

Enhancement of Aluminum Alloy (LM-12) by Reinforcement with Silicon Carbide (SiC) to Improvement of Mechanical and Thermal Properties.

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Abstract:

Aluminum metal matrix composites are widely used in various applications because of their higher Mechanical and Physical properties when compared with their base AL alloy. This paper focuses on the changes in Mechanical, Thermal properties of AL LM-12 when it is reinforced with SiC fabricated by using Stir casting method. For this purpose, AL LM-12 and reinforcement of SiC with different wt % used. SiC is reinforced in 5, 10, 15 and 20 wt. %. Effect of SiC reinforcement on AL LM-12 and its Mechanical properties like Wear resistance, Hardness, FE analysis of tensile strength (using Hyper mesh) and Thermal properties like Thermal conductivity, Thermal diffusivity and Specific heat, are discussed in detail.

I. Introduction:

Composite materials are continuously displacing traditional engineering materials because of their advantages of high stiffness and strength over homogeneous materials formulations. Composites may have metal or polymer matrices and may be reinforced with continuous fibers, discontinuous fibers, or particles (1).

The present work emphasizes only metal matrix composites (MMCs) reinforced with discrete particles. The development of MMCs has been one of the major innovations in materials in the past two decades. Metal matrix composites (MMC) consist of the metal matrix and reinforcement (typically 05 – 20 vol.%). The reinforcement materials are usually ceramics (e.g. SiC, TiC, WC, NbC and Al₂O₃). The composite materials offer such property combinations and performance profiles, which are not available in any conventional engineering materials.

In recent years there have been numerous applications for the metal composite materials (MMCs) in manufacturing the aviation components such as: the frames and casings, turbfan rotors and compressor blades and in producing the automotive parts – the brake discs, internal combustion engine pistons, drive shafts in some sport cars, and various

light trucks, pump and differential housings, brake callipers, and pulleys. The properties of metal matrix composites depend on the shape, size, properties, volume fraction and distribution of the reinforcement material, properties of the matrix materials and compatibility of the matrix and reinforcement.

In most metal matrix composites (MMC's), high strength ceramic fibers or particles reinforce a ductile metal matrix. The reinforcement imparts increased strength and stiffness, and the matrix holds the reinforcements together and provides some degree of ductility. This arrangement can yield a good combination of mechanical properties.

II. LITREATURE REVIEW:

1. **Ali Afzal et.al :(2015)** Study of this Paper is investigating the result of heat treatment and age hardenability on fatigue behavior of aluminum hybrid composite. Aluminum 6061 alloy, aluminium-5wt%silicon carbide composites and aluminium-5wt%silicon carbide- wt% graphite hybrid composite specimens with graphite varied from 1wt% and 3wt% were fabricated by stir casting method. Microstructure and Fatigue strength studies of aluminium alloy and its composites have been carried out. The fabrication of aluminium silicon carbide graphite & aluminium 6061 alloy was done through vortex stir casting methodology. In this alloy of aluminium it was found through Microstructure studies that the particles of graphite and silicon carbide were present.
2. **Pankaj Kumar et.al:(2016)**This thesis report shows the result of abrasive wear test of LM-13 Alloy and composite (6%silicon carbide and 6%titanium diboride) material parallel to the sliding distance of 500 meter with abrasive paper with grit size of mesh 180, 220, 320 and 400 at the sliding speeds of 2.61 m/s, 5.23 m/s and 7.85 m/s and applied load ranging 10N, 20N, 30N and 40N. Wear experiments on

specimens are conducted with a pin-on-disk type wear testing apparatus.

3. **Rajesh Agnihotri et.al:(2017)**Aluminium and its alloys possess excellent properties such as low density, good plasticity and ductility. They find extensive applications in aeronautics, astronautics, automobile and high speed train fields. The matrix alloy, the reinforcement material, the volume and shape of the reinforcement, the location of the reinforcement, and the fabrication method can all be varied to achieve required properties.
4. **Prakash Gadade et.al(2013)** This paper presents the piston static structural analysis for unreinforced alloy and reinforced composite with different weight percentage of reinforcements by considering the combined loading of both gas pressure force and inertia force.The force is applied on crown of piston and model is constrained for all DOF on piston pin mounting hole. In present paper the mechanical behavior or performance of aluminium-flyash-alumina composite is compared with the conventional material and also with zero reinforcement material.
5. **Shubhranshu Bansal et.al:(2015)** Al359 alloy was reinforced with Silicon Carbide and Silicon Carbide/Graphite particles using stir casting process. Thereafter their mechanical and wear properties were investigated. It was found that the hardness of the Al359-Silicon Carbide composite is better than Al359-Silicon Carbide-Graphite composite. The Silicon Carbide/Graphite reinforced composite exhibits a superior ultimate tensile strength against Silicon Carbide reinforced composite. The wear test was conducted at different loading, sliding velocities and sliding distances conditions.
6. **S. A. Mohan Krishna et.al:(2014)** A composite material is a macroscopic combination of two or more distinct materials having a recognizable interface between them. Composites are used not only for their structural properties, but also for electrical, thermal, tribological and environmental applications. The term Metal Matrix

Composites (MMCs) covers a very wide range of materials to simple reinforcements of castings with low cost refractory wool, to complex continuous fibres lay-ups in foreign alloys.

7. **Lisa Winter et.al:(2018)** In this work the high cycle fatigue behavior of a particulate reinforced 2124 aluminum alloy, manufactured by powder metallurgy, is investigated. SiC particles with a size of 3 μ m and 300 nm and a volume fraction of 5 and 25 vol %, respectively, were used as reinforcement component. The present study is focused on the fatigue strength and the influence of particle size and temperature. Systematic work is done by comparing the unreinforced alloy and the reinforced conditions. All of the material conditions are characterized by electron microscopy and tensile and fatigue testing at room temperature and at 180 °C.

Scope

This test method describes a laboratory procedure for determining MMC's materials during test conducted on fatigue analysis, thermal analysis and wear behavior MMC's are teste in pairs under nominally non-abrasive conditions. To suggest the optimum composition of MMC's to industrial usages.

Literature review indicates lack of sufficient data in this area. The optimum quantity of reinforcement material which contributes towards improvement in strength without significant loss in ductility and also the extent of enhancement in strength at room /elevated temperature have to be deciphered by experimentation and analysis.

In the past, the Aluminum alloy LM12 materials are mainly uses for production of pistons in internal combustion engines, but in this field it has been superseded by LM1 3 and LM26 which have the advantage of a Lower thermal expansion.

Alloy LM-12 is used in precipitation hardened condition. A uniform dispersion of SiC at different compositions varies at wt of 5%, wt of 10%, wt of 15% and wt of 20% in the alloy matrix.

Chemical Composition of LM-12 Alloy:

SL No.	Materials		Percentage
1	Copper	Cu	9.0-11.0
2	Magnesium	Mg	0.2-0.4
3	Silicon	Si	2.5
4	Iron	Fe	1.0
5	Manganese	Mn	0.6
6	Nickel	Ni	0.5

7	Zinc	Zn	0.8
8	Lead	Pb	0.1
9	Tin	Sn	0.05
10	Titanium	Ti	0.2
11	Aluminium	Al	Reminder

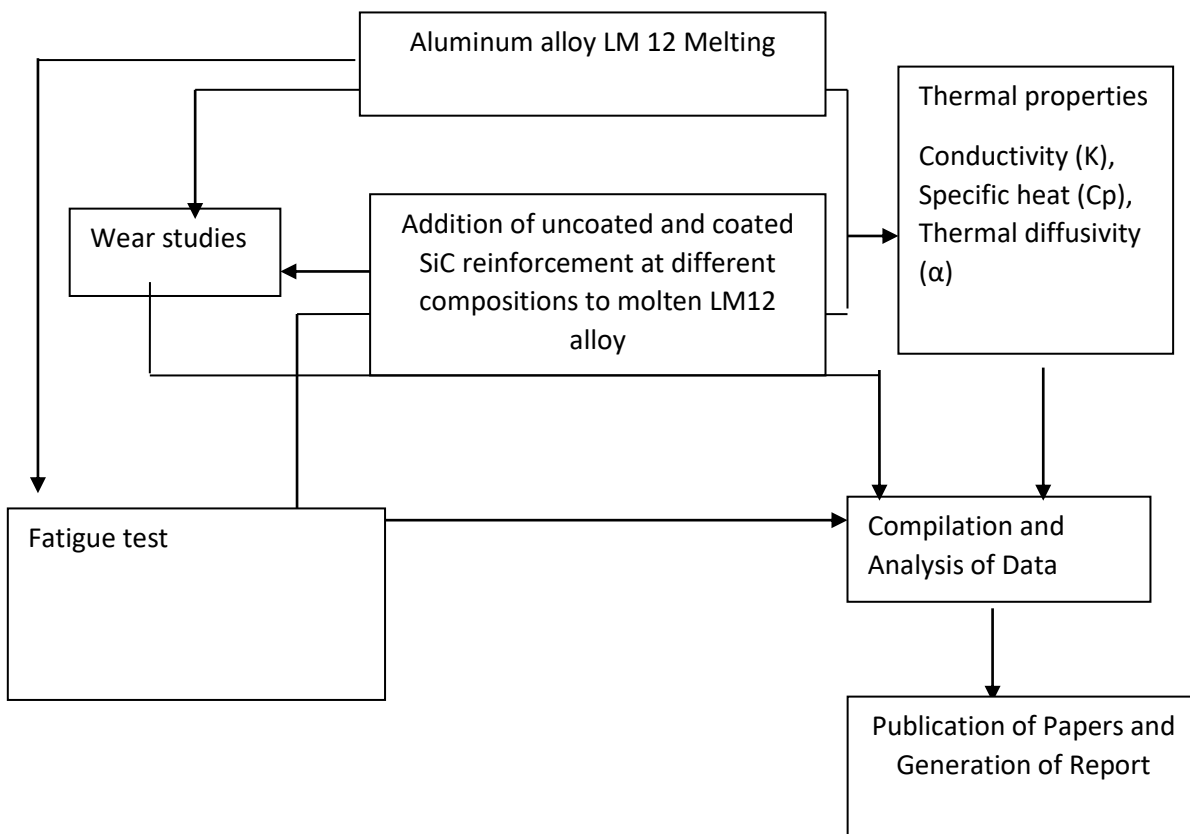
Mechanical Properties of LM-12 Alloy:

0.2% Proof stress	140-170 N/mm ²
Tensile Stress	170 N/mm ²
Elongation	0.5-1.5%
Impact Resistance [Izod]	1.0 N-m
BHN	85-90
Endurance limit [5×10^7 cycles]	60 N/mm ²
Modulus of elasticity	71000 N/mm ²

Strength of LM-12 at Higher Temperature:

Coefficient of Thermal expansion at 20-100°C	0.000022/°c
Coefficient of Thermal expansion at 100-300°C	0.000024/°c
Thermal conductivity at 25°C	0.32 cal/cm ² /cm/°c
Electric conductivity at 20°C	33% copper std
Density	2.94 gm/mm ³
Freezing range	625-525°

Proposed Scheme of Work



Development of Specimen:

Initially ingots of LM-12 aluminium alloy are taken and melted in a furnace. Silicon carbide is added to LM-12 alloy by stir casting technique. Pure LM-12 aluminium alloy is melted in a furnace. Prepared metal moulds for the casting process, Metal mould is shown in Fig. Obtained specimens of good

surface finish by pouring pure LM-12 molten metal into the metal mould. Pouring and specimens obtained by metal mould are shown in Fig.below.



Next prepared specimen of LM-12 alloy by adding 5% of silicon carbide (SiC) by its weight (i.e. 500gms SiC into 10000gms of LM-12 metal alloy). The silicon carbide is a ceramic material having melting point around 2830°C, it will not be melted in the LM-12 alloy, it must have to be mixed thoroughly in the molten metal. The silicon carbide is mixed thoroughly by stir casting technique. Then

the molten metal mixed with silicon carbide is poured into mould to obtain the required specimen.

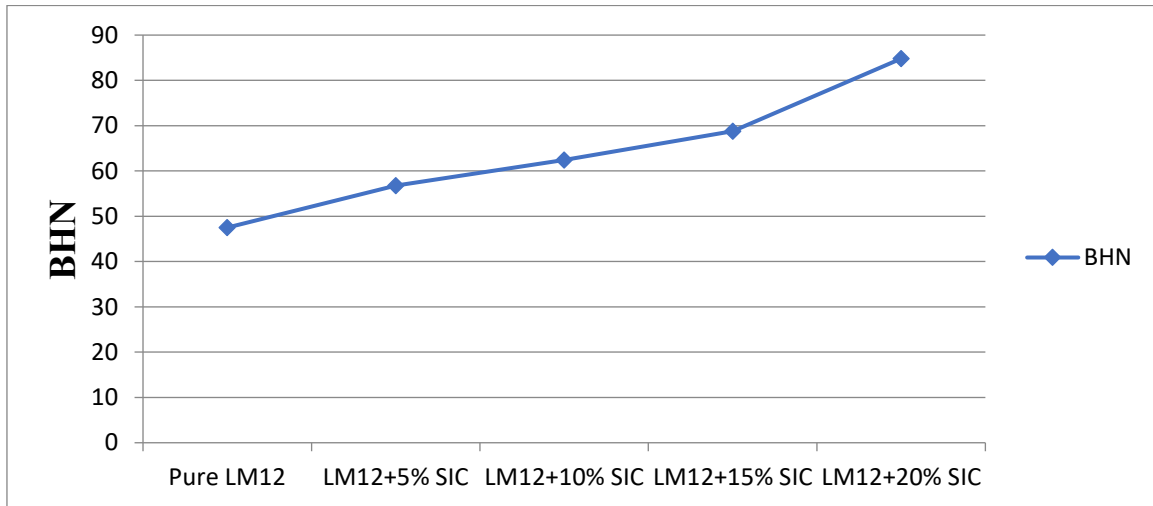
Then the specimens are prepared by varying silicon carbide by 10%,15% and 20% by weight by following same procedure. Then the extra projections and the runner portions are removed from the specimen and the cylindrical specimen of required diameter and length is obtained.

Fabrication of Specimen for BHN:



Specimens are prepared by machining process. And then the specimens are polished to conduct the Hardness test. The views of the prepared specimens and testing of BHN are shown in Fig above.

Material	Ball Diameter D (mm)	Load F (kgf)	Time of Load Application T (sec)	Diameter of indentation d(mm)	B.H.N $= \frac{2P}{\pi D(D - \sqrt{D^2 - d^2})}$ (kgf/mm ²)
Pure LM 12	5	250	20	2.5	47.5
LM 12 + 5% SIC	5	250	20	2.3	56.8
LM 12 + 10% SIC	5	250	20	2.2	62.4
LM 12 + 15% SIC	5	250	20	2.1	68.8
LM12 + 20% SIC	5	250	20	1.9	84.8

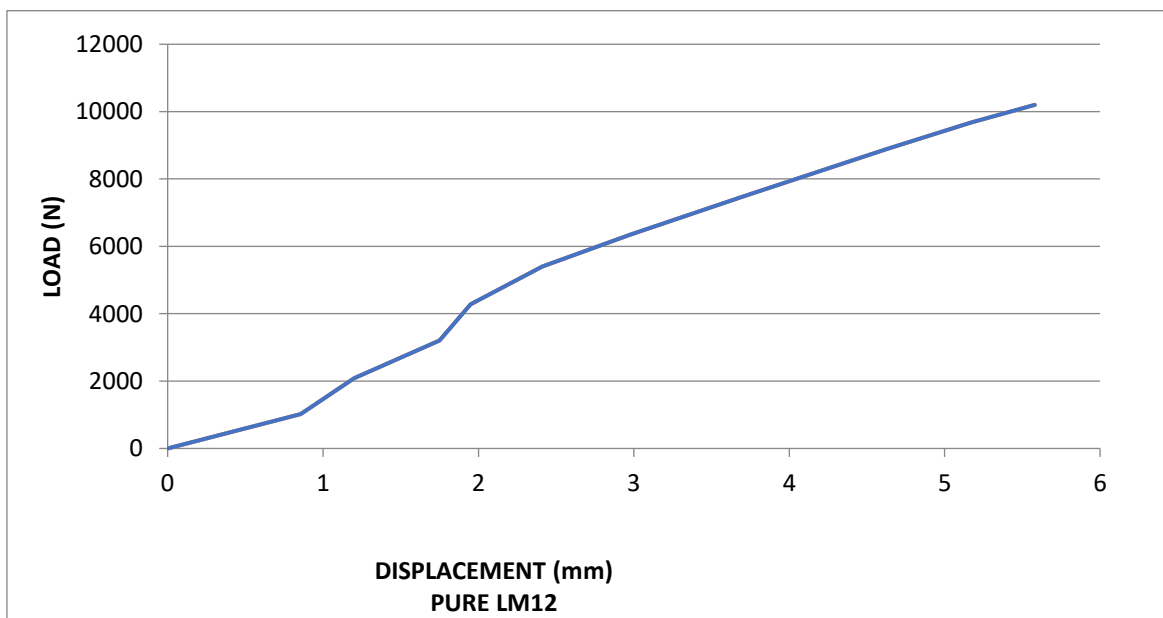


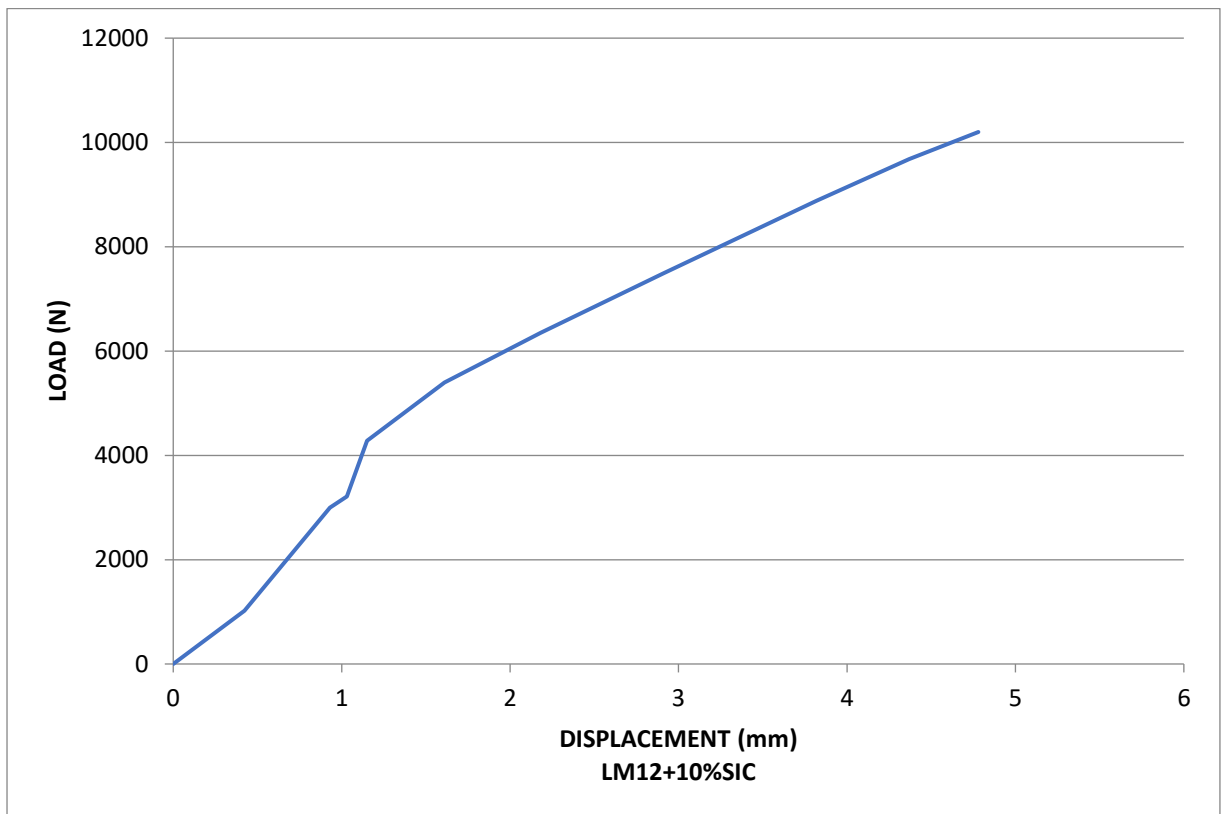
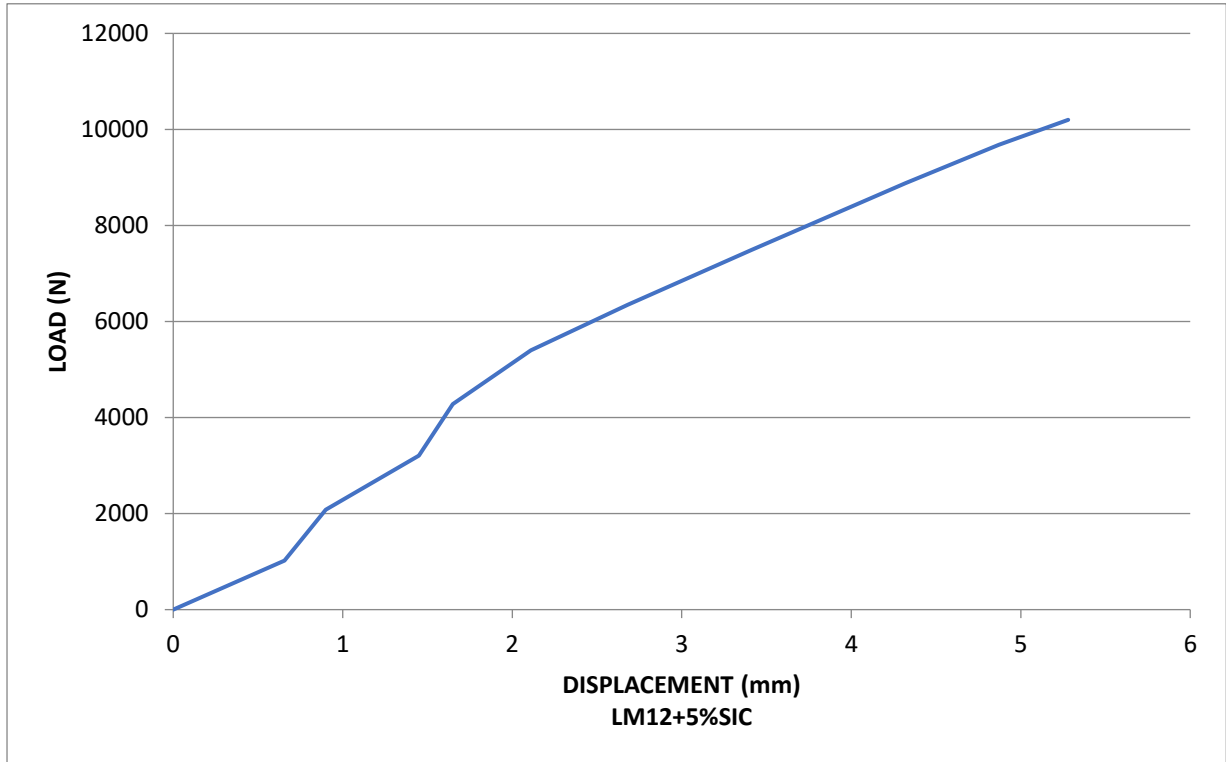
Deformation Analysis of Specimen:

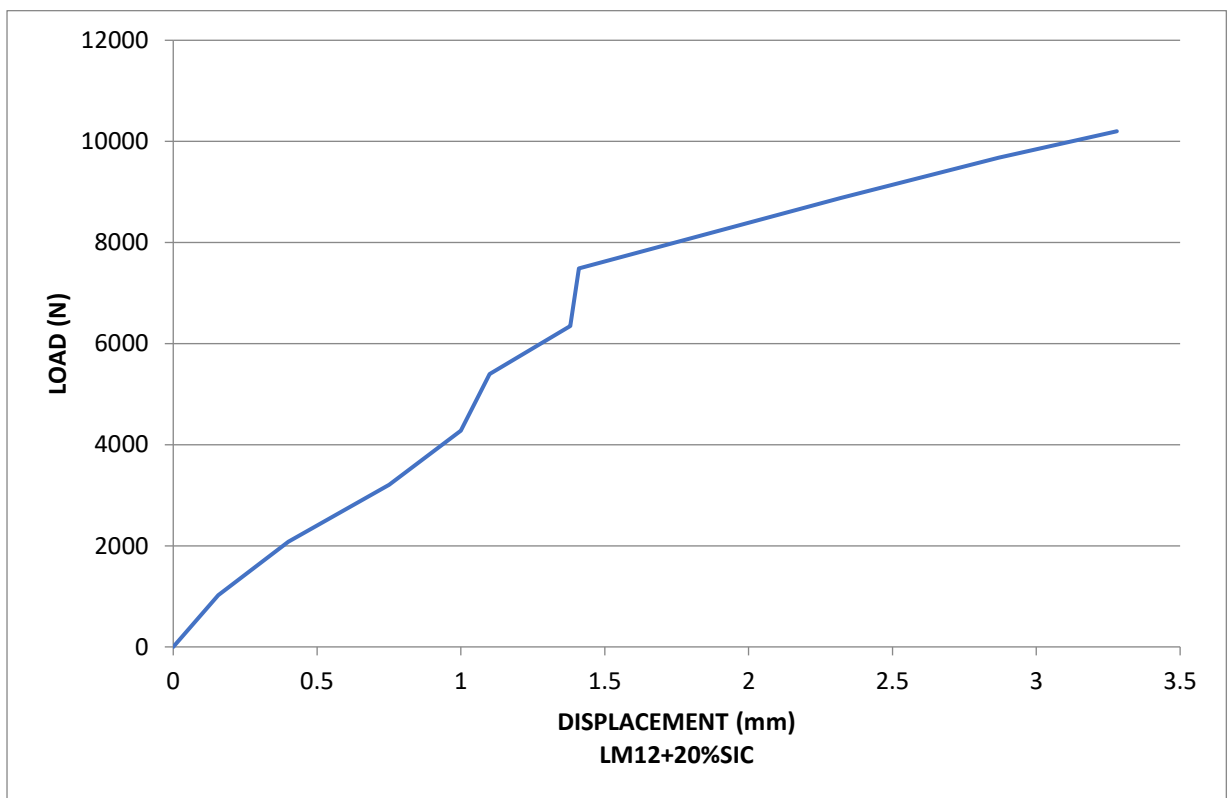
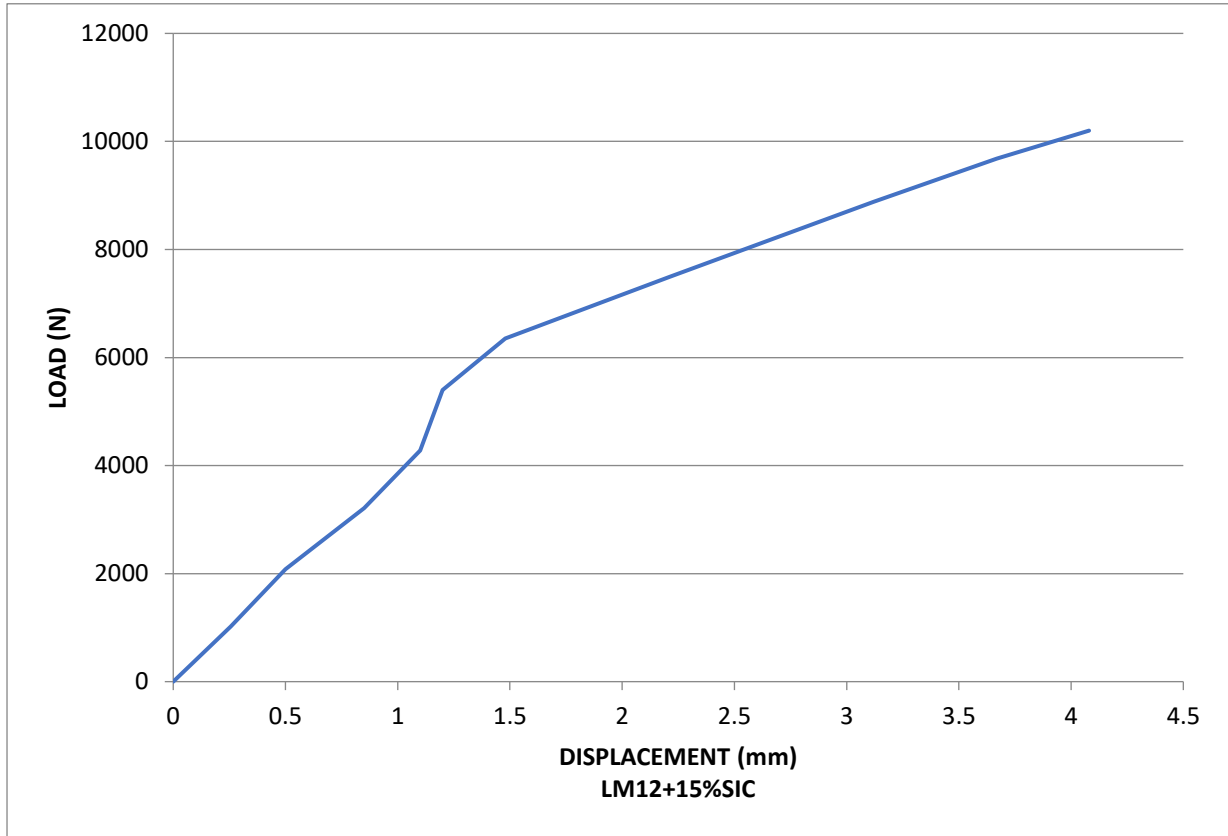


Deformation analysis is done to compare the result between the experimental and numerical deformation using the software. From these results, the percentage of errors is calculated. The input load is taken from the compressibility test and experimental result and the young's modulus and

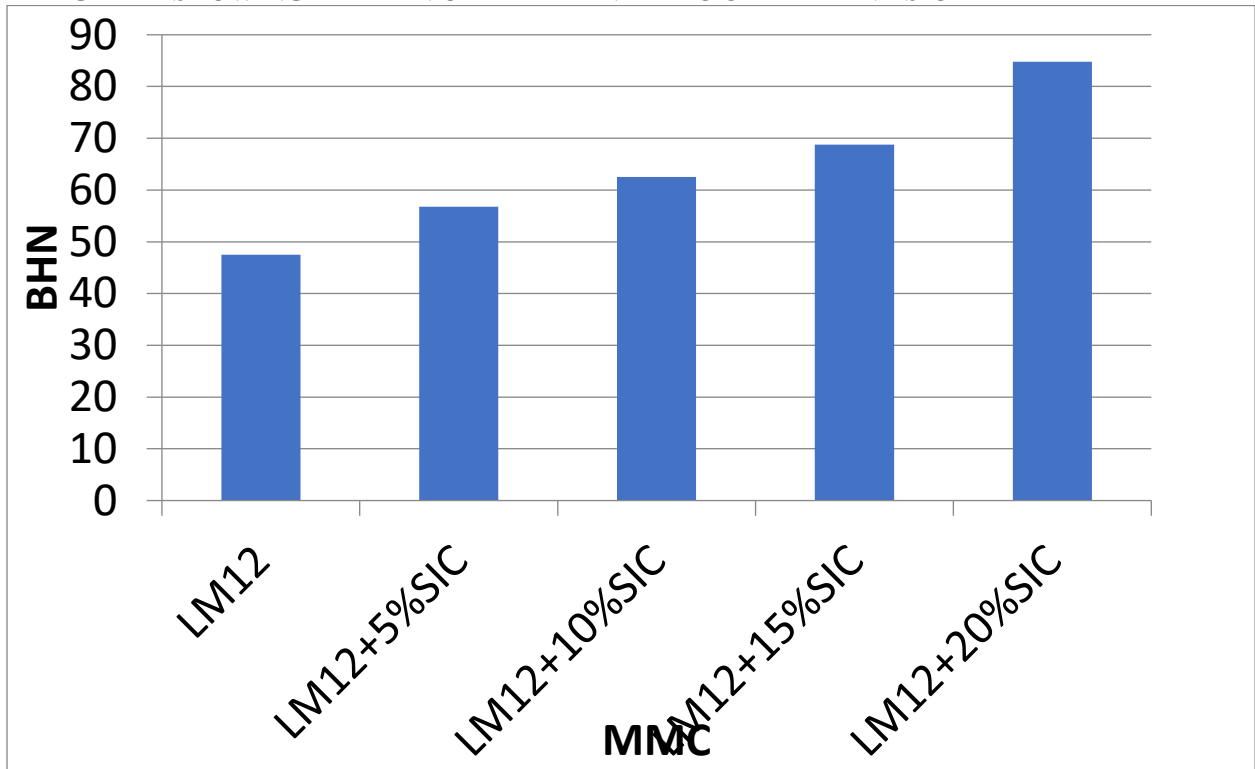
the Poisson's ratio are calculated through the formula. The result of deformation is shown below. The deformation analysis study is used to compare the numerical and experimental results by giving the compressive strength as input load. Due to the presence of unwanted impurities like oxygen, the result variation is caused in the experimental analysis while deformation compares through the Hypermesh-13 software. From that deformation analysis, test result concluded that experimental results are in good agreement with numerical results as shown in below tables. The results of FE Analysis are tabulated as shown in table below.



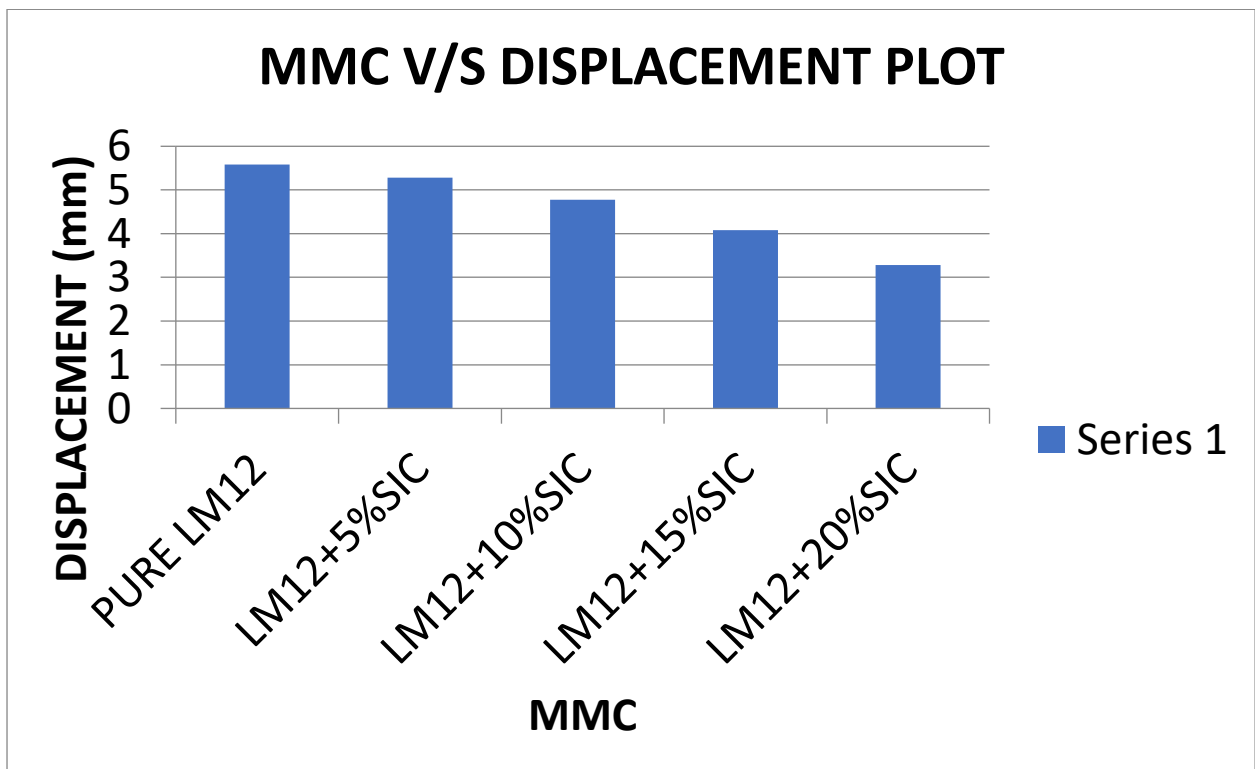




BAR GRAPH SHOWING THE BHN OF DIFFERENT MMC OF LM12 AND SIC



MMC V/S DISPLACEMENT PLOT



III. Conclusion:

- Composites of aluminum alloy LM12 and Sic have been fabricated successfully by stir casting technique.
- Fabrication of specimen for experiments as per ASTM standards are prepared and performed the experiments.
- Wear resistance has found improvement with enhanced silicon content.
- Hardness in the composite has increased with increase in Sic Content.

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