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Fabrication of aluminum matrix composite reinforced by SiC Nano particles for enhancing its mechanical characteristics

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Abstract: The usage of AMCs in ranges from claiming aviation Furthermore auto businesses incorporates performance, monetary What's more natural profits. The key profits of AMCs to transportation division need aid easier fuel consumption, less noise Furthermore bring down contamination and airborne outflows. Presently Al-5000 arrangement is broadly utilized within car sector, marine and aviation sector because of their unrivalled erosion resistance, phenomenal formability, beneficial welding aspects and light weight. Al5083, An non-heat treatable secondary Mg-Al created alloy, is extensively utilized within the car segment. Nano sic particles support over aluminum compound upgrade its mechanical properties such as hardness, ductile strength, compressive quality without affecting the ductility of the material. In this fill in micron Furthermore Nano sic /Al 5083 composites were created toward stir casting process Furthermore investigated it mechanical properties. Effect demonstrated that Hardness, rigidity and compressive quality at 2% sic nano composites might have been higher in comparison of all other compositions. Creation and testing of car gears might have been also conveyed out and found suitable to displace existing materials steel in vehicles.
Key words: Aluminum, SiC, nanomaterial, Al alloy, mechanical properties.

I. INTRODUCTION

A. Composite

A composite is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. The composite generally has superior characteristics than those of each of the individual components.

Generally a composite material is composed of reinforcement (fibers, particles/ particulates, flakes, and/or fillers) embedded in a matrix (metals, polymers). The matrix holds the reinforcement to form the desired shape while the reinforcement improves the mechanical properties of matrix. When designed properly, the new combined material exhibits better than would each individual material.

1) Classification of composite: Composite materials are commonly classified at following two distinct levels:

The first level of classification is usually made with respect to the matrix constituent. The major composite classes include Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs). The term organic matrix composite is generally assumed to include two classes of composites, namely Polymer Matrix Composites (PMCs) and carbon matrix composites commonly referred to as carbon-carbon composites.

The second level of classification refers to the reinforcement form - fibre reinforced composites, laminar composites and particulate composites. Fibre Reinforced composites (FRP) can be further divided into those containing discontinuous or continuous fibres.

Fibre Reinforced Composites are composed of fibres embedded in matrix material. Such a composite is considered to be a discontinuous fibre or short fibre composite if its properties vary with fibre length. On the other hand, when the length of the fibre is such that any further increase in length does not further increase, the elastic modulus of the composite, the composite is considered to be continuous fibre reinforced. Fibres are small in diameter and when pushed axially, they bend easily although they have very good tensile properties. These fibres must be supported to keep individual fibres from bending and buckling.

Laminar Composites are composed of layers of materials held together by matrix. Sandwich structures fall under this category.

Particulate Composites are composed of particles distributed or embedded in a matrix body. The particles may be flakes or in powder
form. Concrete and wood particle boards are examples of this category.

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2) *Properties of composites:* The following are the various properties of Composites:

a) Lower density (20 to 40%)

b) Higher directional mechanical properties (specific tensile strength (ratio of material strength to density) 4 times greater than that of steel and aluminium.

c) Higher Fatigue endurance.

d) Higher toughness than ceramics and glasses.

e) Versatility and tailoring by design.

f) Easy to machine.

g) Can combine other properties (damping, corrosion).

h) Cost

B. Introduction of metal matrix composites

Metal Matrix Composites (MMCs), like all composites; consist of at least two chemically & physically distinct phases, suitably distributed to provide not obtainable with either of the individual phases. Metal matrix composites, at present though generating a wide interest in research fraternity, are not as widely in use as their plastic counterparts. High strength, fracture toughness and stiffness are offered by metal matrices than those offered by their polymer counterparts. They can withstand elevated temperature in corrosive environment than polymer composites. Most metals and alloys could be used as matrices and they require reinforcement materials which need to be stable over a range of temperature and non-reactive too.

Most metals and alloys make good matrices. However, practically, the choices for low temperature applications are not many. Only light metals are responsive, with their low density proving an advantage. Titanium, Aluminium and magnesium are the popular matrix metals currently in vogue, which are particularly useful for aircraft applications. If metallic matrix materials have to offer high strength, they require high modulus reinforcements. The strength-to-weight ratios of resulting composites can be higher than most alloys.

The melting point, physical and mechanical properties of the composite at various temperatures determine the service temperature of composites. Most metals, ceramics and compounds can be used with matrices of low melting point alloys. The choice of reinforcements becomes more stunted with increase in the melting temperature of matrix materials.

For many researchers the term metal matrix composites is often equated the term light metal matrix composites (MMCs). Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications.

1) *Objectives of metal matrix composites*

a) Increase in yield strength and tensile strength at room temperature and above while maintaining the minimum ductility or rather toughness,

b) Increase in creep resistance at higher temperatures compared to that of conventional alloys,

c) Increase in fatigue strength, especially at higher temperatures,

d) Improvement of thermal shock resistance,

e) Improvement of corrosion resistance,

f) Increase in Young's modulus,

g) Reduction of thermal elongation.

To summarize, an improvement in the weight specific properties can result, offering the possibilities of extending the application area, substitution of common materials and optimisation of component properties.

C. Stir casting

This involves incorporation of ceramic particulate into liquid aluminium melt and allowing the mixture to solidify. Here, the crucial thing is to create good wetting between the particulate reinforcement and the liquid aluminium alloy melt. The simplest and most commercially used technique is known as vortex technique or stir- casting technique. The vortex technique involves the introduction of pre-treated ceramic particles into the vortex of molten alloy created by the rotating impeller. Microstructural inhomogeneities can cause notably particle agglomeration and sedimentation in the melt and subsequently during solidification. Inhomogeneity in reinforcement distribution in these cast composites could also be a problem as a result of interaction between suspended ceramic particles and moving solid-liquid interface during solidification. Generally it is possible to incorporate up to 30% ceramic particles in the size range 5 to 100 µm in a variety of molten aluminium alloys. The melt–ceramic particle slurry 11 may be transferred directly to a shaped mould prior to complete solidification or it may be allowed to solidify in billet or rod shape so that it can be reheated to the slurry form for further processing by technique such as die casting, and investment casting. Another variant of stir casting process is compo- casting. Here, ceramic particles are incorporated into the alloy in the semi-solid state.

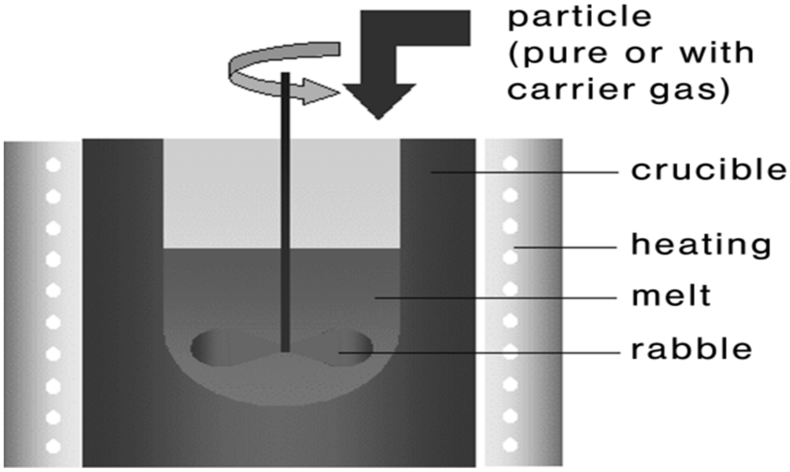

Fig. 1 Schematic operational sequence during melt stirring

II. FABRICATION OF METAL MATRIX COMPOSITE

Following steps are involved in manufacturing of gear using stir casting process:

A. Cut the aluminum alloy-5083 ingot weight it and put it in the ceramic crucible in the electric resistance furnace.
B. Start the electric furnace and set the casting temperature 800ºC.
C. Three castings were done. One for AA5083/10% micron SiC one for AA5083/1% nano SiC and one for AA5083/2% nano SiC. When aluminum alloy-5083 fully melt than added SiC particles 10% micron by weight,1% nano and 2% nano SiC by weight .
D. After addition of SiC particles it mixed by Mechanical stirring.
E. After the fully mixing of SiC particles, then crucible take out from the furnace.
F. Melt was poured in the pre heated mild steel disc die for circular disk and hollow cylindrical die for tensile, compression & hardness specimen.
G. After solidification of melt casted circular disc were removed from die.
H. Machining on circular disc was done on lathe machine to get the gear of required dimensions.
I. After being machined cut the teeth over circular disc by milling machine.

III. MATERIAL SELECTION

A. Composition analysis of al-alloy 5083

Composition analysis of Al-alloy 5083 was carried out in AMPRI Bhopal. Result of this analysis is shown in table 3.1 .Al5000 series are extensively used in marine and aerospace applications because of their superior corrosion resistance, excellent formability and good welding characteristics. Al5000 series are broadly used for the construction of ship buildings/structures; however due to low strength and poor wear resistance the application of this series is limited. Hence we take Al-5083 for this project because Al5083, a non-heat treatable, high Mg-Al wrought alloy, and light weight. It is extensively used for the marine and automobiles applications.

TABLE I. Percentage of composition in Al-alloy 5083

Element	Zn	Fe	Ti	Cu	Si	Pb	Mn	Mg	Cr	Al
%Present	0.03	0.173	0.04	0.0181	0.16	0.0140	0.526	5.13	0.097	Balance

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B. Particle size analysis

This analysis has done to find out the size of the particle. Under this analysis two type of test has conducted to find out Micron and Nano size particle.

1) *Scanning electron microscope (s.e.m.) analysis of sic particle:* SEM analysis of SiC particles were carried out to find out the size micron particles present in SiC powder.

In the below fig. 2 we see the average size (500nm) of particle which is more than 100 nm i.e it is micron particle.

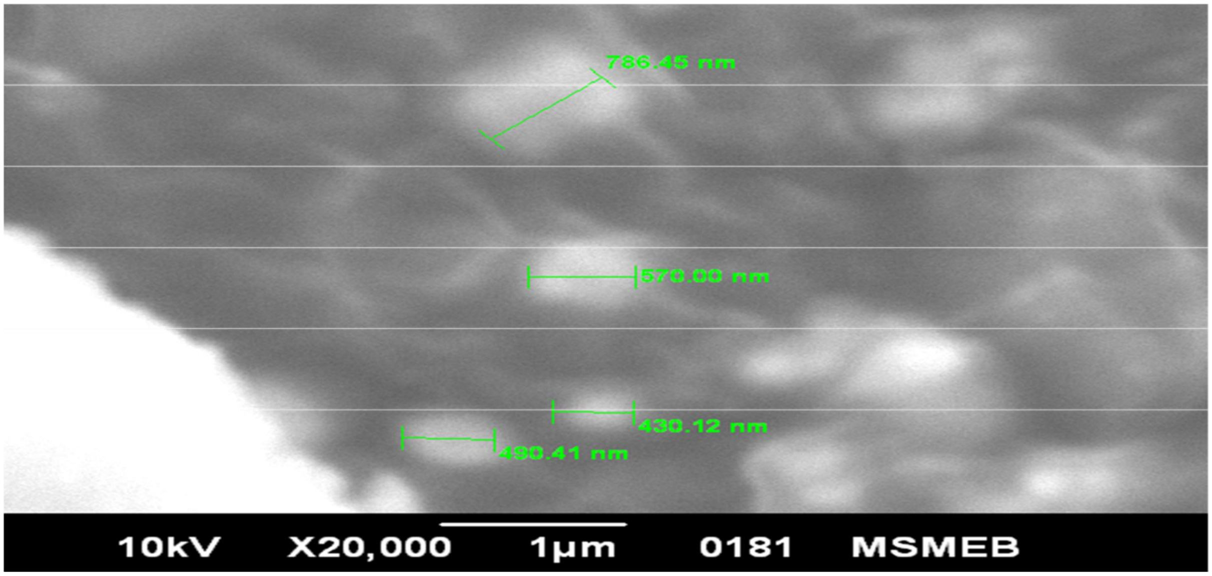

Fig. 2 SEM analysis of SiC particle

2) *Transmission electron microscope of sic particle:* This analysis has done to find out the size of the Nano size particle. The images come from this test which shows the size of the particle. The images has shown below

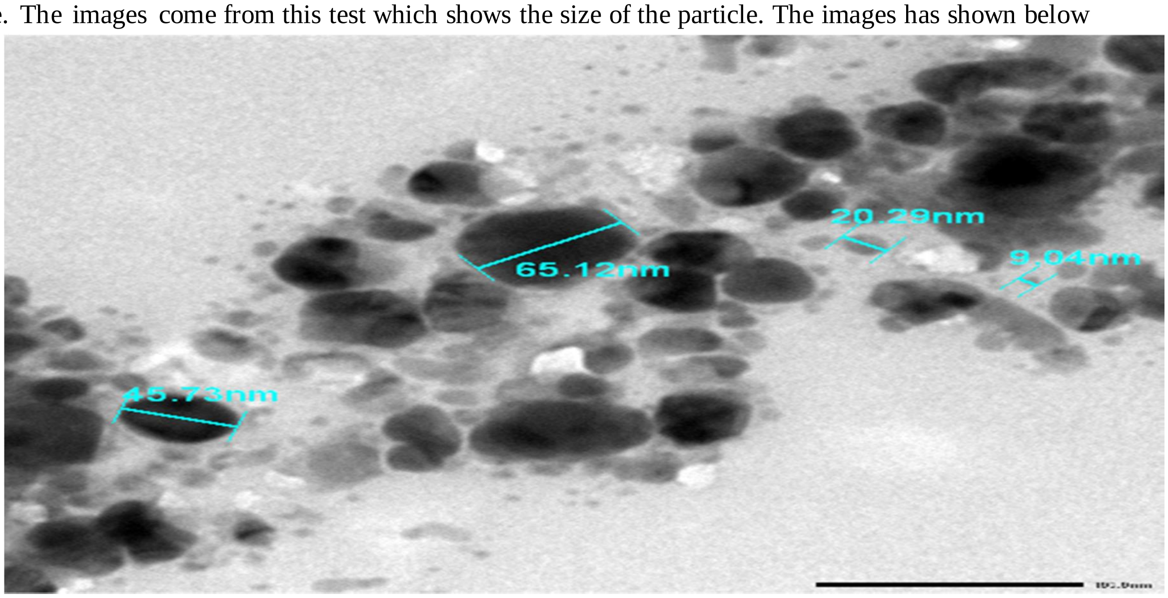

Fig. 3 TEM analysis of SiC particle

From the above fig. 3 of T.E.M. analysis, it has analyzed that the SiC particle are in nano size. From the above fig. it is showing that particles are having average size about
60 nano meters.

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IV. RESULT AND DISCUSSION

A. Hardness result

The average Rockwell hardness values of cast Al-alloy, Al-alloy with 10% SiC composites, Al-alloy with 1% nano composites, and Al-alloy with 2% nano composites measured on the polished surfaces of the samples using B scale on Rockwell hardness tester are shown in table II and Fig.4. Total 100 Kg load applied and 1/16inch indenter used.

TABLE II. Hardness of composite

Composition	Hardness (HRB)
Al alloy	29.1
Al alloy with 10% SiC composite	44.5
Al alloy with 1% SiC nano composite	40.1
Al alloy with 2% SiC nano composite	48.1

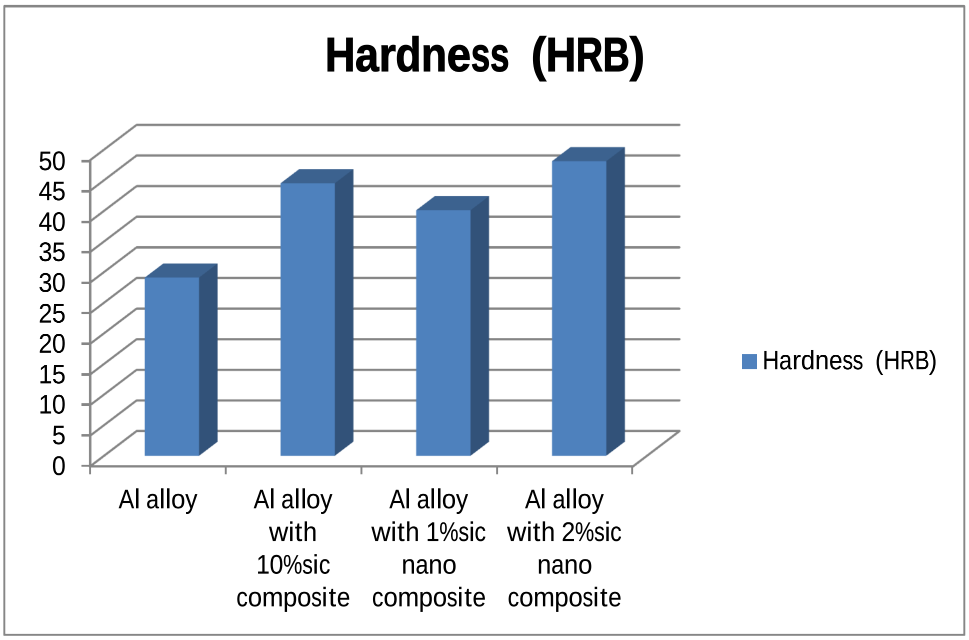

Fig. 4 Hardness of composite

The above table and diagram expressed the effect of SiC particle on alloy of Al-5083. From the above table the following result has found out from Hardness test-

The average hardness of nano particle specimen and micron particle specimen is greater than Al-5083 alloy.

When amount of nano size particle increases then hardness is also increases and it becomes higher then micron size particle specimen after a certain limit of mixing nano particle.

Hence the hardness of Al-alloy with 2% SiC nano composite is more among all tested composition. But hardness of Al alloy with 10%sic composite is more than Al alloy with
1%sic nano composite.

B. Tensile strength result

From the tensile test various results obtained like tensile strength, yield strength, percentage of elongation etc. All required value of these compositions is shown in table III and fig.5.

The average tensile strength values of cast Al-alloy, Al-alloy with 10% SiC composites, Al-alloy with 1% nano composites, and Al-alloy with 2% nano composites measured on the polished surfaces of the samples using U.T.M tester.

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Table III Tensile strength of composites

Composition	Tensile Strength (MPa)	Young Modules (GPa)
Al alloy	224.1	72.1
Al alloy with 10%sic composite	239.2	77.9
Al alloy with 1%sic nano composite	254.8	75.1
Al alloy with 2%sic nano composite	275.1	81.1

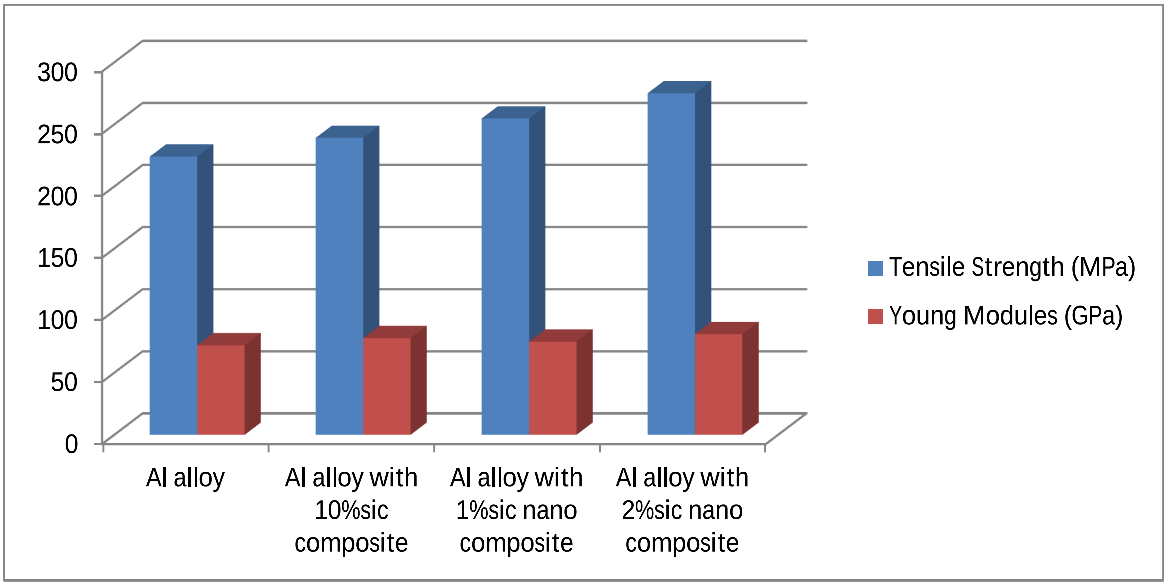

Fig. 5 Tensile strength of composites

The above table is showing the effect of SiC particle on alloy of Al-5083. From the above table the following result has found out from tensile test-

The Tensile strength Young modules of specimen produced by micron particle and nano particle are having strength as compare to pure alloy.

Nano particle specimen having higher tensile strength and Young modules as compare to micron particle. As the amount of nano particle increases the Tensile strength and Young modules value increases.

Hence the tensile strength and young modules of Al alloy with 2% SiC nano composite is more among all tested composition.

C. Compression strength result

From the compression test various results obtained like compressive strength and Poisson ratio. All require value of these compositions is shown in table IV and fig.6.

The average compression strength values of cast Al-alloy, Al-alloy with 10% SiC composites, Al-alloy with 1% nano composites, and Al-alloy with 2% nano composites measured on the polished surfaces of the samples.

Table IV Compression strength of composites

Composition	Compression Strength (MPa)	Poisson Ratio
Al alloy	315	0.33
Al alloy with 10%sic composite	341.5	0.33
Al alloy with 1%sic nano composite	396	0.33
Al alloy with 2%sic nano composite	533.5	0.33

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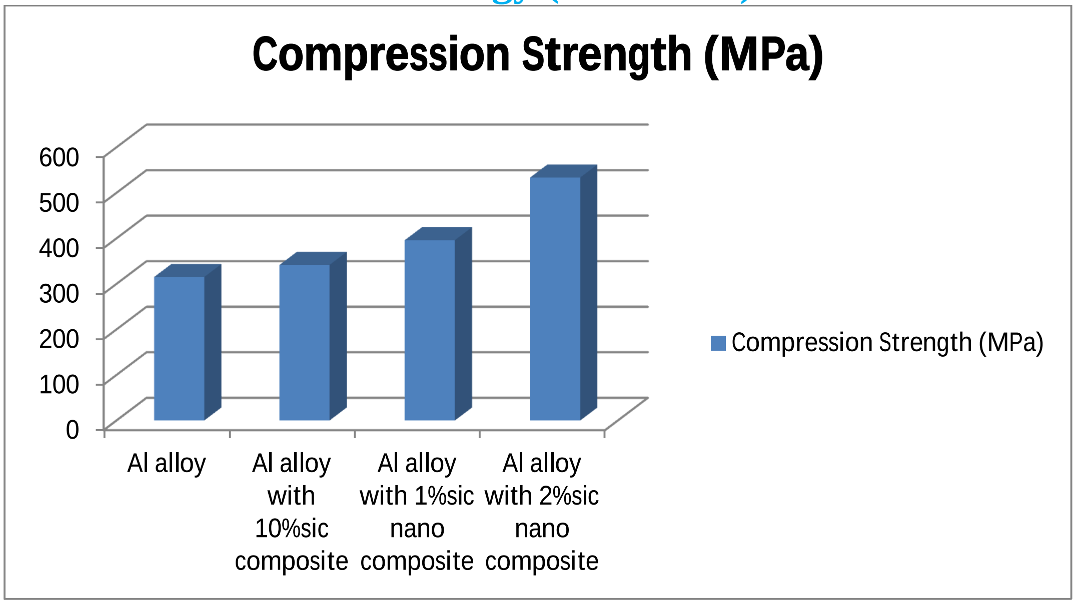

Fig. 6 Compression strength of composites

The above table is showing the effect of SiC particle on alloy of Al-5083. From the above table the following result has found out from tensile test-

1) The compressive strength of micron particle and nano particle has higher than the Al-5083 alloy.

2) Nano particle specimen having higher compressive strength as compare to micron particle.

3) As the amount of nano particle increases the Compressive strength and increases. Poisson ratio value remains constant.

Hence the compression strength of Al alloy with 2% SiC nano composite is more among all tested composition.

V. CONCLUSIONS

The following conclusions were found from the present study:

From the study it is concluded that we can use SiC particle as reinforcement material with Al-5083 alloy as matrix material for having good properties. When addition of nano SiC particle in Al-5083 alloy, material properties like Young Modules, Tensile strength, Compressive strength and Hardness etc. become good as compare to micron particle and Al- alloy. We see that the Al-alloy with 2% nano composite has more Tensile strength, young modulus, compressive strength and hardness as compare to microns particle and al-alloy. But hardness of Al-alloy with 10% SiC composite is more than Al alloy with 1% SiC nano composite. By increasing the amount of nano particle (at a certain limit) material properties improved.

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