MMCs) are advanced materials because the material properties - such as corrosion resistance, high stiffness and high strength-to-density ratio, and sometimes special electrical and thermal properties - are combined. This material is progressively used in the automotive industry; it uses a metal matrix and reinforcement made of advanced ceramic fibers.

LITERATURE REVIEW

M. Sambathkumar (2017) used two step stir casting process to fabricate the composites by varying volume fractions of Silicon Carbide and Titanium Carbide (0 to 15 vol. %). Microstructural analysis, mechanical and corrosion behavior were used to evaluate the performance of the composites. Uniform distribution of reinforcement particle was observed through optical photomicrograph. Al7075 hybrid metal matrix composites exhibited better corrosion resistance than the pure Al matrix in 3.5 wt. % Na Cl solution. Increasing the volume fraction of the reinforcement (Sic and Tic) particulates increased the corrosion resistance of the composites. Michael (2015) studied hybrid AMCs reinforced with agro waste derivatives have shown that high performance levels can be maintained in AMCs at reduced production cost even at about 50% replacement of synthetic reinforcement with the agro waste. The discussion on the combinations of reinforcement used in the synthesis of hybrid AMCs is divided into three broad groups. These are hybrid AMCs with two synthetic ceramic materials; an agro-waste derivative combined with synthetic ceramic materials; and industrial waste combined with synthetic reinforcement. Harish Kumar. S (2018) selected materials like Boron Carbide (B4C) & Tungsten Carbide (WC) can be used for the fabrication of Hybrid aluminium metal matrix composites by stir casting process. The investigation shows the increase in weight percentage of Boron Carbide (B4C) withAluminium (LM25) can improves the mechanical &tribological properties of the composite. The use of Hybrid aluminium metal matrix composites instead of monolithic or metal matrix composites results in reduction of weight which improves the decrease in fuel consumption of automobile vehicles. Rohit Sharma (2017) observed improvement of compressive strength, fly ash particles are the most appropriate ones as it

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indurates the base alloy. Hardness shows the best results when the silicon carbide is employed at 25% weight percent. Hardness increases with the increase in silicon carbide but decreases with increase in graphite. Hence to obtain an optimum hardness of the desired number, both the reinforced material can be used in proper proportions.

MATERIALS AND METHOD

Aluminium alloy (AA7075) is an aluminium alloy, with zinc as the primary alloying element. It has excellent mechanical properties, and exhibits good ductility, high strength, toughness and good resistance to fatigue.

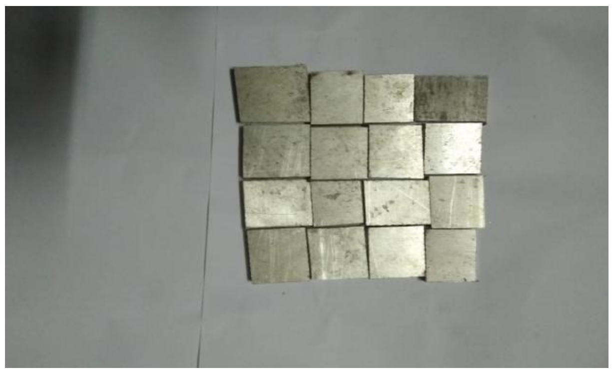

Fig 1. 7075 aluminium alloys

It is more susceptible to embrittlement than many other aluminium alloys because of microsegregation, but has significantly better corrosion resistance than the 2000 alloys. It is one of the most commonly used aluminium alloy for highly stressed structural applications, and has been extensively utilized in aircraft structural parts.

STIR CASTING

Stir casting is a liquid state method of composite materials fabrication in which a dispersed phase (ceramic particles,shortfibers) is mixed with a molten matrix metal by means of mechanical stirring. Among the variety of manufacturing processes available for discontinuous metal matrix composite, stir casting is generaly accepted and currently practiced commercially.

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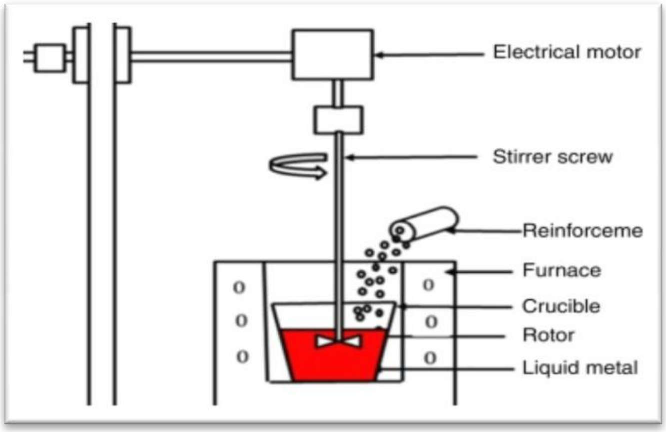

Fig 4 Schematic diagram of stir casting

s.no	Samples	Al7075 (weight %)	SiC (weight %)	Zn (weight%)
1	Sample 1	93	5	2
2	Sample 2	92	6	2
3	Sample 3	89	9	2

AFTER CASTING SAMPLES

SAMPLE 1

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SAMPLE 2

SAMPLE 3

TESTING AND RESULT

MECHANICAL PROPERTIES

Tensile strength

Tensile tests were performed using an Instron model 4301 universal testing machine. The standard type-I specimen specified in ASTM D638–99 2000) had 3.2 mm thickness with 165 mm overall length, 13 mm narrow section width, and 19 mm overall width. The displacement was measured with a 50-mm extensometer. The specimens were tested at 5 mm per minute.

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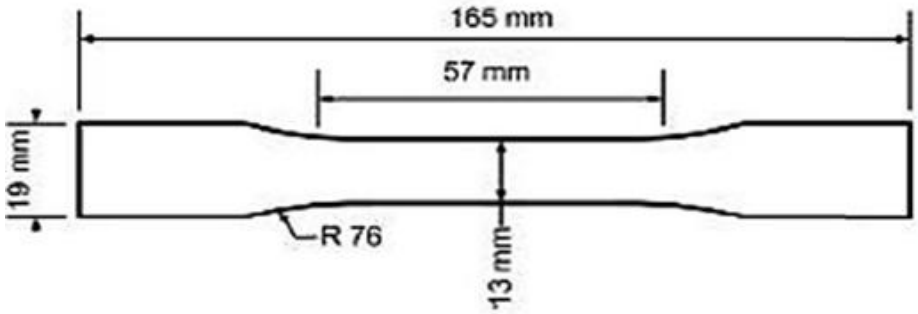

Tensile specimen standard

Observation: (sample 1)

1. Length of thespecimen,L = 165 mm
2. Diameter of thespecimen,d = 19 mm
3. Yieldload.P_y =$144.03*10^3$ N
4. Ultimateload,P_u =$163.31*10^3$ N

Calculations:

1) Yieldstressσ_y=Yield load (P_y) =$144.03*10^3$/283.53 =507.98 N/mm^2
Initial Area(A_i)

2) Ultimatestressσ_u= Ultimate load(P_u) =$163.31*10^3$/283.53 =575.89 N/mm^2
Initial Area (Ai)

Where Ai = Initial Area = $\pi d^2 /4$ =283.53 mm^2

TABLE

S.no	Samples	Yieldstressσ_y(MPa)	Ultimatestressσ_u(Mpa)
1	Sample 1	508	576
2	Sample 2	513	578
3	Sample 3	524	586

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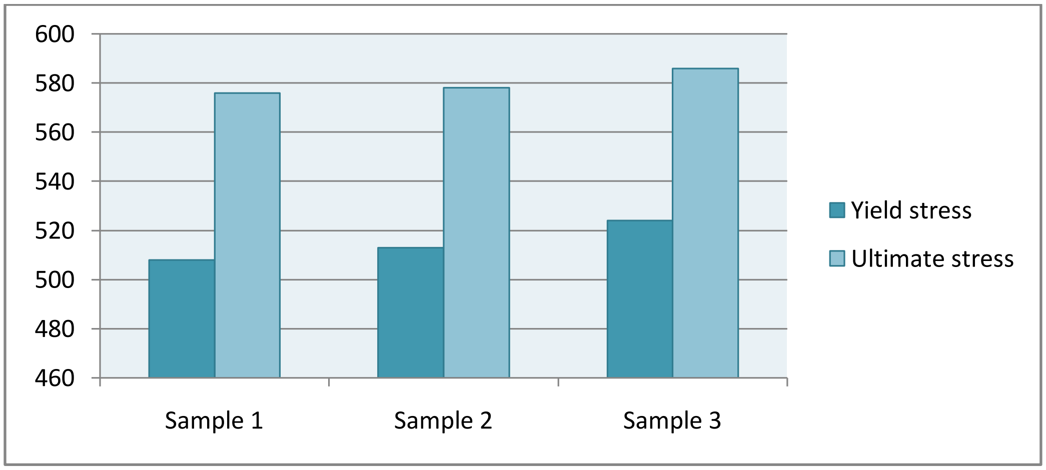
Comparison of Tensile Results



CORROSION TEST

Salt Spray Testing Chamber ASTM B 117

Rectangular samples of definite geometry same grade aluminium with different percentage of composite addition and stir cast are machined to uniform dimensions. These samples were pre-polished and pre-cleaned before subjecting it in to the salt spray chamber for corrosion test. All the specimens were subjected to cleaning with non-aqueous solvent and which is not attacking base material aluminium alloy. The solvent cleaning was done only on the surface of aluminium and care is taken to avoid solvent attack.

These different metal matrix samples were subjected to salt spray chamber fog test as per astm standards. All the machined and coated samples were subjected to Salt spray fog corrosion test as per ASTM B-117 in salt spray chamber. All the specimens were kept in hangers with identification Nos.

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The details of the tests, inferences observed and the conclusions arrived are given below.

Details of testing parameters:

1) Humidity : 98% as measured by hygrometer during the test.
2) Temperature of the test : 33 to 35 Degrees centigrade. (Continuously indicated).
3) Pressure of Air for atomizing : 2 to 3 bar continuously by pressure regulator.
4) Composition of the salt solution : For 1 liter of solution.
   5% of Sodium chloride
   1% of Magnesium chloride
   De-ionized water 94%
5) PH of the solution : Maintained at 7.5 by addition of buffer solution
6) Measurement of pH : Measured once in 8 hours.
7) Type of loading of specimens : Tied with plastic wire and hung in the hangers
8) Measurement of Corrosion : The weight of the Sample at the time of hanging initially and after 24 hours is measured to know the corrosion amount.Then the corrosion samples were cleaned with the 10% HCl and 1g Hexamethyldiamine and heated for some time and were tested.

Corrosion test samples

Table : Corrosion test results of various samples

Sample	Initial weight in g	Final weight in g	Weight loss in g	Width.in mm	Thickness in mm	Height.in mm

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Sample 1	8.691	8.524	0.167	25	5	25
Sample 2	8.848	8.647	0.201	25	5	25
Sample 3	8.782	8.715	0.067	25	5	25

Volume in cm^2	**Density g/cm^2**	**Area in cm^2**	**Corrosion mm/year**	**Corrosion mils/year**
3.125	2.68064	78.5	0.00060709	0.286546268
3.125	2.73152	78.5	0.000374491	0.1767598
3.125	2.7472	78.5	0.000541605	0.25563703

<u>Input data:</u>

a = 18mm; b= 36.5mm; c= 3.5mm

Area= (a*b) + (b*c) +(c*a) Area: 847.75 mm^2 Density: 2.71 g/cm^3 Operating hrs.: 24

Corrosion Rate: 87.6*(Weight loss in g) / (Area in cm^2 X Density g/cm^3 X Time in Hrs)

Model Calculation:

Corrosion rate = 87.6*(0.011)/ (8.4775*2.71*24) = 0.00174971 mm/year

Micro Structure

- Optical micrograph of the specimens of 5%, 6%, and 9% B_4CReinforcement along with 2% BN and rest Aluminium 7075 alloy were taken under two types of conditions. In the first type, the specimen was polished with fine emery sheet and photograph was taken.
- In the Second type, the specimen was etched using Keller's Reagent Solution and the photograph was taken.
- Under each conditions, the photograph were taken with Magnification 100X & 200X.

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Micro structure sample

Microstructure of plated samples

Sample No: 1

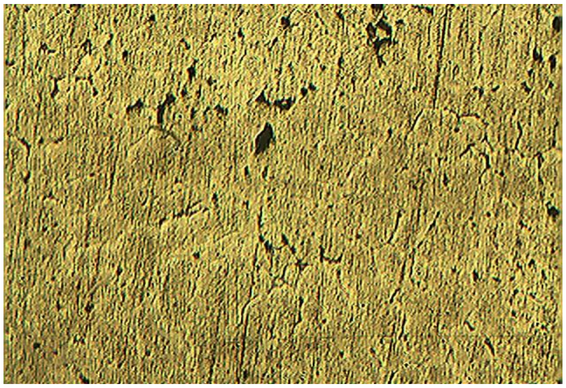

Photo-1

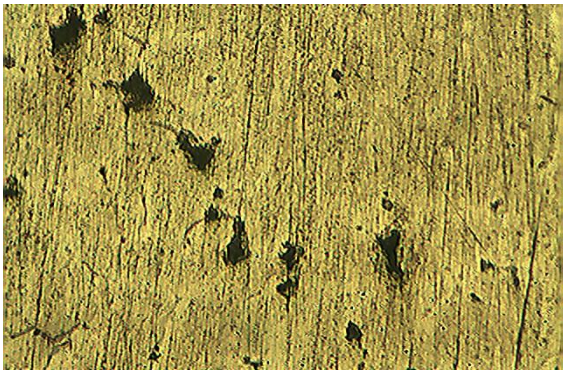

Photo-2

Magnification: 100X & 200X

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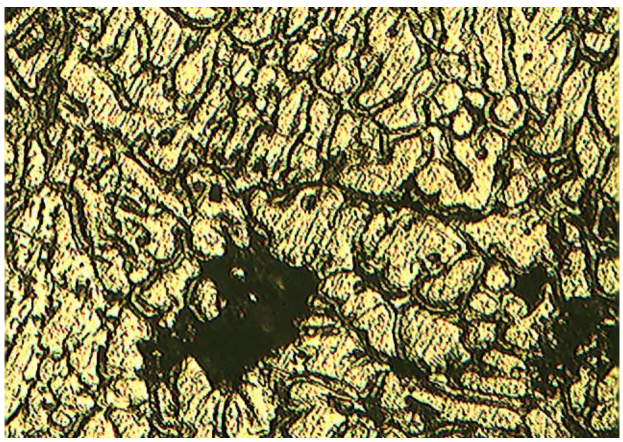
Photo-1: Shows the polished surface of the metal matrix composite sample with 5% composite addition and stir cast. The polished matrix shows the distribution of the dark colored composite particles in bright metal matrix. As composite particles are opaque they do not reflect light and appear black in reflective metal matrix surface. The magnification is 100X and the distribution is lean in photo-1. The BN are with definite geometrical shaped grains.

Photo-2: Shows the same sample at another field in which the particles are more clearly resolved as big particles as the magnification is raised to 200X. The higher magnification resolved the composite particles independently. Photo-2 shows uniform distribution of the composite particles in the metal matrix.

As Etched Microstructures:Photo-1



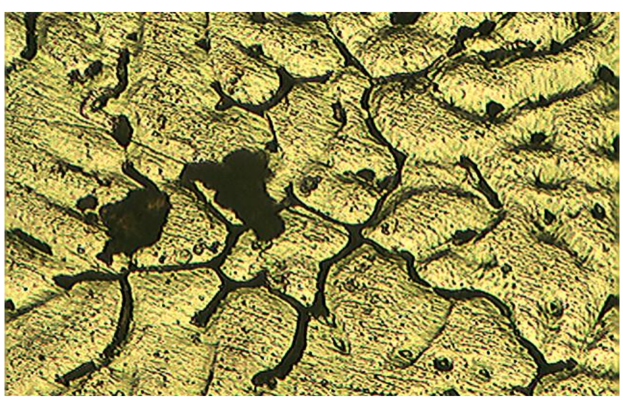


Photo-2

Magnification: 100X & 200X **Etchant:** keller's Reagent solution.

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Photo-1: Shows the etched metal matrix composite microstructure where the metal matrix is etched and the composites are not. Photo-1 shows the large cluster of particles of composite addition in one location and at along the grain boundaries of primary alpha aluminium matrix. The matrix of aluminium being chill cast shows fine inter-dendritic pattern of grains with precipitated and deposited composite particles at the junction of the grain boundaries. Photo-1 shows distribution of the composite particles at the grain boundary junctions.

Photo-2: The micrograph at Photo-2 shows lumps of composite in metal matrix and at the grain boundaries which are thick. Some fine particles of composite is also observed. The higher magnification of 200X resolved the grain boundaries of primary aluminium phase. Photo-2 shows higher percentage of distribution in the matrix.

Microstructure of plated samples

Sample No: 2

As polished:

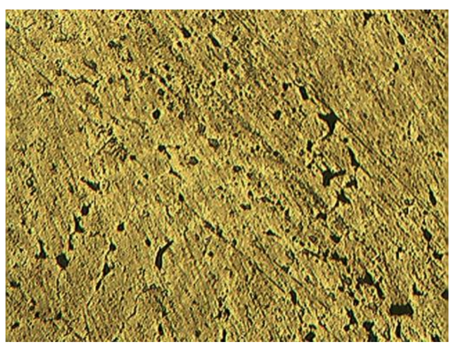

Photo-1

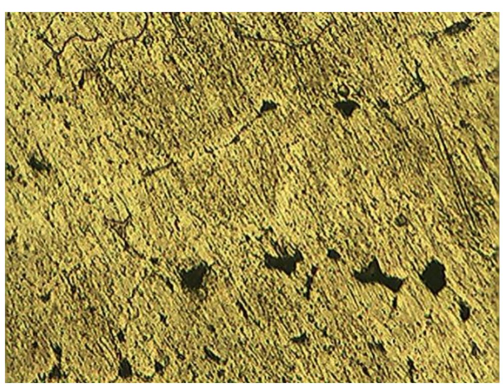

Photo-2

Magnification: 100X & 200X

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Photo-1: Shows the polished surface of the metal matrix composite sample with 6% composite addition and stir cast. The polished matrix shows the distribution of the dark colored composite particles in bright metal matrix. As composite particles are opaque they do not reflect light and appear black in reflective metal matrix surface. The magnification is 100X and the distribution is uniform in photo-1. Photo-1 shows lean and uniform distribution of the composite particles in the matrix and shows fine particles in one isolated region.

Photo-2: Shows the same sample at another field in which the particles are more clearly resolved as big particles as the magnification is raised to 200X. The higher magnification resolved the composite particles independently. The photo-2 shows more uniform distribution of the composite particles in the metal matrix. Photo-2 Shows uniform distribution of the all the composite particles in the matrix. Out of this Si_3N_4 is of uniform geometrical shapes.

As Etched Micro structures.

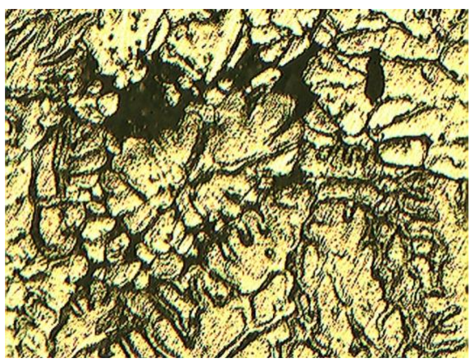

Photo-1

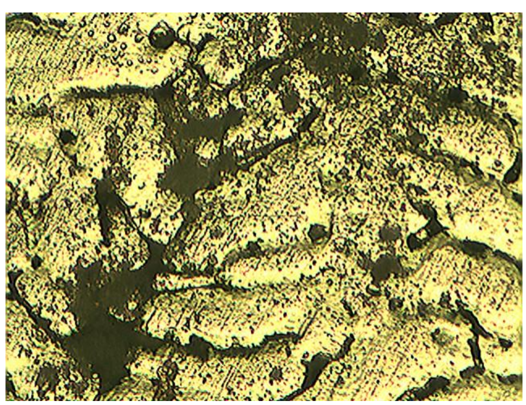

Photo-2

Magnification: 100X & 200X **Etchant:** Keller's Reagent soln.

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Photo-1: Shows the etched metal matrix composite microstructure where the metal matrix is etched and the composites are not. Photo-1 shows the large cluster of particles of composite addition in one location and at along the grain boundaries of primary alpha aluminium matrix. The matrix of aluminium being chill cast shows fine inter-dendritic pattern of grains with precipitated and deposited composite particles at the junction of the grain boundaries. Photo-1 shows distribution of the composite particles at the grain boundary junctions. The higher percentage addition of composite shows higher distribution of the composite in the metal matrix. Photo-1 shows the isolated cluster of composite particles in the metal matrix.

Photo-2: The micrograph at Photo-2 shows lumps of composite in metal matrix and at the grain boundaries which are thick. Some fine particles of composite are also observed. The higher magnification of 200X resolved the grain boundaries of primary aluminium phase. Photo-2 shows lumps of composite inside the matrix and at the boundaries of primary grains.

Sample No: 3

Microstructures

As polished:

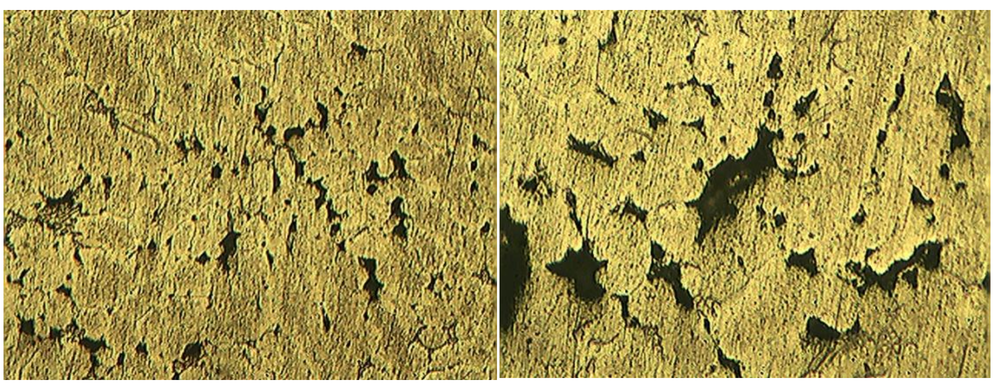

Photo-1 Photo-2

Magnification: 100X & 200X

Photo-1: Shows the polished surface of the metal matrix composite sample with 9% composite addition and stir cast. The polished matrix shows the distribution of the dark colored composite particles in bright metal matrix. As composite particles are opaque they do not reflect light and appear black in reflective metal matrix surface. The magnification is 100X and the distribution is uniform in photo-1.

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Photo-2: Shows the same sample at another field in which the particles are more clearly resolved as big particles as the magnification is raised to 200X. The higher magnification resolved the composite particles independently. Photo-2 shows uniform distribution of the composite in the matrix of aluminium metal. On the other hand, the photo-2 shows lumps of composite in the metal matrix. The Si_3N_4 composite shows uniform geometrical shapes.

As Etched Micro structures.

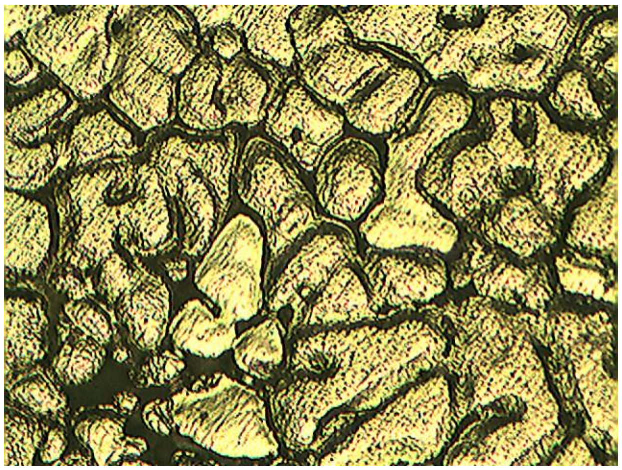

Photo-1

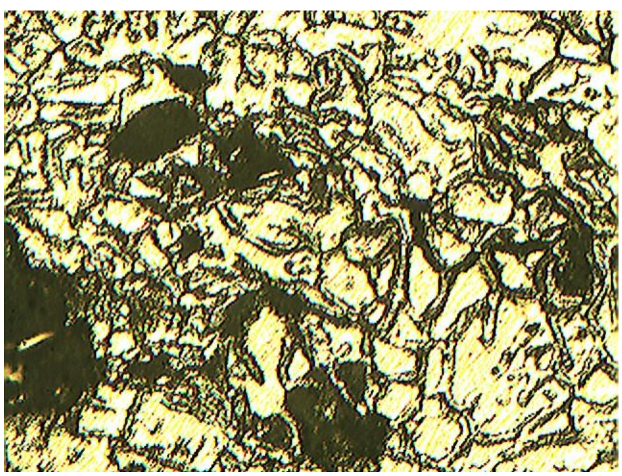

Photo-2

Magnification: 100X & 200X **Etchant:** keller's Reagent solution.

Photo-1: Shows the etched metal matrix composite microstructure where the metal matrix is etched and the composites are not. Photo-1 shows the large cluster of particles of composite

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addition in one location and at along the grain boundaries of primary alpha aluminium matrix. The matrix of aluminium being chill cast shows fine inter-dendritic pattern of grains with precipitated and deposited composite particles at the junction of the grain boundaries. Photo-1 shows distribution of the composite particles at the grain boundary junctions.

Photo-2: The micrograph at Photo-2 shows lumps of composite in metal matrix and at the grain boundaries which are thick. The higher concentration of composite particles showed higher quantum of composite in the metal matrix. Some fine particles of composite is also observed. The higher magnification of 200X resolved the grain boundaries of primary aluminium phase. Photo-2 shows uniform distribution of composite particles in the metal matrix.

CONCLUTION

- Aluminium metal matrix composites with Zinc(Zn) as an alloying element and Silicon carbide (Sic) as reinforcement were made and tests were carried out.. The test results were analyzed and discussed.

  a) 93%Al 7075+5%Sic+2%Zn

  Ultimate Tensile Strength : 576MPa

  b)92%Al 7075+6%Sic+2%Zn

  Ultimate Tensile Strength : 578MPa

  a) 89% Al 7075+ 9%SiC + 2% Zn

  Ultimate Tensile Strength :586MPa

- Silicon carbide weight percentage was varied to be 5%, 6%, and 9%. Specimens were machined out of the cast product and were tested for corrosion and wear resistance. Optical micrographs were taken and studied for the distribution of Silicon carbide. From the test results, it is observed that the corrosion rate decreased with increase in the weight percentage of Silicon carbide.
- While comparing the different compositions (93% Al 7075+5% Sic +2% Zn), (92% Al 7075+6% Sic+2% Zn), and (89% Al 7075+ 9%SiC + 2% Zn) Thecomposition (89% Al 7075+ 9%SiC + 2% Zn) has given better ultimate tensile properties and other mechanical characteristics.

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