ANALYSIS OF MECHANICAL PROPERTIES OF ALUMINIUM ALLOY WITH REINFORCEMENT OF SILICON CARBIDE (SiC) POWDER

ABSTRACT-The trend towards the use of composites is increasing rapidly in the ongoing scenario and is likely to increase more rapidly in the future. Nowadays aluminium and its alloy based composites are gaining importance in the upcoming fields of engineering. Aluminium-silicon alloys have gained increasing market share in the automotive and aerospace industry because of increased environmental demands. These alloys have a high strength-to-weight ratio, good corrosion resistance, cast ability and recycling potential.

In this study, aluminium alloying with copper and reinforced with silicon carbide metal matrix composites (MMCs) of different compositions were prepared under different loads. six different types Al-SiC composite specimens having 0%, 4%, 8%, 12%, 16% and 20% volume fractions of silicon carbide were fabricated using conventional stir casting process. The specimens of different compositions were prepared for investigating the behavior of material under tensile, compression and hardness test. The obtained results show that density and hardness of the composites creates dramatically changes by volume fraction of silicon carbide particulates.

KEYWORDS-Aluminium metal matrix composite(AMMCs), mechanical properties, stir casting, composite particulate.

1.__INTRODUCTION__-

The growing demands in the automotive and aerospace industry for reduction in energy consumption and producing more fuel-efficient vehicles continues to be a big challenge. The aluminium-silicon alloys have gained increased market shares in the aerospace and automotive industry and have replaced competing ferrous materials. Aluminium-silicon alloys are widely used in the automotive industry due to the high strength-to-weight ratio, good corrosion resistance and good cast ability.

Now days the need of advanced engineering materials for various engineering applications goes on increasing. To meet such demands metal matrix composite is one of reliable source. In composites materials are combined in such a way as to enable us to make better use of their parent material properties while minimizing to some extent the effects of their deficiencies.

In the past few years, materials development has shifted from monolithic to composite materials for adjusting to the global need for reduced weight, specific strength and high performance in structural materials. Driving force for the utilization of AMCs in areas of aerospace and automotive industries include performance, economic and environmental benefits. In traditional stir casting process, reinforcement material is being added to molten matrix and poured in to permanent molds after stirring mechanism. By the Stir casting process results better bonding between matrix and reinforcement. The Metal Matrix Composites are difficulty to fabricate in achieving homogeneous distribution of particles, wettability, chemical reactions at the interface and porosity and Maximum Al based MMC's fabrication has been being on SiC, Al2O3, TiB2 as reinforcement material in present research works. The major advantages of aluminum metal matrix composites (AMCs) over traditional Materials are-

- Low density
- High strength to weight ratio
- Improved wear resistance
- High specific stiffness
- Improved damping capabilities
- Tailor able thermal expansion co-efficient
- Good corrosion resistance etc.

2.__EXPERIMENTAL DETAILS__-

2.1 Stir Casting-

In the conventional and cost effective stir casting technique, normally reinforcement in the form of particles like SiC, Al2O3, TiC, MgO, B4C etc. are incorporated into the aluminum matrix melt by creating forced vortex stirring action. Two step mixing is the recent and interesting growth in stir casting technique. In this technique, firstly the matrix alloy is heated above its liquidus temperature to ensure complete melting. The temperature of the molten metal is then lowers down in between the liquidus and solidus points such that the molten slurry remains in a semi-solid state. The preheated reinforcement particles are mixed into the semi-solid slurry by manual stirring at this stage. The slurry containing the reinforcement particles is again heated just above its liquids temperature and at this stage stirring is done with the help of a suitably designed mechanical stirrer. The obtained microstructure of the composite made by two step stir casting process is more uniform than that produced with traditional stirring mechanism.

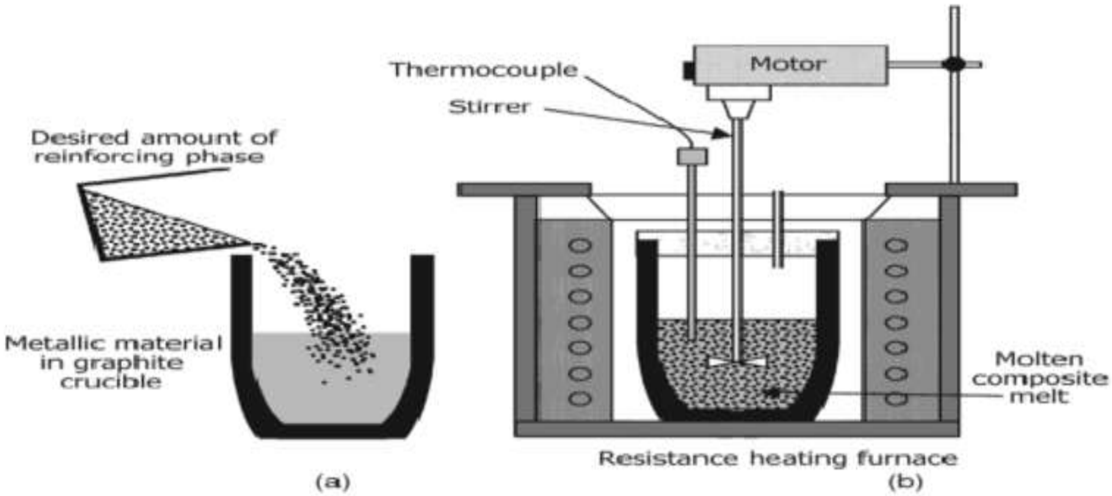


Fig.1 Stir casting setup

2.2 Material Description-

(A)<u>PARENT METAL</u>- In this research we used the most useful metal of the engineering applications. Here aluminium metal is treated as the parent material. There are numerous advantages of aluminium metal in the present world situation. Aluminium is a silvery-white metal, the 13th element in the periodic table. One surprising fact about aluminium is that it's the most widespread metal on Earth, making up more than 8% of the Earth's core mass. It's also the third most common chemical element on our planet after oxygen and silicon. At the same time, because it easily binds with other elements, pure aluminum does not occur in nature.

- Melting point: 660 °C
- Boiling point: 2467 °C
- Density: 2,700 kg/m³
- Relative atomic mass: 26.98gm/mol
- Oxidation number: 3
- Atomic radius: 118 pm

(B)<u>ALLOYING METAL</u>-Here copper is used as the alloying metal. The copper provides substantial increases in strength and facilitates precipitation hardening. The introduction of copper to aluminium can also reduce ductility and corrosion resistance. The susceptibility to solidification cracking of aluminium-copper alloys is increased. Consequently, some of the alloys can be the most challenging aluminium alloys to weld. These alloys include some of the highest strength heat treatable aluminium alloys. The most common applications for the 2xxx series alloys are aerospace, military vehicles and rocket fins.

(C)<u>ALLOYING PROPORTION</u>-Here we use 80:20 as the alloying proportion by weight of the metal. As per 100gm of sample weight proportion is-

Aluminium metal-80gm

Copper metal-20gm

(D)<u>COMPOSITE MATERIAL</u>-Here we using silicon carbide(SiC) as a composite material. SiC particulates have attained a prime position among the various particulate aluminium metal matrix composite (PAMC). This is due to the fact that introduction of SiC to the aluminium matrix substantially enhances the strength, the modulus, the abrasive wear resistance and thermal stability. The density of SiC (3.2g/cm3) is nearer to that of aluminium alloy (2.7g/cm3). The resistance of SiC to acids, alkalis or molten salts up to 8000^{o} C makes it a good reinforcement candidate for aluminium based MMC. Addition of Silicon carbide particle results in excellent mechanical properties this produces a very hard and strong material.

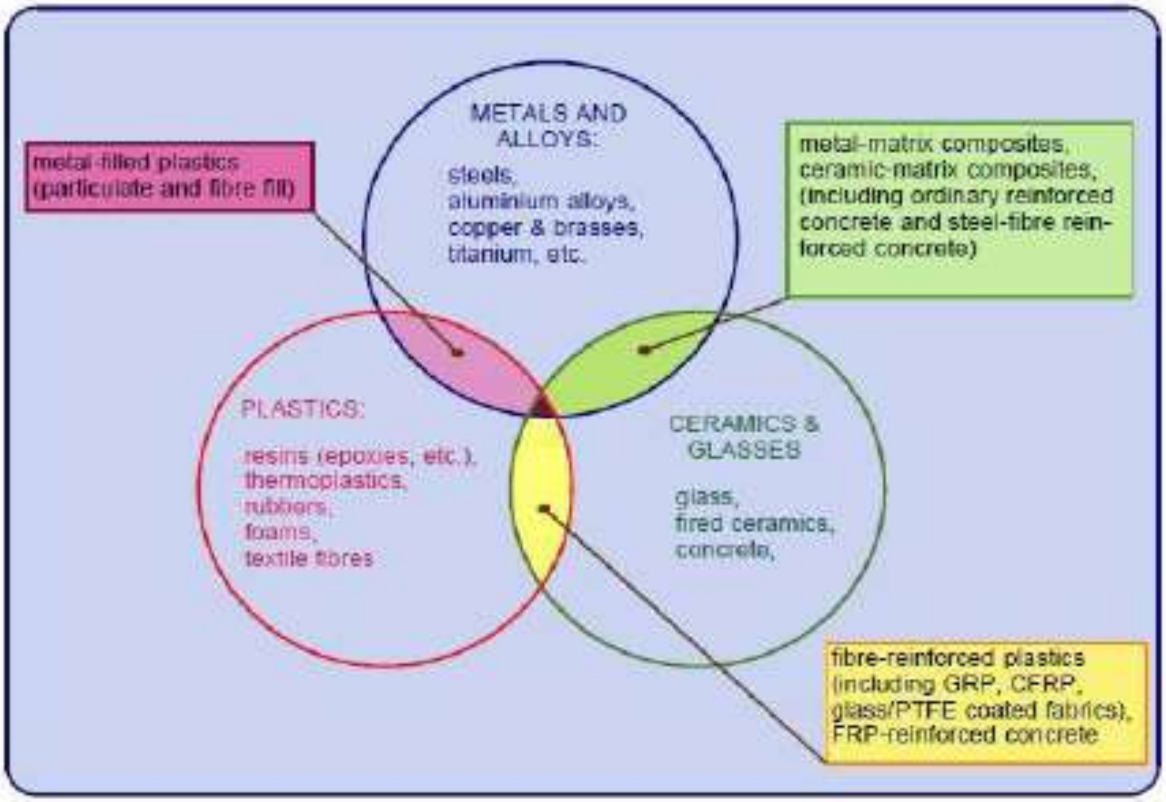


Fig.2 Composite material diagram

2.3 Testing Machine-

Here we are performing three different mechanical test over the number of samples and for testing we used two machines for performing it.

(A)<u>BRINELL HARDNESS MACHINE</u>

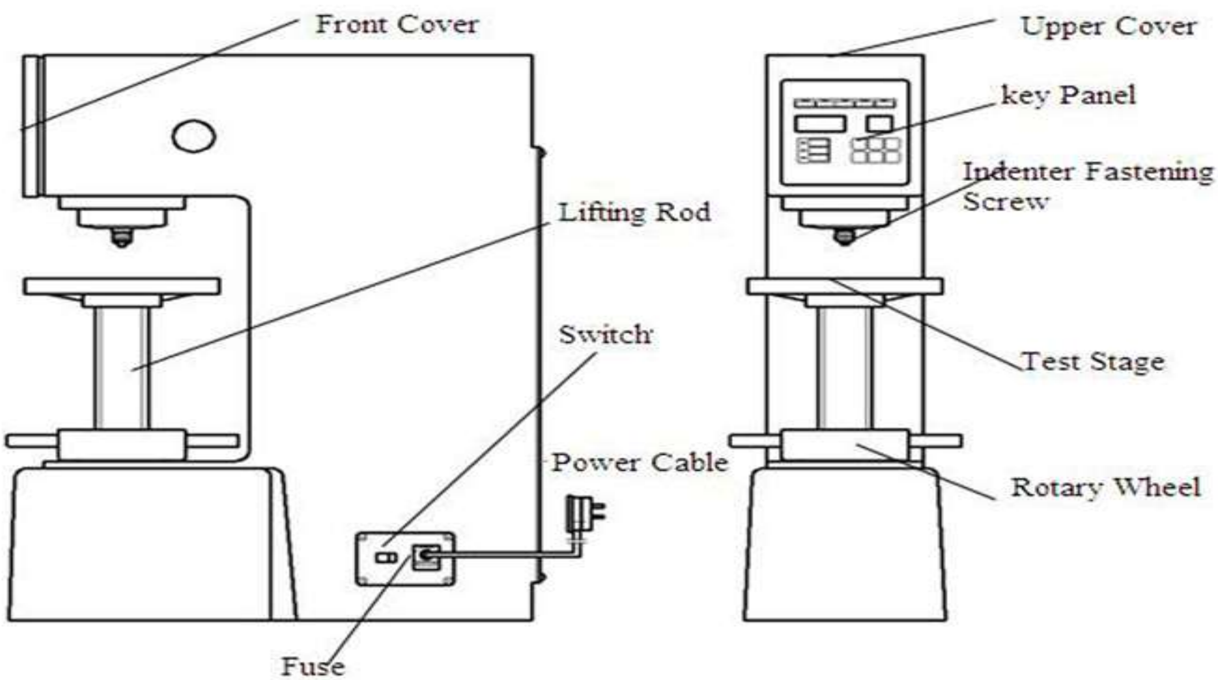


Fig.3 Labelled diagram of brinell hardness machine

Fig.4 Original brinell hardness machine

(B) <u>10 TON AMSLER TESTING MACHINE</u>

Fig.5 10 ton amsler testing machine

3.<u>RESULT AND DISCUSSIONS</u>-

(A)<u>TENSILE STRENGTH-</u>

Here we are testing the tensile strength of the samples, the specimen of tensile testing is given below here.

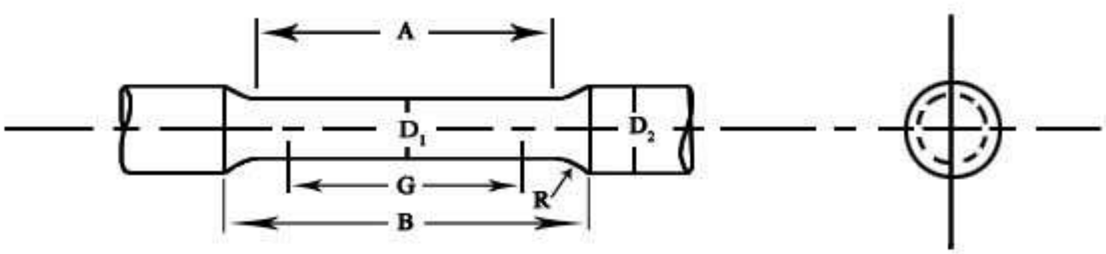


Fig.6 tensile strength specimen

Where,

D_1=14mm , B=10cm , G= 6.80cm , D_2=18mm , R=2mm

SAMPLE-1 SAMPLE-2

P=1.86 (TON)
$A=(\pi/4)\ D_1^2=153.86mm^2$
Tensile strength=P/A=120.490 MPa

P=2.02 (TON)
$A=(\pi/4)\ D_1^2=153.86mm^2$
Tensile strength=P/A=130.854 MPa

SAMPLE-3
P=2.11 (TON)
$A=(\pi/4)\ D_1^2=153.86mm^2$
Tensile strength=P/A=136.685 MPa

SAMPLE-4
P=2.19 (TON)
$A=(\pi/4)\ D_1^2=153.86mm^2$
Tensile strength=P/A=141.867 MPa

SAMPLE-5
P=2.31 (TON)
$A=(\pi/4)D_1^2=153.86mm^2$
Tensile strength=P/A=149.641 MPa

SAMPLE-6
P=2.47 (TON)
$A=(\pi/4)D_1^2=153.86mm^2$
Tensile strength=P/A=160.005 MPa

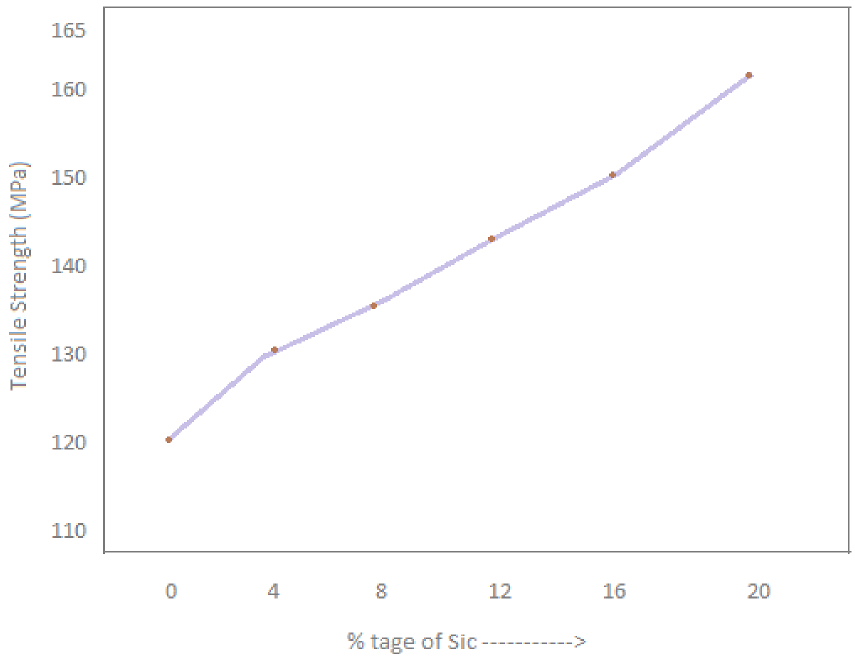


Fig.7 tensile strength curve

(B)<u>COMPRESSIVE STRENGTH-</u>
Here we are testing the compressive strength of the samples, the specimen of compressive testing is given below here.

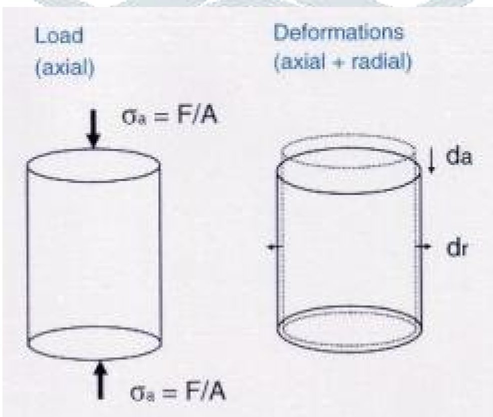


Fig.8 compression test specimen

Length=20mm, Diameter=18mm

SAMPLE-1
P=2.92 (TON)
$A=(\pi/4)\ D_1^2=254.34mm^2$
Tensile strength=P/A=114.428 MPa

SAMPLE-2
P=3.26 (TON)
$A=(\pi/4)\ D_1^2=254.34mm^2$
Tensile strength=P/A=127.751 MPa

SAMPLE-3
P=3.43 (TON)
A=(π/4) D_1^2=254.34mm^2
Tensile strength=P/A=134.413 MPa

SAMPLE-4
P=3.56 (TON)
A=(π/4) D_1^2=254.34mm^2
Tensile strength=P/A=139.391 MPa

SAMPLE-5
P=3.71 (TON)
A=(π/4)D_1^2=254.34mm^2
Tensile strength=P/A=145.386 MPa

SAMPLE-6
P=3.89 (TON)
A=(π/4)D_1^2=254.34mm^2
Tensile strength=P/A=152.440 MPa

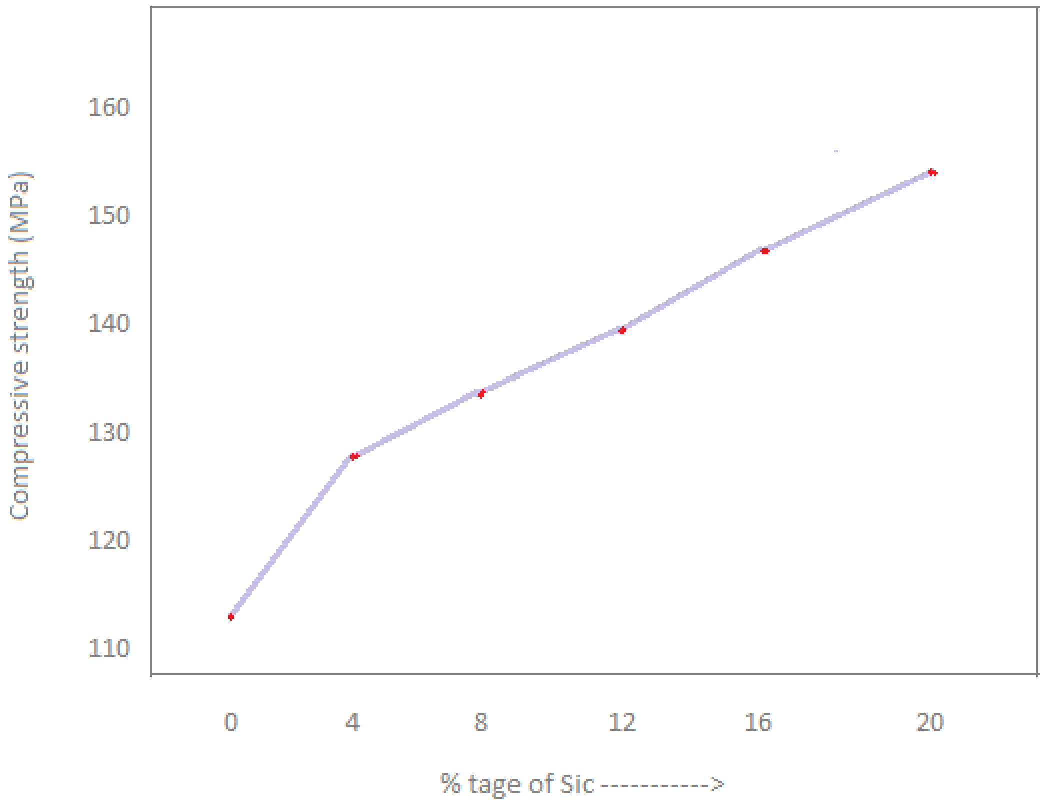
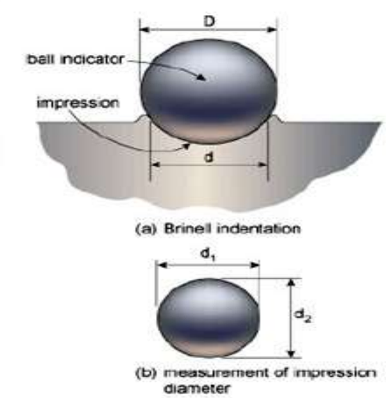


Fig.9 compressive strength curve

(C)HARDNESS TEST-



$$BHN = \frac{P}{\frac{\pi D}{2}\left[D - \sqrt{D^2 - d^2}\right]}$$

Where:
P is the test load [kg]
D is the diameter of the ball [mm]
d is the average impression diameter of indentation [mm]

Fig.10 hardness testing ball

Here,
P=1000, D=10mm

SAMPLE-1
d=3.012mm
hardness=274.174BHN

SAMPLE-2
d=2.994mm
hardness=275.23BHN

SAMPLE-3
d=2.987mm

SAMPLE-4
d=2.981mm

hardness=277.17BHN	hardness=279.32BHN
SAMPLE-5	SAMPLE-6
d=2.971mm	d=2.941mm
hardness=281.97BHN	hardness=287.93BHN

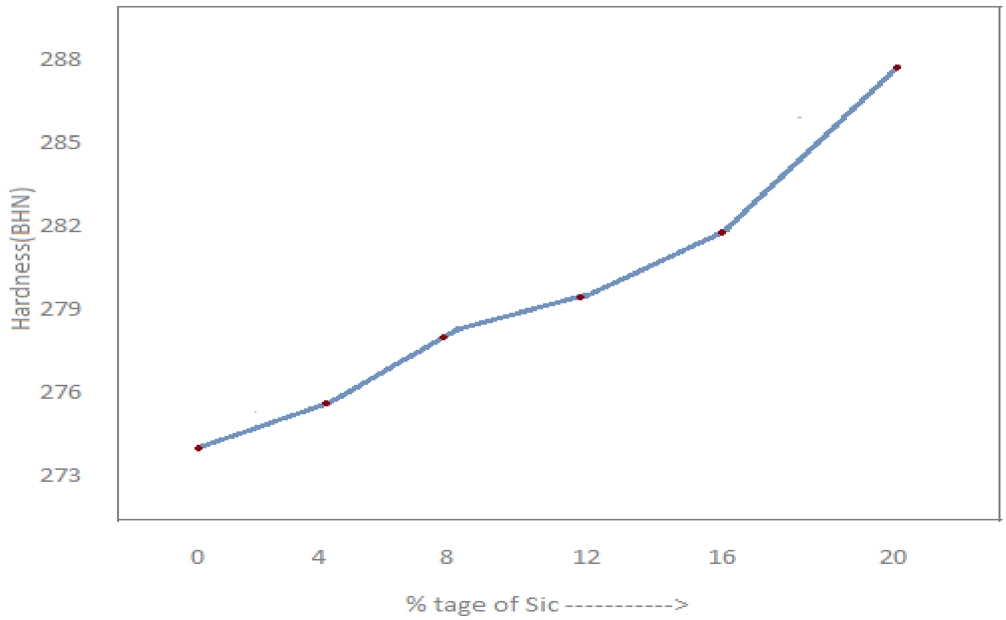


Fig.11 hardness curve

4.CONCLUSION-

It is concluded that aluminium alloy with reinforcement of silicon carbide is clearly better to base alloy. The main results come from the above calculations are given below: -

- It improves the mechanical properties with their excellent quality of tensile strength.
- The liquid metal processing technique known as Stir casting technique is well suited, economical and can be successfully employed to produce Al-matrix composite materials possessing desired mechanical, microstructural and wear properties.
- Aluminum and its alloys reinforced with ceramic agents exhibited significant improvement in microstructural, mechanical and tribological performances.
- Compressive strength of material also increases with increase in percentage of composite.
- Hardness quality also improves than the base alloy material.
- Corrosion resistance improves.
- Fatigue properties of aluminium cast alloy is also presents a better result as compared to other materials but sometimes presence of porosity may cause not so much desirable results.
- It is also concluded that after adding of reinforcement to the base metal properties like electrical and thermal are also improve compared to base metal.

5.REFERENCES-

[1] Md. Habibur Rahmana,,H. M. Mamun Al Rashedb "Characterization of silicon carbide reinforced aluminum matrix Composites''10th International Conference on Mechanical Engineering, ICME 2013.

[2] AKM Asif Iqbal, Dewan Muhammad Nuruzzaman "Effect of the Reinforcement on the Mechanical Properties of Aluminium Matrix Composite: A Review''International Journal of Applied Engineering Research ISSN 0973-4562 Volume 11, Number 21 (2016) pp. 10408-10413.

[3] Sijo M T a, K R Jayadevan "Analysis of stir cast aluminium silicon carbide metal matrix composite: A comprehensive review'' International Conference on Emerging Trends in Engineering, Science and Technology
(ICETEST - 2015).

[4] V. Auradia, Rajesh G.La and S. A. Korib "Processing of B4C Particulate Reinforced 6061Aluminum Matrix Composites by melt stirring involving two-step addition"3rd International Conference on Materials Processing and Characterization (ICMPC 2014).

[5] P.B.Pawar, Abhay A. Utpat "Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite for Spur Gear"3rd International Conference on Materials Processing and Characterisation (ICMPC 2014).

[6] R Kheirifard1, N Beigi Khosroshahi1, R Azari Khosroshahi1,R Taherzadeh Mousavian1 and D BrabazonJ "Fabrication of A356 based rolled composites reinforced by Ni–P-coated bimodal ceramic particles" Materials: Design and Applications 0(0) 1–13.

[7] Nikhil N.S., Akhil Raj V.R., Benzer K. Thimothy, Bovas C. Thomas, Clemin C.J., Jerin P.K. Machining Of an Aluminum Metal Matrix Composite Using Tungsten Carbide Inserts.The International Journal Of Engineering And Science (IJES) || Volume || 4 || Issue || 3 || Pages || PP.06-11 || 2015 || ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805.

[8] M.F. Amateau, Progress in the Development of Graphite- Aluminum Composites Using Liquid Infiltration Technology. Journal of Composite Materials 1976 10: 279.
[9] Suryanarayanan K, R. Praveen, S. Raghuraman, Silicon Carbide Reinforced Aluminium Metal Matrix Composites for Aerospace Applications: A Literature Review. International Journal of Innovative Research in Science, Engineering and Technology.
[10] Mohammad M. Ranjbaran, Experimental investigation of fracture toughness in Al 356-SiCp aluminium matrix composite american journal of scientific and industrial research © 2010.
[11] K Karvanis, D Fasnakis, A Maropoulos And S Papanikolaou, Production And Mechanical Properties Of Al-Sic Metal Matrix Composites, IOP Conf. Ser.: Mater.Sci. Eng. 161 012070.
[12]Kaftelen, Hulya., Unlu, Necip., Gultekin, Goller., Lutfi, Ovecoglu., Hani, Henein., 2011. Comparative processing-structure property studies of Al-Cu matrix composites reinforcewith TiC particulates. Composites: Part A. 42, 812-824.
[13]Yang, Yongbiao., Zhang, Zhimin., Zhang, Xing., 2012. Processing map of Al2O3 particulate reinforced Al alloy matrix composites. Materials Science & Engineering A. 558, 112-118.
[14]Umasankar, V., Anthony Xavior, M., Karthikeyan, S., 2014. Experimental evaluation of the influence of processing parameters on the mechanical properties of SiC particle reinforced AA6061 aluminium alloy matrix composite by powder processing. Journal of Alloys and Compounds. 582, 380-386.
[15]Nie, Cunzhu., Gu, Jiajun., Liu, Junliang., Zhang, Di., 2008. Investigation on microstructures and interface character of B4C particles reinforced 2024Al matrix composites fabricated by mechanical alloying. Journal of Alloys and Compounds. 454, 118-122.

[16]C. Carreno Gallardo, I. Estrada Guel, C. Lopez Melendez, R. Martinez Sanchez. Dispersion of Silicon Carbide Nano Particles in AA2024 Aluminium Alloy by a High Energy Ball Mill. Journal of Alloys and Compounds 2014; 586: S68-S72.
[17] Feng Tang, Masuo Hagiwara, Julie M Schoenung. Microstructure and Tensile Properties of Bulk Nano Structured Al5083/SiCp Composites Prepared by Cryomilling. Materials Science and Engineering A2005; 407:306-314.
[18] A. J. Knowles, X. Jiang, M. Galano, F. Audebert. Microstructure and Mechanical Properties of Al 6061 Alloy Based Composites with SiC Nano Particles. Journal of Alloys and Compounds 2014; 615: S401-S405.
[19] L. Kollo, C. R. Bradbury, R. Veinthal, C. Jaggi, E. Carreno Morelli, M. Leparoux. Nano Silicon Carbide Reinforced Aluminium Produced by High Energy Milling and Hot Consolidation. Materials Science and Engineering A 2011; 528:6606-6615.
[20] Sivaiah Bathula, Saravanan M, Ajay Dhar. Nano Indentation and Wear Characteristics of Al 5083/SiCp Nano Composites Synthesized by High Energy Ball Milling and Spark Plasma Sintering. J. Mater. Sci. Technol 2012; 28(11): 969-975.
[21] M. Sherif EI. Eskandarany. Mechanical Solid State mixing for Synthesizing of Al/SiCp Nano Composites. Journal of Alloys and Compounds 1998; 279: 263-271.
[22] M. R. Dehnavi, B. Niroumand, F. Ashrafizadeh, P. K. Rohatgi. Effects of Continuous and Discontinuous Ultrasonic Treatments on Mechanical Properties and Micro-Structural Characteristics of Cast Al413/SiCnp Nano Composite. Materials Science & Engineering A 2014; 617:73-83.
[23] Kalpakjian Schmid, Manufacturing Engineering And Technology, Fourth Edition Pearson Publication-Book.