

EFFECTS OF REINFORCEMENT ON THE PROPERTIES OF ALUMINIUM MATRIX COMPOSITE

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ABSTRACT

Engine Piston is one of the most useful and least researched topics. Engine Pistons are made up of aluminium alloy LM13 (Al 85%, Si 12.2%, Mg 1.0%, Cu 0.9%, Ni 0.9%). So in this research we will be enhancing the property of engine piston (LM13 alloy). So in this research we added reinforcement Sic particles to aluminium matrix alloy (LM13). Silicon Carbide reinforcement is added in different compositions (5wt.% 10wt.% 15wt.%). Through stir casting process after that we have performed different tests like tensile test, wear test, vicker's hardness and optical microscope. After performing all the experimentation we came to know tensile strength and hardness get increased and wear get decreased.

Keywords – Aluminium metal composite (AMC), Metal matrix composite (MMC), Silicon carbide (SiC), Hardness, Wear, Tensile

INTRODUCTION

Aluminium an important industrial material that has the advantage of being relatively light compared to other metals and is used in wide variety of areas. However aluminium suffers from low strength, stiffness and wear, and thus it fails in application where these properties are needed. Strengthening of aluminium by the addition of small quantities of soluble metals or alloying element is not enough to compete with other strong alloys such as steel.

It is obvious, for composites, that it is not enough to overcome the cost hurdle in the improvement in manufacturing technology. It is essential that there be an integrated effort in design, material, process, tooling, quality assurance, manufacturing, and even program management for composites to become competitive with metals. The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite applications from aircraft to other commercial uses has become prominent in recent years. Increasingly enabled by the introduction of newer polymer resin matrix materials and high performance reinforcement fibres of glass, carbon and aramid, the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs. High performance FRP can now be found in such diverse applications as composite armoring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers. For certain applications, the use of composites rather than metals has in fact resulted in savings of both cost and weight. Some examples are cascades for engines, curved fairing and fillets, replacements for welded metallic parts, cylinders, tubes, ducts, blade containment bands etc. Further, the need of composite for lighter construction materials and more seismic resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases dead weight but also absorbs the shock & vibration

With the continued technological advancement in aeronautics, demand for advanced pneumatic components for ultra high end applications is on the rise.[1]. Apart from aeronautics industry the demand for such materials are also coming from automobiles sector in which presently used materials such as plastics are likely desired to be replaced by efficient alternates [2].

The Al(aluminium) metal matrix alloy structural materials ushered in a revolution in the last decade into the field of automobile engineering by enabling manufacture of light weight body parts and components which significantly reduced fuel consumption in addition to improving the strength of the components and also addressing various concerns on environmental safety and security grounds[3,4].improvising the advantageous abilities of Al matrix alloy by fine tuning the properties of strength and hardness of the alloy is the need of the hour since global demand for high efficiency Al matrix alloy material is rising exponentially[5].As we know LM 13 is engine piston alloy this material is used to form engine pistons . For pistons we have to take care of hardness tensile strength and wear property

The properties of aluminium matrix composite are:-

- Higher thermal stability, i.e., creep resistance,
- Significantly improved cyclic fatigue characteristics.

With respect to PMCs (Polymer matrix composite), MMCs offer these distinct advantages:

- Higher strength as well as stiffness,
- Higher service temperatures with high thermal stability,
- Higher electrical conductivity.

Properties of reinforcement (SiC) that we added in our base alloy (LM13).

Table 1.1: Properties of Silicon Carbide (SiC)

Molecular formula	SiC
Molar mass	40.10 g·mol ⁻¹
Density	3.21 g/cm ³ , solid.
Melting point	2,830 °C (5,130 °F; 3,100 K)
Boiling point	2730 °C (4,946 °F; 3,000 K)
Acidity (pKa)	6–7 (20 °C)
Appearance	Dark Gray or Black Powder
Solubility in water	Insoluble

Till now a lot of work is done on the same aluminium matrix composite that is LM13. The study of many researchers said that the reinforcement of many types of particles is added to the base alloy like B4C, ZrB2 etc but research on SiC+base alloy(LM13) is very less out of these they used many different techniques for mixing LM13 and SiC like fibre reinforcement technique or structural technique but in this research we used particle technique to get complete uniformity in the composite.LM13 aluminium alloy containing 12% silicon is widely used in manufacturing internal combustion engines parts such as pistons, cylinder blocks, cylinder heads due to its high resistance to wear, corrosion & thermal conductivities [7]. Londhe et al. have observed the wear increases with increase in normal load at ambient temperature and the wear decreases with increase in normal load at elevated temperature (125°C) of LM 13-SiC10% composite [8].The mechanical strength and wear resistance of composites increases by adding SiC particulates to the matrix alloy. Prashant et al. conducted experiments on Al 6061-SiC composite and concluded the hardness of metal matrix composite increases with increase in reinforcement content and the wear rate of the Al6061- SiC composite decreased with increasing SiC content [9]. Fuel economy is of great importance in the present automotive industry. Frictional losses in heavy duty diesel engines (HDDE) lead to 2-2.5% of fuel consumption in the normal driving condition. Half of these frictional losses are mainly due to the piston and piston rings [10]. Every automotive industry focuses on to manufacture parts with light weight, excellent tribological properties and better performance.

A special consideration is given during manufacturing in parts such as pistons, piston rings, bearings, bushes and brake system components where wear resistance is highly essential. AMMCs is considered as a potential alternative material with conventional monolithic aluminium alloys in many applications owing to its high specific strength and stiffness, low density, low thermal expansion coefficient and high wear resistance. AMMCs are used in numerous industries that are not limited to aerospace, automotive, defense, naval, electronic packaging, thermal and sports [11– 14].

Experimentation

Material used:-

Premium grade aluminum alloy LM13 (godavari alloys, India) containing 12.2 wt. % Si , magnesium 1 wt % , copper and nickel 0.9 wt % was chosen as the matrix and silicon carbide (Aksharchem, India) with a particle sizes ranging 100-200m are used.

Methodology:-

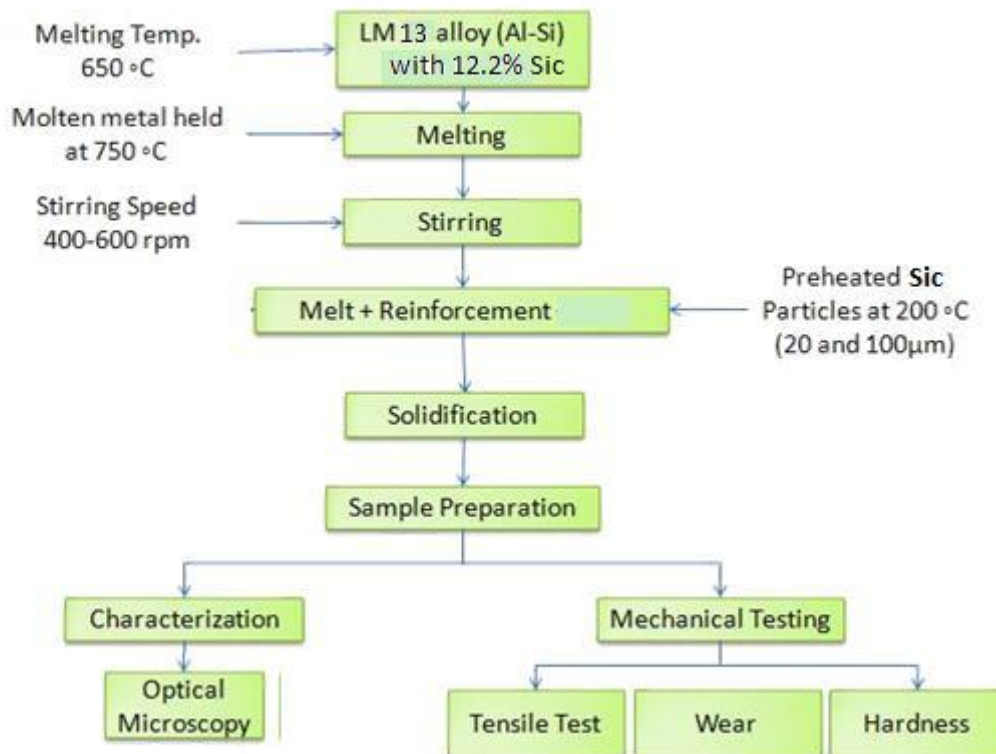


Figure 3.1: Flow chart for methodology

The purpose of the present research is to develop a particle reinforced aluminum matrix composite that will have superior properties (i.e. increase in tensile strength, high hardness, high wear resistance, high toughness) to that of aluminum alloy and study their mechanical properties.

To develop (AMCs) by stir casting process by varying the composition of reinforcement (SiC). To study the different metallurgical and mechanical properties of (LM13-SiC) composite.

To study the wear, tensile strength, and hardness of these composite.

To study the structural parameters and mechanical properties of AMCs materials by:

Optical microscopy

Hardness testing

Tensile testing

Wear analysis

Characteristics:-

Optical microscope:-

For metallographic study, alloy (LM13) and final composite samples were mechanically polished and etched with Keller's reagent. The chemical composition of Keller's reagent is shown in Table 3.4. The surface morphology of each sample was examined with the help of optical microscope at different magnifications.

Chemicals	Distilled water	Nitric acid	Hydrochloric acid	Hydro-fluoric acid
Amount(ml)	190	5	3	2

Table 3.1: Chemical composition of Keller's Reagent

Optical microscope specification:-

Company name- Suxma Company

Objective- 10x 20x 40x 100x

Eyepiece -10x

Camera magnification- 30x

Vicker's hardness test:-

The micro hardness measurement at different phases of composites has been carried out to know the effect of reinforced particulates on the alloy matrix. Micro hardness of the LM13/Sic composite was taken at 100kgf load with vickers hardness testing machine (Mitutoyo, japan). Vickers hardness (Hv) was calculated by using the formula as

$$Hv = 1.854F/d^2$$

Where F is load in kgs ,d = arithmetic mean of the 2 diagonal d1 and d2 in mm. Vickers test can be used for all metals and has one of the widest scales among hardness tests. The unit of hardness given by the test is known as the **Vickers Pyramid Number (HV)**



Figure 3.2: Samples for vickers hardness test

Tensile test:-

Tensile properties dictate how the material will react to forces being applied in tension. A tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, and reduction in area, tensile strength, yield point, yield strength and other tensile properties. The main product of a tensile test is a load versus elongation curve which is then converted into a stress versus strain curve. Since both the engineering stress and the engineering strain are obtained by dividing the load and elongation by constant values (specimen geometry information), the load-elongation curve will have the same shape as the engineering stress-strain curve. The stress-strain curve relates the applied stress to the resulting strain and each material has its own unique stress-strain curve.

The prepared tensile specimen were inspected after machining and loaded in the tensile testing machine or universal testing machine and the tensile force is given.

A tensile specimen is a standardized sample cross-section. It has two shoulders and a gauge (section) in between. The shoulders are large so they can be readily gripped, whereas the gauge section has a smaller cross-section so that the deformation and failure can occur in this area.



Figure 3.3: Samples for tensile testing

Wear test:-

Wear is a process of removal of material from one or both of two solid surfaces in solid state contact. As the wear is a surface removal phenomenon and occurs mostly at outer surfaces, it is more appropriate and economical to make surface modification of existing alloys than using the wear resistant alloys.

For the pin-on-disk wear test, two specimens are required. One, a pin with a radiused tip, is positioned perpendicular to the other, usually a flat circular disk. A ball, rigidly held, is often used as the pin specimen. The test machine causes either the disk specimen or the pin specimen to revolve about the disk center. In either case, the sliding path is a circle on the disk surface. The plane of the disk may be oriented either horizontally or vertically

This test is performed on the pin-on -disk apparatus where we can vary speed, load (1kg, 3kg,5kg) .



Figure 3.4 : Wear samples

Wear Calculation

1. Area

$$\text{Cross sectional Area, } A = \pi r^2$$

2. Volume loss

$$\text{Volume loss} = \text{Cross sectional Area} \times \text{Height loss}$$

3. Wear rate

$$\text{Wear rate} = \text{Volume loss} / \text{Sliding distance}$$

4. Sliding distance= $2\pi RNT$

Where R= Radius of Wear Track

N= Speed in rpm

T= Time in min.

5. Wear resistance

$$\text{Wear resistance} = 1/ \text{Wear rate}$$

6. Specific wear rate

$$\text{Specific wear rate} = \text{Wear rate}/\text{load}$$

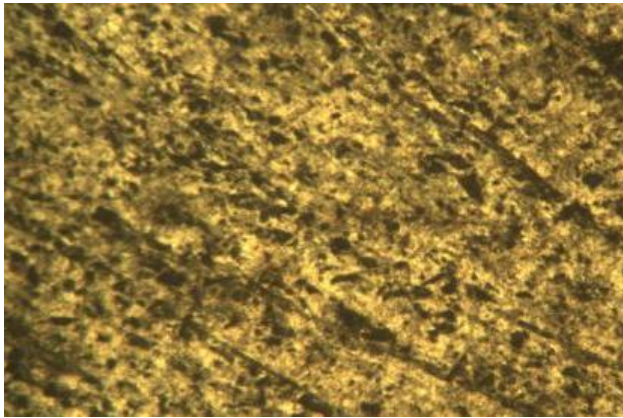
RESULTS AND DISCUSSION

Optical microscope test :-

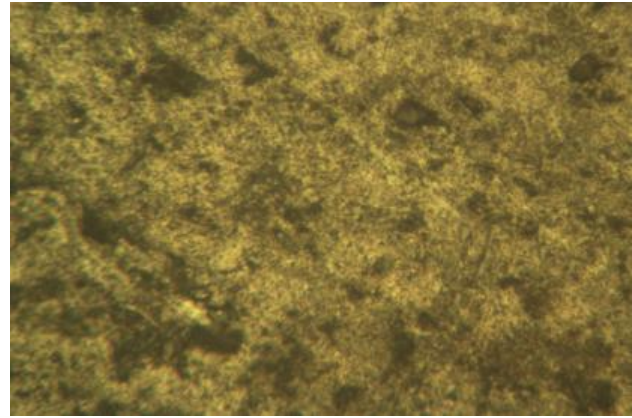
In this optical test we are going to check the sample under the optical microscope at lower focus and at higher focus and then we going to discuss the mixability of SiC reinforcement into base alloy.

In this we have taken samples of different reinforcement composition (0%, 5%, 10%, 15%)

At 0% silicon carbide



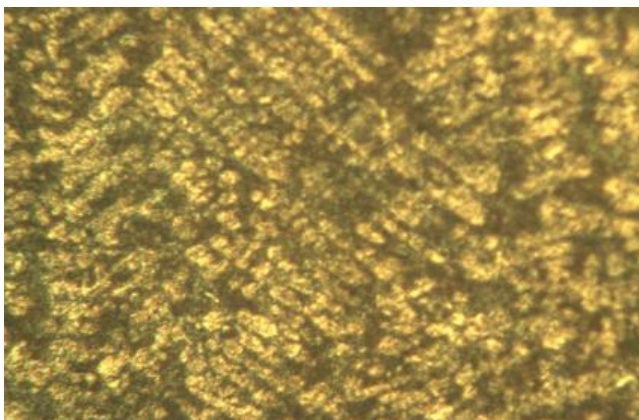
(a)



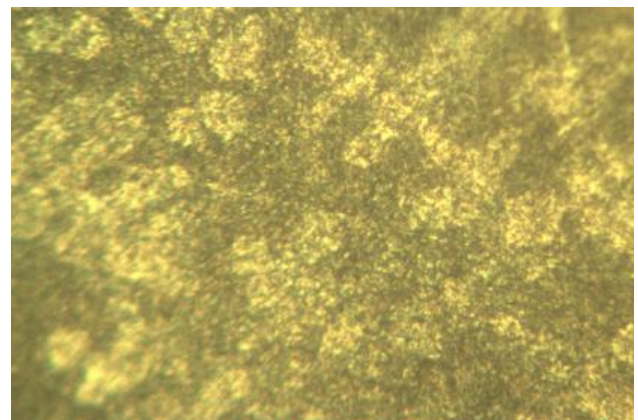
(b)

Figure 3.5(a) 10X magnification, (b) 40X magnification

At 5% silicon carbide



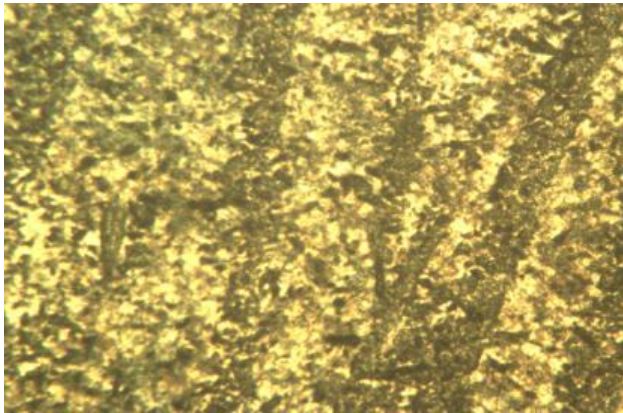
(a)



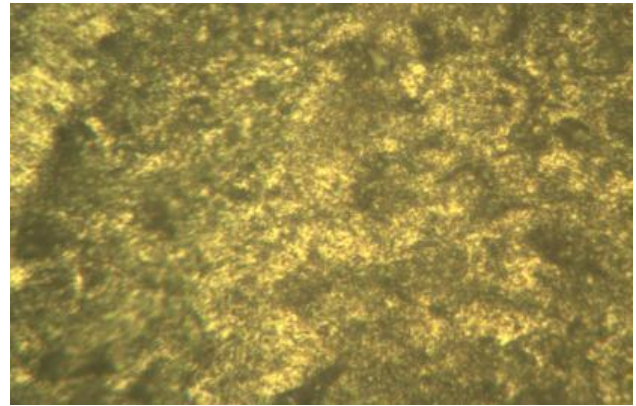
(b)

Figure 3.6(a) 10x magnification, (b) 40X magnification

At 10 % silicon carbide



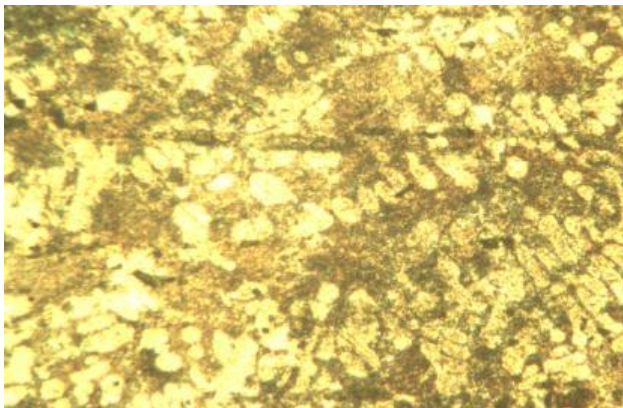
(a)



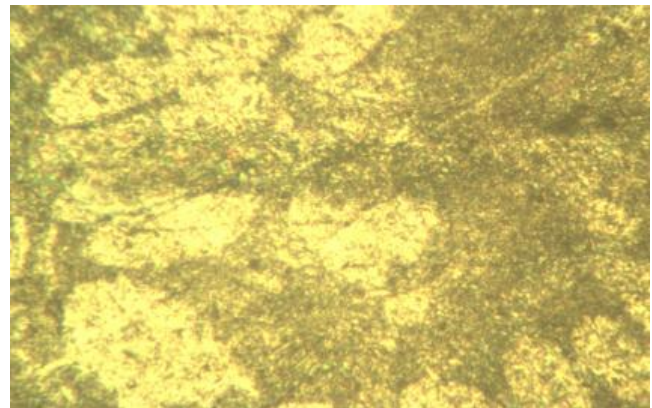
(b)

Figure 3.7 (a) 10X magnification, (b) 40X magnification

At 15% silicon carbide



(a)



(b)

Figure 3.8(a) 10X magnification, (b) 40X magnification

After performing optical test we obtain microstructure at 10X and 40X magnification figure 3.5 clearly shows that no reinforcement is added into the base alloy. Figure 3.6 shows the addition of 5% silicon carbide reinforcement which we can see in the structure as a white spots but the gap in between white spot is more and in figure 3.7 and figure 3.8 the silicon carbide added to the base alloy is 10% and 15% respectively. We clearly see that white spots(SiC) increases as we move from 5% to 15% silicon carbide. From the base micrograph to the 15% Sic composite graph we clearly see that how the silicon carbide get indulge into the structure and also from these microstructure we can clearly say that the Sic reinforcement get mixed with the base metal alloy uniformly.

This uniformity in the composites helps us to perform our test properly. Proper uniformity of the composite helps in increasing hardness and tensile strength and reducing wear.

Vicker's hardness test:-

The test that is done to check the hardness of the material.

This test is done at a constant load of 2kg ,force of 19.61 and dwell size 10

Vicker's Hardness Test						
Silicon Content	Load	D1	D2	F	Dwell	Hardness (HV2)
0%	2Kg	171.1	176.3	19.61	10	122.9
5%	2Kg	165.2	155.1	19.61	10	144.6
10%	2Kg	154.4	158.7	19.61	10	151.3
15%	2Kg	192.4	183.3	19.61	10	105.1

This table is generated after performing hardness test on different samples from where we can see that hardness get increase as the % concentration increase but after 10% concentration the value tends to decrease.

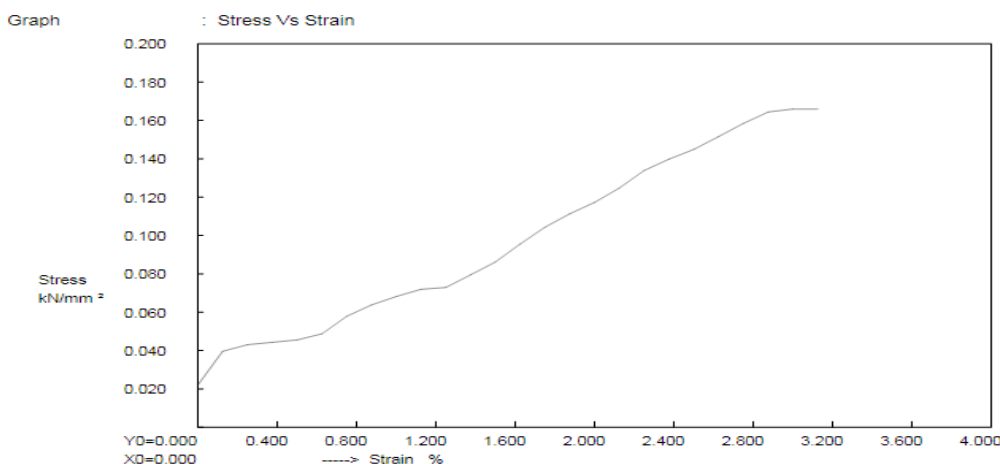
Tensile test:-

These are the reading table and the graphs that are obtain from the UTM test.

UTM test is done to check the tensile strength of the material and tells the load at which the specimen get break.

TENSILE TESTING		
COMOSITION	LOAD	TENSILE STRENGTH
0%	10.560 KN	0.166KN/mm2
5%	16.320 KN	0.256KN/mm2
10%	15.640 KN	0.246KN/mm2
15%	18.260 KN	0.287KN/mm2

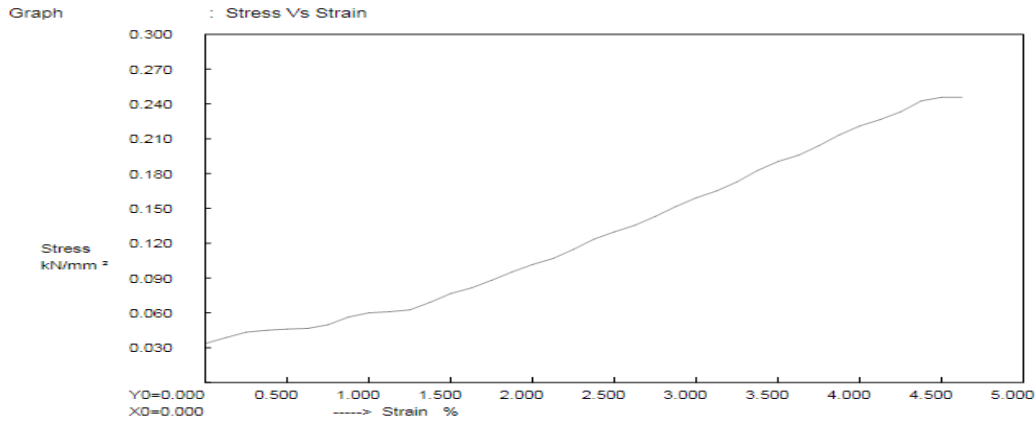
These are the stress vs strain graphs that we obtain after performing tensile test at different concentration sample



(stress vs strain at 0% silicon carbide)

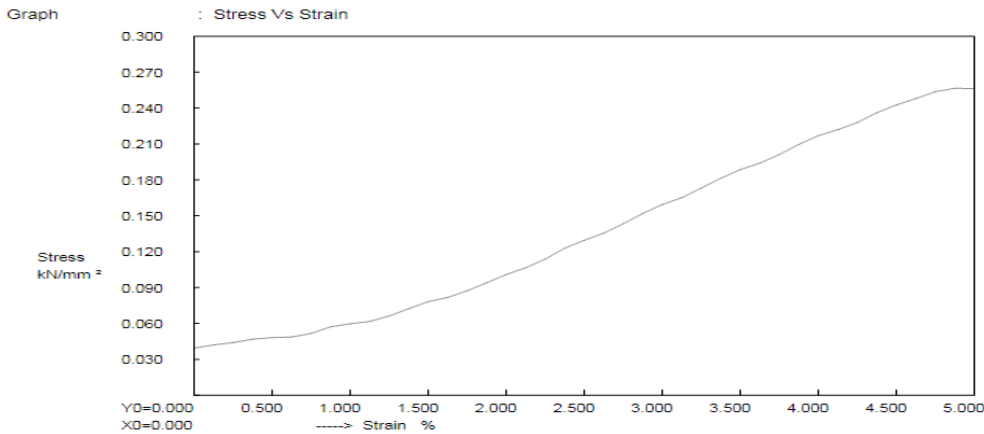
From this graph we can interpret that as the stress get increase the strain wil also get increase.

From this we also conclude that the material get break at 0.166kn/mm2 stress value and near about 3.20 strain value



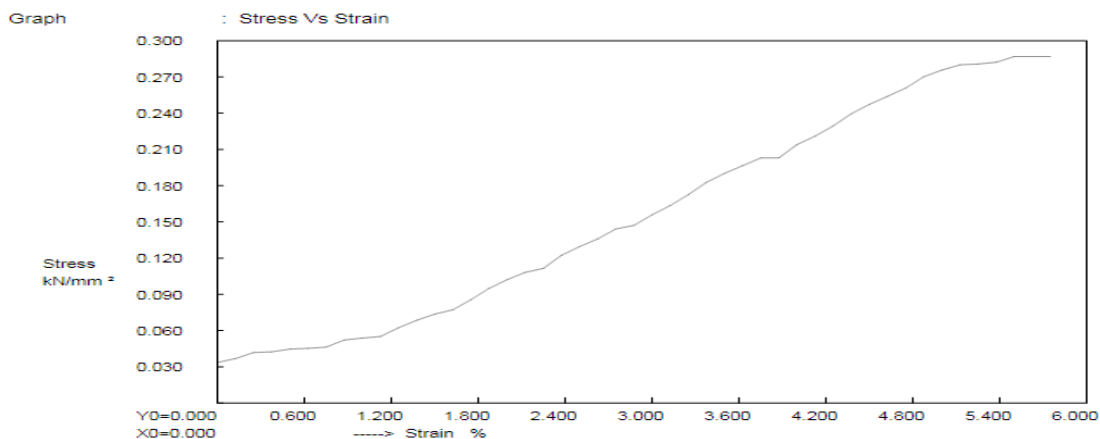
(stressvs strain at 5% silicon carbide)

This graph interprets the relation between stress and strain at 5% silicon carbise reinforcement, this graphs depicts that stress and strain increase almost linearly



(stressvs strain at 10% silicon carbide)

This graph interprets the relationship between stress and strain at 10% silicon carbide where stress reaches maximum to 0.246KN/mm²



(stressvs strain at 15% silicon carbide)

This graph interprets the relationship between stress and strain at 15% silicon carbide reinforcement as we see the value of stress is high as compared to other compositions that is 0.287KN/mm²

Wear test:-

Wear test has been done on pin-on-disk apparatus.

These are the readings obtain after performing wear test.

Wear Test			
Condition			
0% silicon carbide			
350 rpm, 20 minutes			
	Initial (gm)	Final (gm)	
1kg	9.643	9.598	0.045
3kg	9.595	9.547	0.048
5kg	9.545	9.491	0.054

Wear Test			
Condition			
5% silicon carbide			
350 rpm, 20 minutes			
	Initial (gm)	Final (gm)	
1kg	12.15	12.124	0.026
3kg	12.18	12.152	0.028
5kg	12.122	12.092	0.03

Wear Test			
Condition			
10% silicon carbide			
350 rpm, 20 minutes			
	Initial (gm)	Final (gm)	
1kg	10.37	10.353	0.017
3kg	10.392	10.372	0.02
5kg	10.351	10.328	0.023

Wear Test			
Condition			
15% silicon carbide			
350 rpm, 20 minutes			
	Initial (gm)	Final (gm)	
1kg	11.468	11.453	0.015
3kg	11.486	11.47	0.016
5kg	11.451	11.433	0.018

These are the reading that we have obtained after performing wear test at diferent load and at different concentration. We compile all the tables on the basis of load variation in the machine initially we took 1kg load with 20 minutes process time and at 350 rpm the we vary load as 3kg and 5kg we perform the same test with or without adding silicon carbide reinforcement and then we compile all the values in the table and after analyzing all the values we clearly say that wear tends to decrease as we increase the SiC % concentration and increase the value of wear as we increase the load.

CONCLUSION

The present study is carried out to determine the influence of particle size and concentration of silicon carbide reinforcement on mechanical properties of stir cast Al-Si alloy LM 13

Following conclusions are made from the study:-

Stir casting has resulted in uniform distribution of reinforced particle Sic within the Al matrix.

There is a sufficient increase in the hardness as we increase the amount of reinforcement in the matrix. But it get increased to some extent after a particular limit it start decreasing.

The tensile strength of the composite material is increase as we increase the amount of Sic reinforcement from this behaviour we can conclude that adding silicon reinforcement is beneficial for for the aluminium alloy LM 13

We have performed wear test at different load after performing the test we have concluded that with increase in % of Sic particle in the composite, weight loss of the composite has decreased, from this we can clearly say that adding silicon reinforcement is beneficial for aluminium metal composite LM13.

The value that we have obtained from the optimum table, we finally concluded that aluminium matrix composite with 10 wt% composition of Sic offers better wear resistance, better tensile strength and better hardness than the base aluminium alloy LM13.

REFERENCES

1. Opeka, M. M., I. G. Talmy, and J. A. Zaykoki. "Mechanical properties of ZrB₂ composites." *J. Mater. Sci. Elsevier Sc. I* 32 (2004): 5887-5894.
2. Luo, A. "Processing, microstructure, and mechanical behavior of cast magnesium metal matrix composites." *Metallurgical and Materials Transactions A* 26.9 (1995): 2445-2455.
3. Saravanan, R. A., and M. K. Surappa. "Fabrication and characterisation of pure magnesium-30 vol.%SiCp particle composite." *Materials Science and Engineering: A* 276.1-2 (2000): 108-116.
4. Hassan, S. F., and M. Gupta. "Development of high strength magnesium based composites using elemental nickel particulates as reinforcement." *Journal of Materials Science* 37.12 (2002): 2467-2474.
5. Daniel, Sumod, and G. Harish. "A Study on the behaviour of Aluminium alloy (LM13) reinforced with Nano ZrO₂ Particulate." *IOSR Journal of Engineering* 4.2 (2014): 58-62.
6. Kaur K, Anant R, Pandey OP. Tribologicalbehaviour of SiC particle reinforced Al–Si alloy. *Tribology Letters*. 2011 Oct 1;44(1):41.
7. Jayaprakash, R. H. Budan, A. and Hemanth, J. Preparation and Investigation on Properties of Cryogenically Solidified Nano Metal Matrix Composites, *International Journal of Engineering Research and Applications*, 4, 2014, pp. 74-79
8. Londhe, V. D., Mhaske, M. S. and Kapgate R. A. Evaluation of TribologicalBehaviour of LM13-Silicon Carbide Composite under Ambient & Elevated Temperature. *International Journal of Scientific Research Engineering & Technology*, 3, 2014, pp. 334-340.
9. Prashant, S. N., Nagaral, M. and Auradi, V. Preparation and evaluation of mechanical and wear properties of Al 6061reinforced with graphite and sic particulate metal matrix composites. *International Journal of Mechanical Engineering and Robotics Research*, 3, 2012, pp. 106-12.
10. Richardson, D.E. Review of power cylinder friction for diesel engines. *J Eng Gas Turbines Power*, 122(4), 2000, pp. 506–19.
11. Alaneme, K. K. and Sanusi, K. O. Microstructural characteristics, mechanical and wear behaviour of aluminium matrix hybrid composites reinforced with alumina, rice husk ash and graphite, *Eng. Sci. Technol. Int. J*, 18, 2015, pp. 416–422.
12. Lara, R. D., Soltani, N., Bahrami, A., Castañeda, E. G., Sánchez, E. G. and Rodríguez, M. A. L. H. Tribological characterization of Al7075–graphite composites fabricated by mechanical alloying and hot extrusion, *Mater. Des*, 67, 2015, pp. 224–231.
13. Liu, H., Hu, Y., Zhao, Y. and H. Fujii. Microstructure and mechanical properties of friction stir welded AC4A + 30 vol.%SiCp composite, *Mater. Des*, 65, 2015, pp. 395–400.
14. Shoba, C., Ramanaiah, N. and NageswaraRao, D. Effect of reinforcement on the cutting forces while machining metal matrix composites – An experimental approach, *Eng. Sci. Technol. Int. J.*, 18, 2015, pp. 658–663.