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RESEARCH ARTICLE

DEVELOPMENT AND CHARACTERIZATION OF METAL MATRIX NANOCOMPOSITES OF ALUMINUMAND SILICON CARBIDE NANO PARTICLES.

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Abstract

Metal matrix composites (MMCs) constitute an important class of design and weight-efficient structural materials that are encouraging every sphere of engineering applications. There has been an increasing interest in composites containing low density and low cost reinforcements. Aluminum is a low density metal which is more advantageous in many applications due to a high stiffness-to- weight ratio. In a pure state it is soft and its strength can be increased by the inclusion of alloying element as well as the harder particles resulting in a high strength to weight ratio. Ceramic particles are very tough. Thus it is beneficial to improve mechanical properties and tribological properties. If Sic particles are distributed in the aluminum alloys uniformly it will give very good isotropic properties.

The properties of particulate metal matrix composites depend on its microstructure or the distribution of the particulates in the matrix. This project is intended to get better homogeneity in particle distribution as compared to existing method in a cost effective way by synthesizing MMNC using 'Indirect Non-Contact Type Ultrasonic Method'. Thereafter these composites were observed with the help of 'High Resolution Transmission Electron Microscope' and its strength is measured by 'Rockwell Hardness testing machine'.

Introduction: -

The composite material is a mixture of combination of two or more micro constituents insoluble in each other and differing in form and or in material composition. The continuous fibers reinforced composite has better strength but the processing methods is highly expensive which hinders their adoption. Therefore, particulate reinforced composites are widely used. In metal matrix composites, numbers of fabrication processes have been attempted such as mechanical alloying, vertex process and spray deposition, stir casting, equal channel angular pressing, in situ processing (Zhang, Z et.al., 2008) ;(Zhang, Z et.al., 2006) ;(Sanaty-Zadeh,2012), However, But the above processes are expensive& difficult to achieve uniform distribution of particles especially with higher volume fraction of the particulates though there are some problems (Shehata, F,2009). So, presentprocess attempts to develop Al-Sic MMNC based upon 'Indirect Non-Contact Type Ultrasonic method'. This process represents a step towards a long term goal, namely the development of a thorough model of solidification in industrial castings, allowing the effect on microstructure of parameters such as movement of grains as well as particles, temperature particle volume fraction etc. to achieve better mechanical properties. In composite system the new technique developed will show a

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new horizon in processing to get uniform distributions as per the particle size. This will enable aluminum producers to control, modify and optimize their casting processes, resulting in better products and economic savings. Further it will suggest a guide line for the processing technique of composites if the particle size is known.

Experimental Method: -
This process is divided into three categories Melting, Mixing, and Solidification.

Melting: -
In melting process, the molten Aluminum is prepared by Pit furnace.

Pit Furnace: -
A furnace made in pit for melting metal for taking casting process is called a pit furnace. It consists of a cylindrical steel shell, closed at the bottom with a grate and covered with a removable lid. The shell is lined with refractory bricks from inside. Sometimes the furnace is completely made in brick work instead of a steel shall. The draft of the air through the furnace may be a natural draft for low melting temperature metals but a force draft with the help of a blower to accelerate the melting process in case of higher melting temperature metals and alloys. To prepare the furnace for melting, a deep bed pf coke is kindled and allowed to burn until a state of good combustion is attained. Some of the coke is removed to make place for the crucible. The crucible is then lowered into furnace. The coke is replaced and additional coke is put to surround the crucible on all sides. Metal is then charged in the crucible and the furnace lid is replaced to give natural draft. When the metal melts and reaches the desired temperature (**660·c**).

Mixing: -
Mixing of liquid molten metal and Silicon Carbide powder is carried out using a special type of mixing chamber which is subjected to vibration.

Design of equipment: -
Description of mixing chamber consists of nanoparticle feeder, molten aluminum Feeder, Copper plates, helix, heater, sieve shaker as shown in Fig1.

A. Nanoparticle feeder – It facilitates the feeding of nanoparticles into the mixing chamber. It has a group of three sieves with different grades. These sieves ensure uniform falling of nanoparticles into the molten aluminum.
B. Molten aluminum feeder – There are two such feeders attached opposite to each other to the mixing chamber. It is of tube shape with enlarged openings which facilitates easy pouring of molten aluminum.
C. Copper plates – There are two copper plates inside the mixing chamber attached exactly at the points where molten aluminum feeders are fabricated to the main body. It decreases the velocity of flow of molten aluminum. Due to this the Nano powder of Sic are allowed to mix with the molten aluminum.
D. Helix – When the above mixture moves downward, its velocity again increases. So a helix is provided on the inner wall of tube which maintains a constant rate of flow of mixture into the mould. It is bent at edges to prevent agglomeration of Sic particles.
E. Heater – The lower part of mixing chamber is subjected to heating by means of a heater. This helps to maintain the molten aluminum at a constant temperature and avoid solidification of aluminum inside the mixing chamber. The viscosity of molten aluminum doesn’t increase as solidification process is not allowed to initiate inside the chamber due to heating.
F. Sieve shaker – The whole mixing chamber is held by sieve shaker. It ensures continuous falling of Nano powder from sieve as well as uniform mixing of Nano powder in molten aluminum.

Solidification: -
Setup for solidification consists of an ultrasonic generator which generates ultrasonic waves at a frequency of 35 kHz (Bandelin-Germany Make – Model: RK – 100H), an ultrasonic chamber, steel die and hanging heating filament.

Sufficient water was kept around the die for effective transmission of ultrasonic waves from the sides of the chamber. Mould was preheated to avoid thermal cracking. The preheated mould was kept in the ultrasonic chamber and the chamber was subjected to vibration at a frequency of 35 kHz. Liquid aluminium and Sic particulate having average size of 12.3 nm were simultaneously poured into the vibrating mould from the mixing chamber. After the simultaneous pouring the heating element was immediately brought down above the liquid metal in order to delay the solidification. The vibration was carried out for a period of five minute to ensure complete mixing.

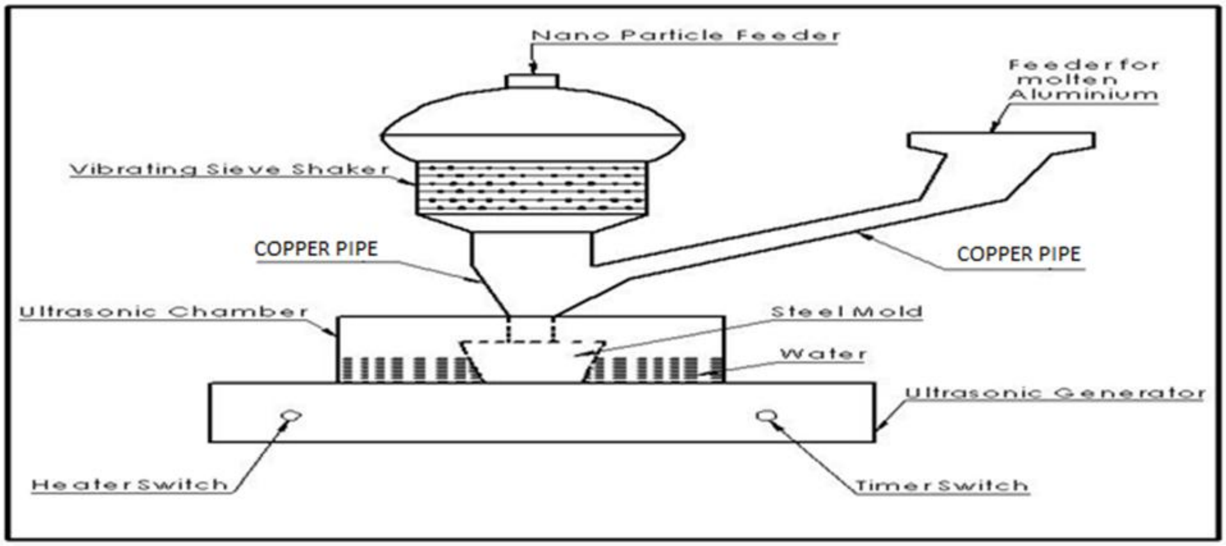

Fig 1: - Illustrates schematic diagram of experimental setup.

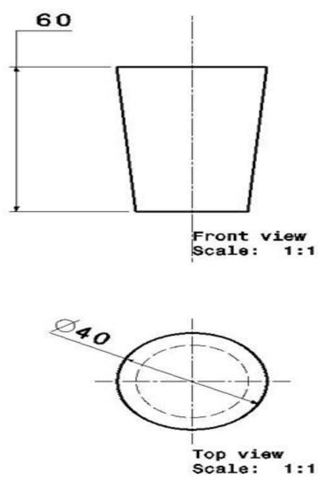

Figure 2: - illustrates schematic diagram of sample prepared during experiment.

Procedures for characterization of cast ingot: -

Specimen preparation for micro structural study: -

The ingots were cut into smaller samples as shown in Figure 3. Fig 3 (b) show the locations of samples cut out from the ingot at different location for Rock Well hardness tests.

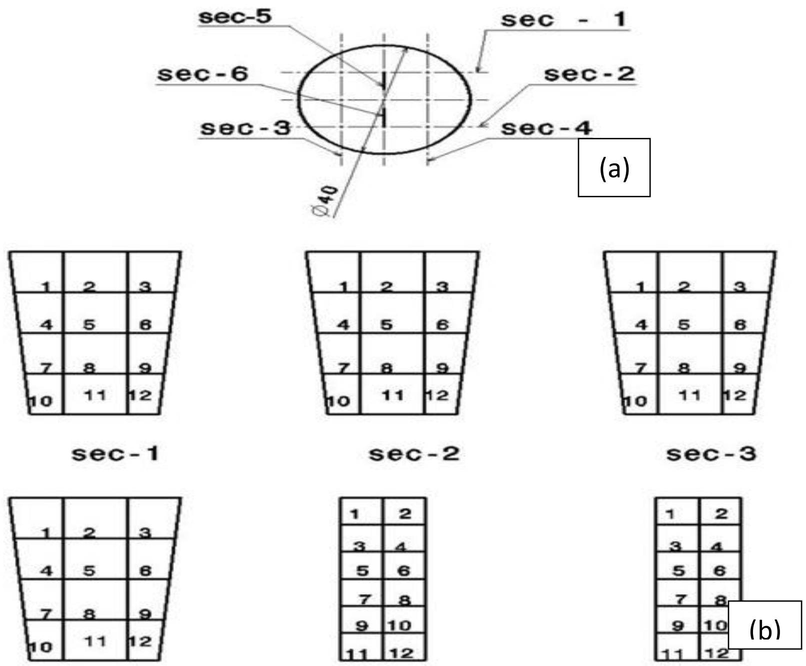

Fig 3: - Illustrates schematic diagram of sectioning of sample prepared during experiment.

Rockwell Hardness Test: -

The Rockwell hardness test method, as defined in ASTM E-18, is the most commonly used hardness test method. The Rockwell method measures the permanent depth of indentation produced by a force/load on an indenter. First, a preliminary test force (commonly referred to as preload or minor load) is applied to a sample using a diamond indenter. The Rockwell hardness was measured on the polished samples using steel ball indenter of 1.588 mm diameter with a load of 100kgf. The reported value is an average readings taken at different locations on the 6 section on the specimens.

Table 1: - Hardness distributions of Al-Sic Nano composites.

SECTION	SAMPLE	MAX HRB	MIN. HRB	MEAN HRB
1	1	97	82	90.75
2	2	94	81	88.41
3	3	90	81	85.83
4	4	92	83	87.33
5	5	95	84	89.25
6	6	97	87	93.25

Analysis of HRTEM and phase images of Al-Sic Nano nanoparticles: -

For TEM analysis High Resolution TEM (JEOL, JEM-2100) was used. The TEM operated at an accelerating voltage of 200 kV. Bright field images of Nano-particulates spread in the Al matrix were taken and selected area diffraction patterns were recorded. EDAX was also carried out.

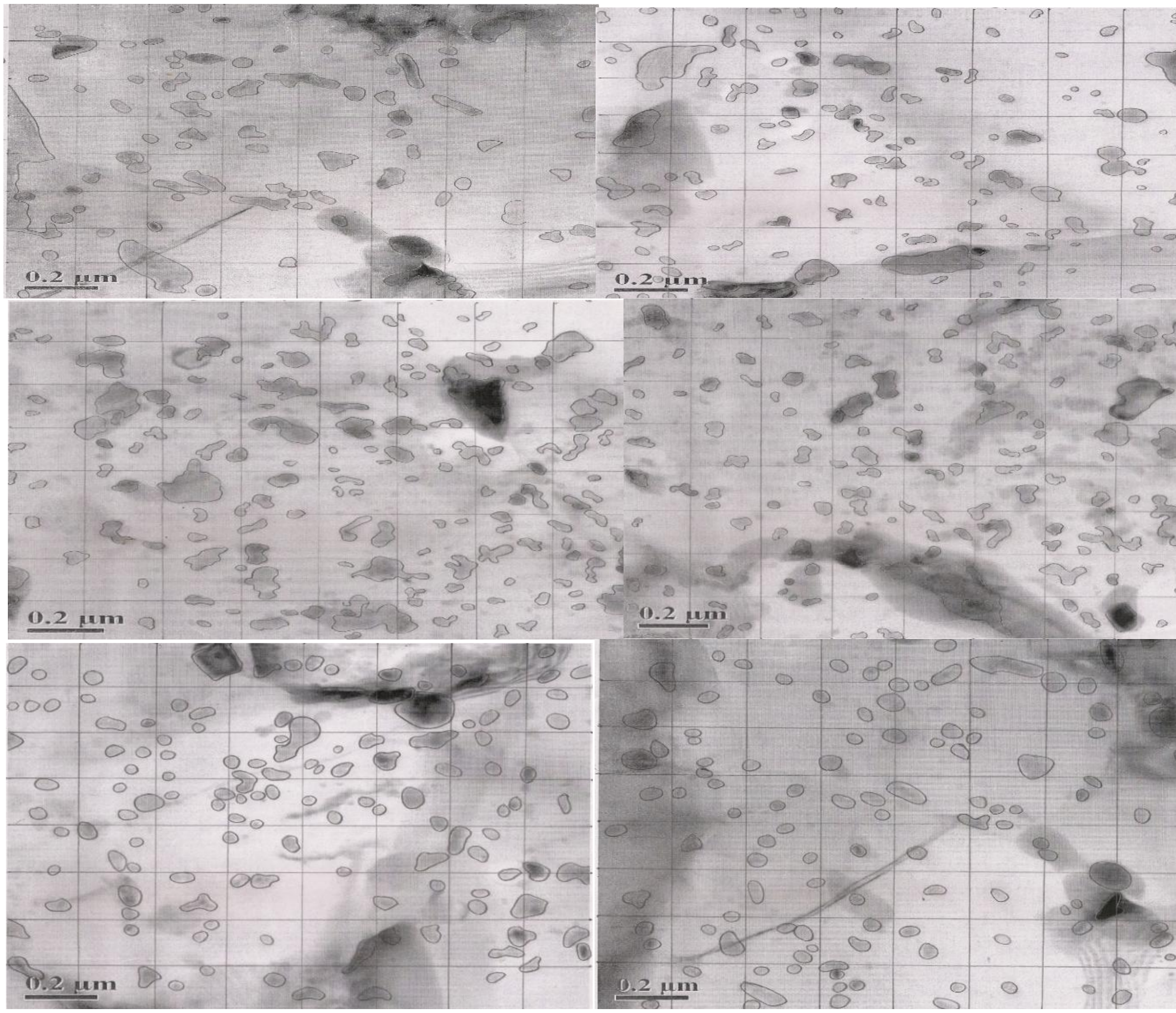

Fig 4: -HRTEM micrograph divided into number of cells according to scale.

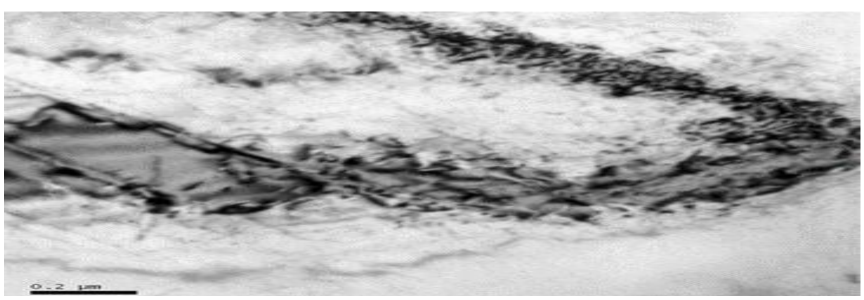

Fig 5: -TEM micrographs of Al-Sic Nano composites.

Table 2: -Depicts Particle Distribution of Individual HRTEM Figure of Different Section of cast ingot.

SECTION	MAX NO. OF PARTICLE	MIN NO. OF PARTICLE	MEAN OF PARTICLE	VOLUMETRIC FRACTION (IN %)
1	14	1	3.75	6.63
2	14	1	3.82	6.75
3	8	1	3.95	6.99
4	9	1	2.96	5.25
5	10	1	2.87	5.08
6	8	1	2.98	5.26

High resolution micrograph of various sections of 6 samples were done with the help of HRTEM. Some of those were chosen randomly for analysis. From analysis average volumetric fraction came to be 5.99.

Field Emission Scanning Microscopy& Energy Dispersive X-ray Analysis (FESEM&EDX):-

The casted specimen is polished and etched as per the standard metallographic procedure. Themicrostructures of color etched specimens were observed using a scanning electron microscope (FESEM). Silicon Carbide (Sic) analyzed by scanning electron microscope was shown in Figure 7 with average size of 10 microns.

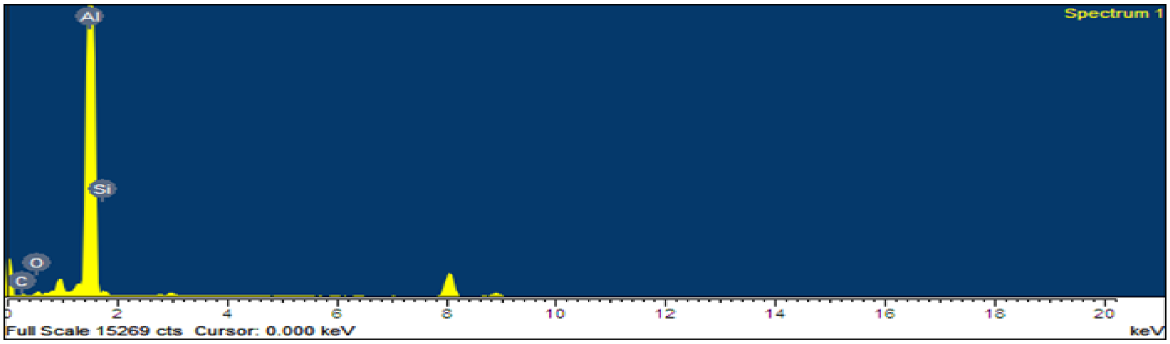

Fig 6: -Energy Dispersive X-ray Analysis of Al-Sic Nano composites

Fig7: -Field Emission Scanning Microscopyof**Al-**Sic Nano composites

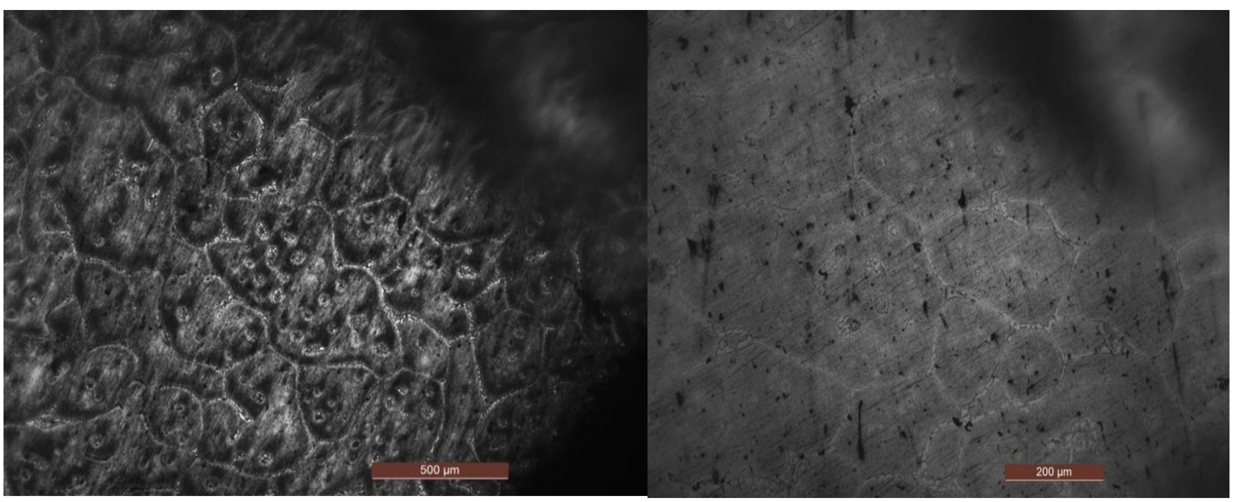

Fig 8: -Optical microscopy ofAl-Sic Nano composites.

Result & Discussion:-

From the hardness values taken from different locations of the ingot it is clear that the distribution of nano-particles is uniform across the ingot. It appears that in the liquid metal nano-particles were uniformly dispersed and the segregation of the particles near the grain boundaries is due to pushing of the nano-particles during the growth of the grains. As the grains grew, the nano-particles were pushed into the remaining liquid regions. In majority of metal-ceramic combinations gives the critical velocity for engulfment of particulate in solidified metal. Microstructure of the composites presented in Figure 5 clearly reveals the homogeneous distribution of and SiC in the Al alloy matrix and there is no evidence of porosity and cracks in the castings. This might be related toproper process parameters employed for the production of castings.

The Figure 6 shows EDX of Al-SiC nano composites confirming the SiC nano particles in the composites.TEM samples were made from different regions of the cast. From the qualitative observation it can be inferred that the SiC nano-particles have got dispersed uniformly within the ingot. Table 2 shows that analysis average volumetric fraction by usingHRTEM micrograph and can achive uniform volume fraction throughout the specimen.This shows the SiC nanoparticles spread uniformly through out the ingot.

Conclusions: -

- From the hardness values taken from different locations of the ingot it is clear that the distribution of Nano-particles is uniform across the ingot.
- From HRTEM micrograph shows the uniform volume fraction throughout the specimen.
- The hardness of the parent metal increased by comparing with the composite material.
- Lack of porosity exhibited in the microstructure of Al-Sic matrix composite indicates there is a rather good particulate – matrix interface bonding.

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