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The Strength and Stiffness of Aluminium Alloy LM12 / SiC (23 Microns) Metal Matrix Composites and Comparison of Brinell Hardness Test Experimental Results With Axi Symmetricfeanalysis

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ABSTRACT

The aluminum alloy is produces the excellent and superior properties, these alloys are widely uses in different industrial sectors like, agriculture, constructions, aerospace, automobile, utensils, and general engineering industries, due to this alloys are very favorable in microstructure behavior, hardness, less weight ratio, high strength and having good mechanical properties. In this work the aluminum alloy LM12 is the base material reinforced with the silicon carbide. These metal matrix composites are fabricated by using the stir casting techniques with the uniform distribution of SiC and confirmed by using the BHN test, SEM,XRD and EDX analysis. The MMC's evaluate the mechanical properties such as Brinell hardness number experiment test results are comparison with the BHN Finite element analysis. The FEA model has been prepared by using the ABQUS software evaluate the maximum stress, deformation and load carrying capacity. The MMC's obtained results are compared with the pure AALM12 alloy without of silicon carbide addition. The reinforced silicon carbide varies with the 0%, 5%, 10%, 15% &20%wt.fraction. Increment of SiC in MMC's, the Brinell hardness number values also be increases due to matrix is became good in strength and strong, these are the properties are presented in this paper.

Keywords : 23µmSiC, AALM12, MMC'sFabrication, Brinell hardness number experiment test results comparison with FEA, SEM, EDX and XRD analysis of MMC's.

I. INTRODUCTION

Aluminum alloy metal matrix composites are very popular aluminum alloy many series used in different industrial sectors. These are mainly used in aircraft structure design one of the major criteria due to their high strength ratio and less in weight ratio. Due to this mandate in high recital of the aircrafts weight reduction methods are used in aviation sector and new materials are under search in automobile sectors used. (1-3). The aluminum alloys reinforced with silicon carbide (MMC's) having possess superior symbols in order to decrease the weight and consequently proved to be improved structural

components to provide strength to the structure. Enormous research work has been experiencing in the area of MMC's. Because of their weight to strength ratio, MMC's are gradually replacing the popular aluminum .alloys which were used post world war in Aircraft and in other
Applications like agriculture, automobile sectors and construction fields etc. (4-6).
Current work is describes the production of MMC's by using the popular technology of stir casting technique, tensile test experimented results as well as FEA results are analysis, density test and porosity. Aluminum alloy LM12 with reinforcement of silicon carbide with various %wt and compositions of AALM12 has been shown in below fig.

Element	Wt.%	Element	Wt%
Copper	09-11	Zinc	0.8 max
Magnesium	0.2-0.4	Lead	0.1 max
Silicon	2.5 max	Tin	0.05 max
Iron	1.0 max	Titanium	0.2 max
Manganese	0.6 max	aluminum	Balance
Nickel	0.5 max		

Compositions of AALM12

II. DEVELOPMENTOF METAL MATRIX COMPOSITES

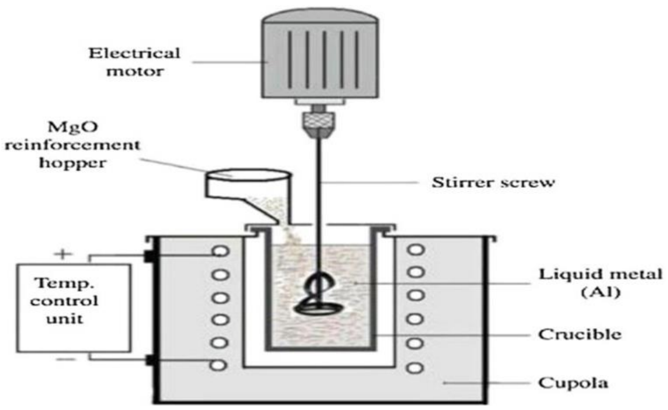
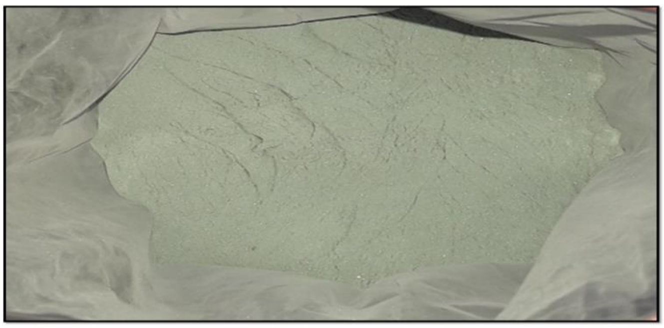


Fig:1 Stir casting set up

The MMC's are fabricated by using the popular stir casting technique, this setup have been shown in the fig:1. The AALM12 aluminum alloy bars were kept inside the crucible furnace which is made up of graphite material and the heating source is supplied by the electrically. The aluminum alloy is slowly turn into molten stages when it is exceeded the temperature of 6500C -7500C.Their after calculated weight percentage of SiC slowly pour into the molten metal with uniform speed, meanwhile maintain the stirrer speed in uniformly ranges from 300rpm-400rpm and this is operated by supporting of electrical motor and Also different wt%SiC composites are fabricated with followed same procedure.

AA7075 bar



23 micorns SiC

Fig:2 Cast product and SiC

III. EXPERIMENTATION

Hardness test is essential to measures the resistance of the material to lasting shape change when a force is applied. In this work, Brinnal hardness test is used to carry out the deformation (hardness) of the fabricated composite. The test is carry through as per the standard ASTM: E10. In this test, 250kg load is load is applied for a period of 20 seconds. The test result has been expressed in the format of number called brinell hardness number.

BHN test Samples

Table:1 Specifications

Model	KAB-1
Max test height	225mm
Depth of thread	130mm
Max depth of screw below base	260mm
Max Load	250kgf

Ball material	BHN
Specimen material	Al alloy LM12
Specimen Dimensions (mm)	12
Ball diameter (mm)	5
Load (kgf)	250
Testing time (sec)	20

$$\frac{F}{\frac{\pi}{2} D \left(D - \sqrt{D^2 - D_1^2} \right)}$$

Experiment BHN Results

Compositions	Depression dia D_1 in mm	Trail 1	Trail2	Trail3	Avg.BHN
Pure	2.5	47	46	49.5	47.5
5% SiC	2.3	54.5	59	57	56.8
10% SiC	2.2	62.5	60	64.8	62.4
15% SiC	2.1	67.5	70	69	68.8
20% SiC	1.9	84	85.5	85	84.8

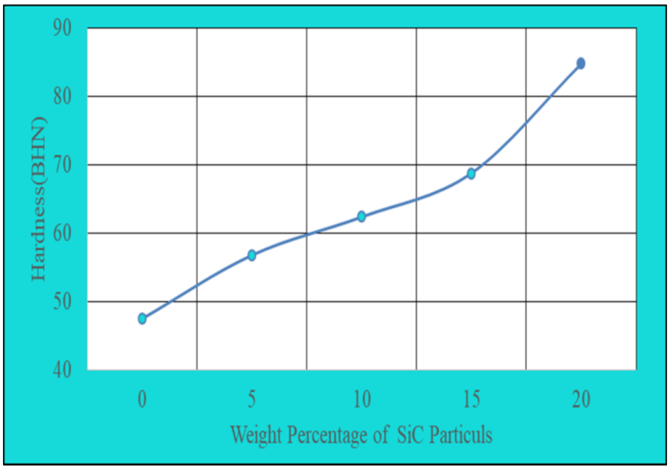


Fig:3 BHN Results

Hardness analysis of as-cast composite confirmed (84.8 kgf/mm2) superior hardness values without addition of filler material composite than as-cast composite (84.8 kgf/mm2) that shown in fig:3.This improved results are indicated to better tensile characteristics of composites. Comparative analysis confirmed improvement in ultimate strength and decrease in percentage elongation for the composite. Fractographic analysis of as-cast composite reveals Trans granular failure of composites [3]. As observed from the hardness value increases up to 20% weight fraction of SiC and beyond this weight fraction the hardness trend started decreasing. In the hardness test, severe plastic flow has been concentrated in the localized region directly below the indentation, outside of which material still behaves elastically. Directly below the indentation the density of the particles increased locally, compared to regions away from the depression. The results of the Brinell hardness measurements are shown in figure. It increases with increasing wt% of the particulates used in this work. These increases can be related as mentioned before to the interaction of the dislocations with the particulates and grain refinement with increasing wt%of SiC[5].

IV. FE ANALYSIS OF BHN

$$BHN = \frac{F}{\frac{\pi}{2}D\left(D-\sqrt{D^2-D_1^2}\right)} \quad \text{Kg/mm}^2$$

Where
F= load Applied kg f
D= Steel ball diameter of in mm
D1= Depression diameter in mm

In hardness test, first of all samples of 20mm diameter and 15mm length in cylindrical round bar were developed from manufacturing process. The specimens were fabricated by filing for making perfectly parallel Brinell before hardness testing. Samples were polished by using different types of emery papers and tests were carried out by using Brinell hardness tester with load of 250kg at room temperature condition.

Young's modulus of MMC's is given by Kerner equation

$$\mathbf{E_c = E_m\left[1 + \frac{V_p}{1-V_p} \times \frac{15(1-m_m)}{8-10m_m}\right]}$$

Where Em is Youngs modulus
of the Matrix i.e 71 GPa
V_p is the volume fraction of particulate
M_m = poisons ratio

$$\mathbf{E_{c5\%SiC} = 71\left[1 + \frac{0.04606}{1-0.04606} \times \frac{15(1-0.33)}{8-10(0.33)}\right] = 78.199\ GPa}$$

The calculated the young's modulus of metal matrix composites by using the karner question, the results shows that linearly increased with increased reinforced SiC.

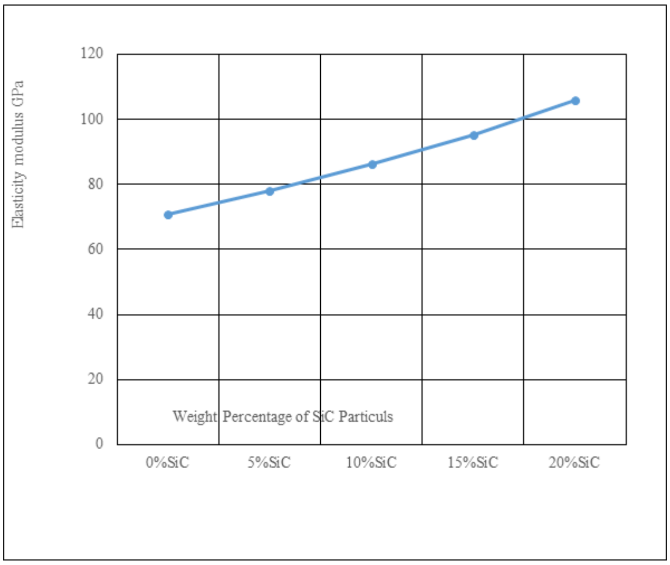


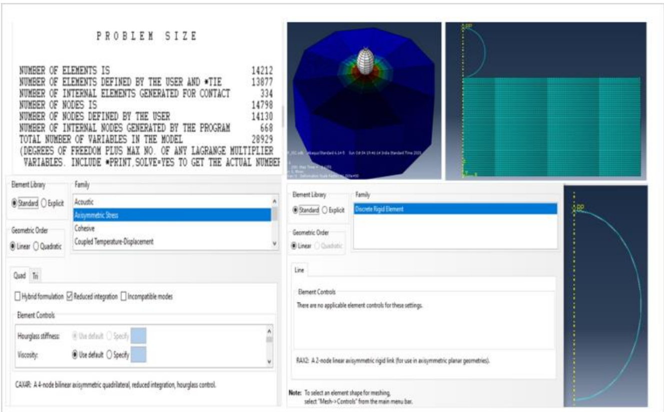
Fig:4 Elasticity modulus

Table:2 Properties

Compositions	E using Karner Eqn.	Experiment Yield strength MPa
Pure	71	68
5%SiC	78.199	78
10%SiC	86.312	79
15%SiC	95.426	93
20%SiC	105.766	74.5

The Elasticity modulus of metal matrix composites linearly increases with increased SiC as shown in fig:4. The youngs modulus and Yield strength values are feed into FE analysis and to get the BHN results in FEA.

Procedure have been followed to do the FE Analysis of BHN



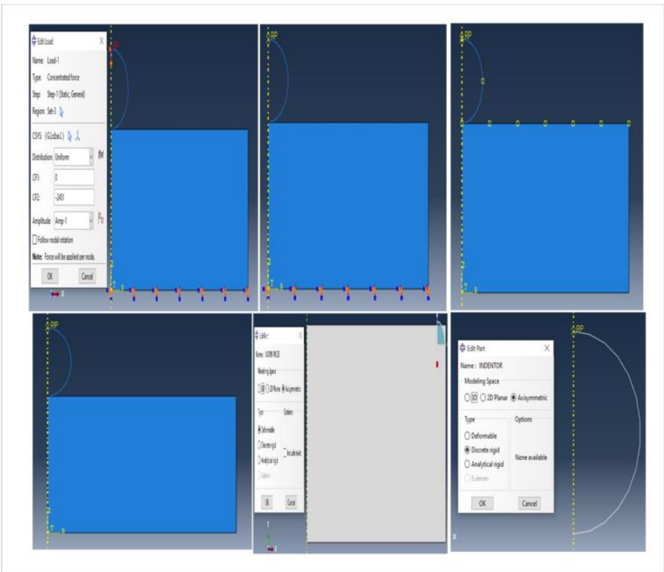
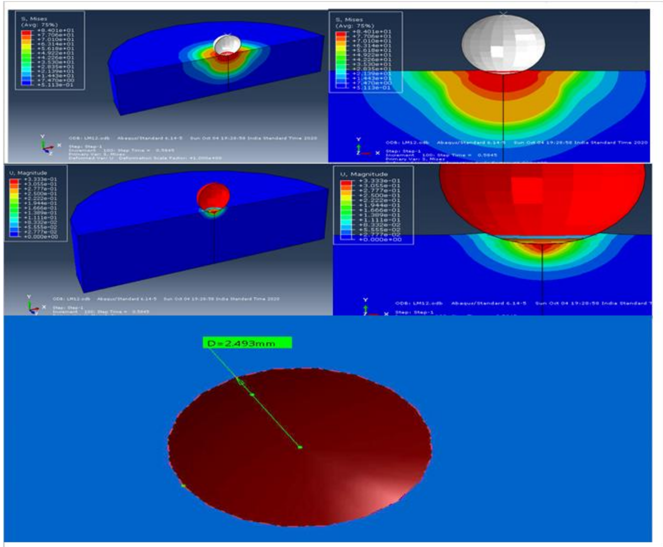
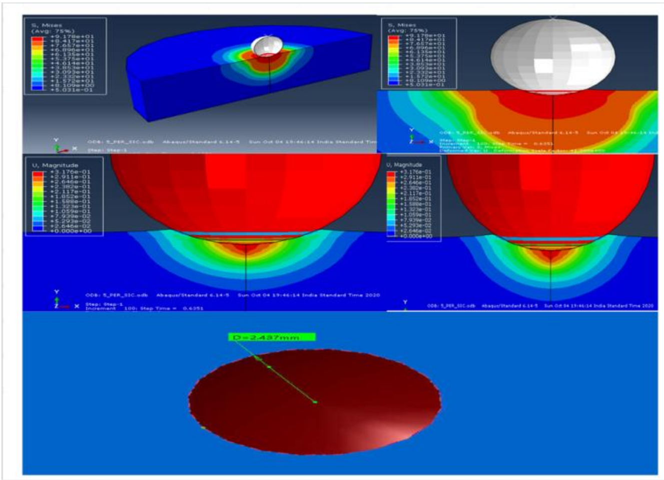


Fig:5 BHN FEA Model

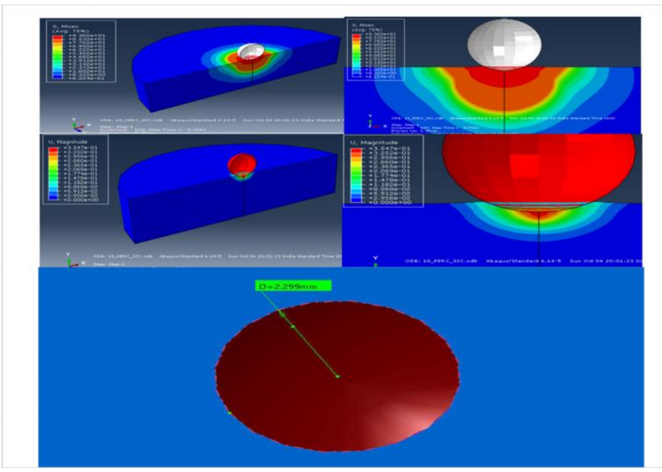
Numerical analysis (FEA)



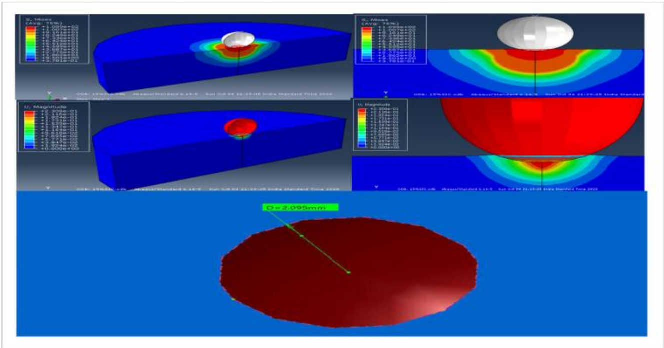
PureAALM12



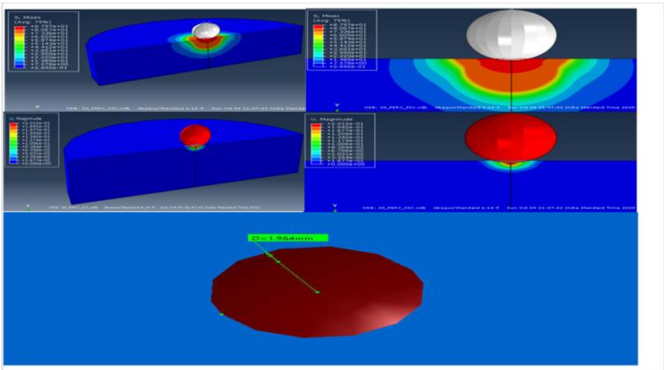
5%SiC



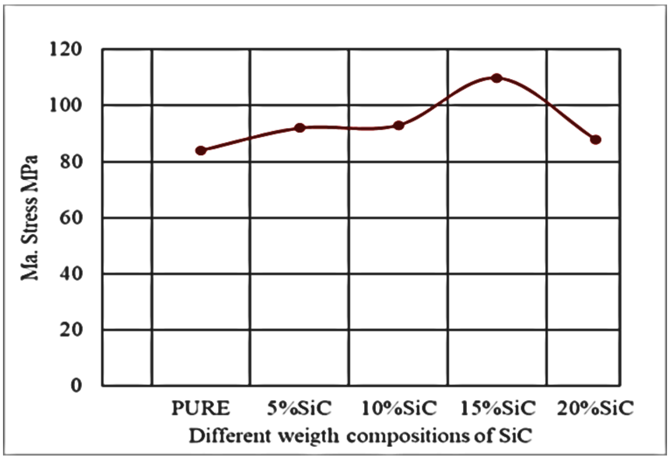
10%SiC

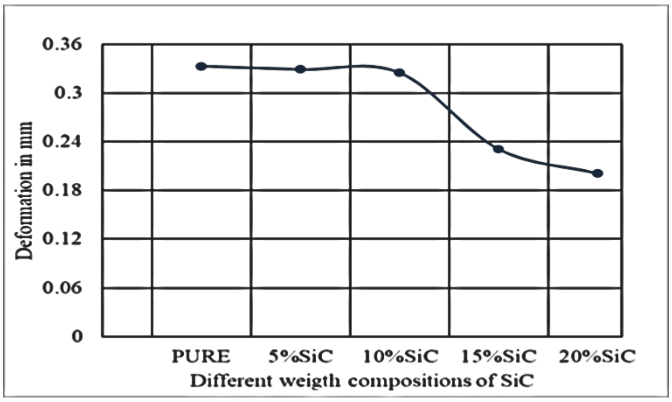


15%SiC



20%SiC





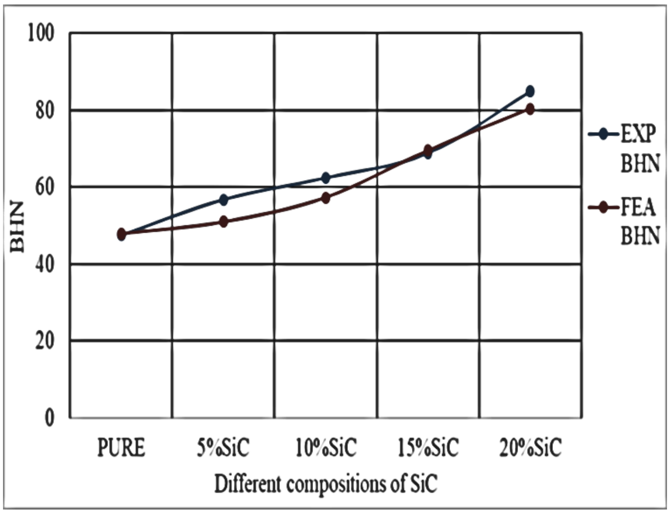
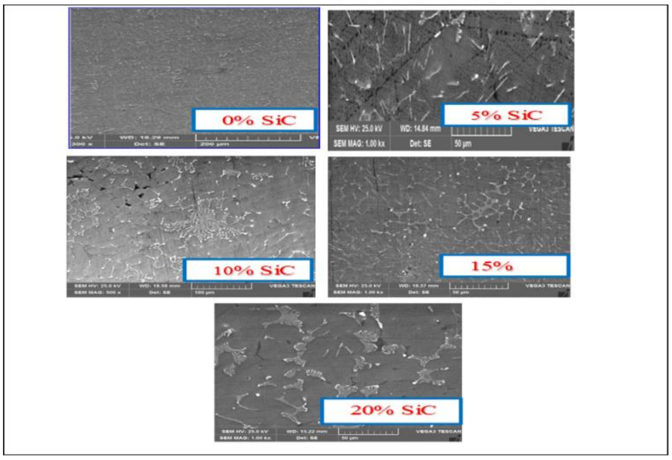


Fig:6 BHN FE analysis results

To prepare the BHN test specimen as per the ASTM standards by using the ABAQUS software and approach the numerically this have been shown in Fig:5.The young's modulus of MMC's increased linearly with increased SiC that shown in fig:4 by using the Karner equation. And the values of yield strength, these are the results are feed in to FE analysisi. The effect of matrix alloy on mechanical properties are shown fig:6 in the influence of matrix alloy on the yieldstrength (YS) of Al-SiC composites. It can be seen that the reinforced with SiC of Al alloy LM12 matrix alloy exhibits larger YS than unreinforced SiC of Al alloys LM12

SEM and EDX analysis



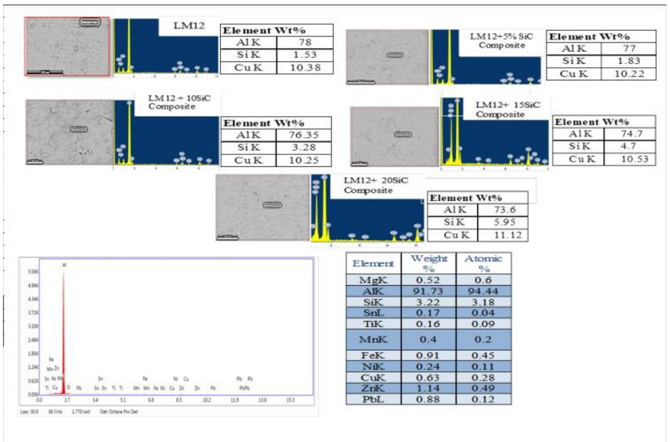


Fig:6 SEM and EDX imag

SEM analysis is carryout the studied of the reinforcements of SiC is distribution and confirmation of inside the matrix are essential to the final properties of composites prepared through stir casting process shown in fig To investigate distribution of reinforcements on composites by using the SEM analysis was performed that observed from the images and it showed that particles were homogenously and uniformly distributed [6]. That showed in SEM images and some clusters of SiC particles are observed in SEM micrographs few researcher

The EDX analysis is observed in the aluminum alloy LM12 metal matrix composites from the SEM images that shown in the fig: 6.10. But Al, Mg and Cu particles are shown inXRD and EDX analysis composites. It shows the qualitative analysis and indicating the presence of Al, Mg, SiC and Cu in the composites material of different reinforced SiC. On the other hand, a high amount of SiC have been indicating due to the surface modification of composites, which are the compositions are having in the composites that is confirmed from this analysisshow in fig:6. [7]

The FEA model of tensile test specimen prepared as per the ASTM E-8 by using ABAQUS software and Finite element analysis at the maximum stress, strain and Deformation at Ultimate tensile strength condition for the different compositions of MMC's[11]

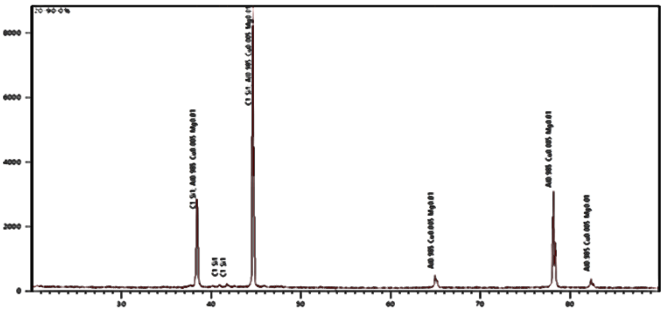


Fig.4 Peak positionsLM12

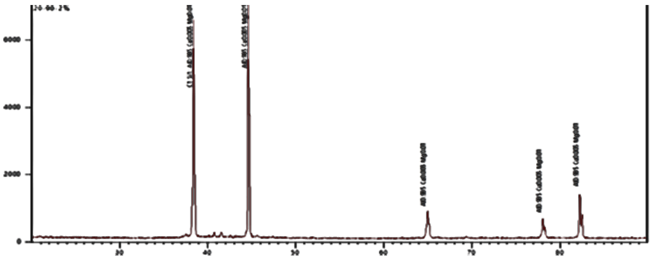


Fig.5 Peak positions-5%SiC

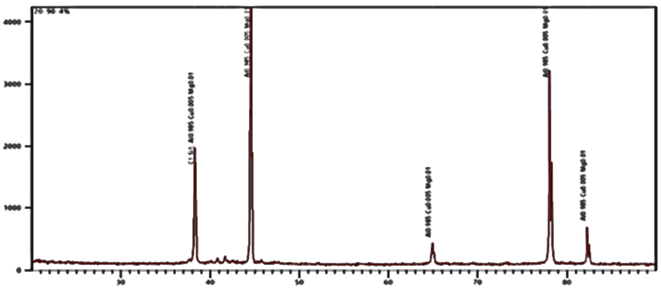


Fig.6 Peak positions-10%SiC

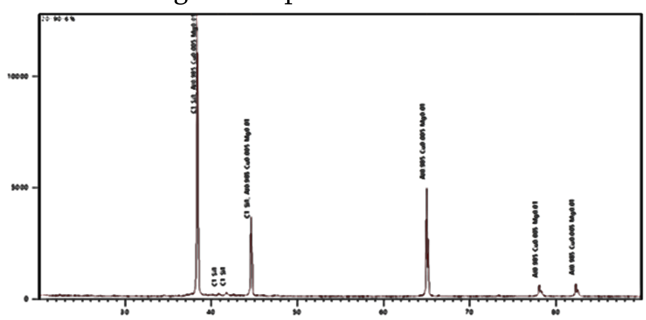


Fig.7 Peak positions-15%SiC

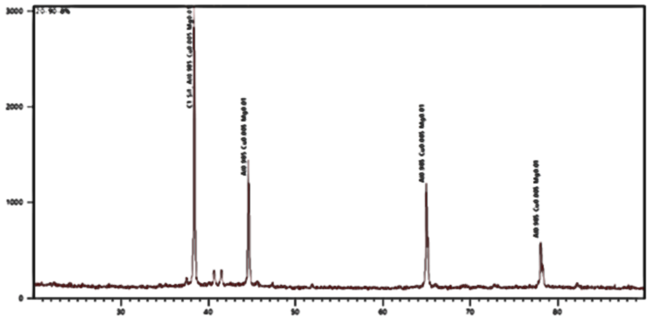


Fig.7 Peak positions-20%SiC

Pos. [°2θ]	Height [cts]	FWHM Left [°2θ]	d-spacing [Å]	Rel. Int. [%]
38.3943	2149.39	0.1437	2.34262	25.92
40.8785	62.84	0.2414	2.20581	0.76
41.7696	60.40	0.3978	2.16079	0.73
44.6330	8292.64	0.0684	2.02858	100.00
64.9752	312.02	0.2042	1.43414	3.76
78.1293	2837.74	0.1264	1.22231	34.22
82.3242	246.17	0.1743	1.17033	2.97

Table.2 FWHM& d spacing details for LM12

Pos. [°2θ]	Height [cts]	FWHM Left [°2θ]	d-spacing [Å]	Rel. Int. [%]
37.4953	69.95	0.1674	2.39670	1.10
38.3687	5388.57	0.1221	2.34412	85.02
40.6990	84.93	0.2872	2.21512	1.34
41.4860	118.44	0.2348	2.17490	1.87
44.6185	6338.25	0.0965	2.02921	100.00
64.9519	722.53	0.1920	1.43459	11.40
78.0611	531.18	0.1766	1.22321	8.38
82.2628	1313.36	0.1481	1.17104	20.72

Table3 FWHM& d spacing details for 5%SiC

Pos. [°2θ]	Height [cts]	FWHM Left [°2θ]	d-spacing [Å]	Rel. Int. [%]
38.2765	1472.72	0.1518	2.34956	44.56
40.7896	45.97	0.3925	2.21041	1.39
41.6797	61.15	0.4172	2.16524	1.85
44.5456	3305.33	0.1347	2.03236	100.0
64.8791	301.67	0.1828	1.43603	9.13
78.0355	3112.08	0.1270	1.22355	94.15
82.2445	571.19	0.1305	1.17126	17.28

Table3 FWHM& d spacing details for 10%SiC

Pos. [°2θ]	Height [cts]	FWHM Left [°2θ]	d-spacing [Å]	Rel. Int. [%]
38.3658	10890.18	0.1100	2.34429	100.00
40.8112	56.69	0.4779	2.20929	0.52
41.7791	78.62	0.6301	2.16032	0.72
44.6180	3113.59	0.1059	2.02923	28.59
64.9912	4858.31	0.1043	1.43382	44.61
78.0829	466.70	0.1794	1.22293	4.29
82.2926	573.10	0.1622	1.17070	5.26

Table4 FWHM& d spacing details for 15%SiC

Pos. [°2θ]	Height [cts]	FWHM Left [°2θ]	d-spacing [Å]	Rel. Int. [%]
37.4799	63.69	0.2141	2.39765	2.52
38.3656	2530.96	0.1046	2.34430	100.0
40.6601	123.40	0.2030	2.21715	4.88
41.4713	129.25	0.2166	2.17564	5.11
44.5826	1066.27	0.1275	2.03076	42.13
64.9657	1000.97	0.1370	1.43432	39.55
78.0668	426.16	0.1721	1.22314	16.84

Table4 FWHM& d spacing details for 20%SiC

XRD analysis of MMC's

V. RESULTS AND DISCUSSIONS

Comparison of BHN in EXP and FEA

To conduct the BHN test in experimentally, the hardness of MMC's have been increased with increased SiC. Due to the reinforced SiC uniform distribution and made to material highhardened. The specimen prepared in FEA model by using the ABAQUS software after that the young's modulus of MMC's calculated by using the Karner equation these values and experiment yield strength values are feed in to the FEA model.in the influence of SiC of matrix alloy on the yieldstrength and Youngs modulus of Al-SiC composites it has been increases shown in fig:. The comparison of the BHN test results in experimentally and FE analysis both results are increased linearly and correlated, The maximum stress correlated each other and deformation of MMC's in experiment and FE analysis decreased gradually that phenomenon also shown in fig:7.

Compositions	EXP BHN	FEA BHN	Max, Stress Mpa	Deformation in mm
PURE	47.5	47.95	84.01	0.333
5%SiC	56.8	51	91.98	0.329
10%SiC	62.4	57.36	93.02	0.325
15%SiC	68.8	69.57	109.9	0.231
20%SiC	84.8	80.44	87.97	0.201

Fig:7 Results comparison

SEM, EDX and XRD analysis

That showed in SEM images and some clusters of SiC particles are observed in SEM micrographs for the confirmed in the composites. The EDX analysis is observed in the al alloy LM12 metal matrix this composites from the SEM images that shown in the fig:6. But Al, Mg and Cu particles shows SEM image,XRD and EDX pattern A Alloy LM12composite. It shows the qualitative analysis, indicating the presence of Al, Mg, SiC and Cu.

VI. CONCLUSION

Based on the results of this investigation following conclusions were drown

1. Aluminum alloy LM12-SiC composites were prepared by using the stir casting techniques and 23micron meter size of SiC have been used as reinforcement. Succeffully,
2. The tensile yield strength and Young's modulus of metal matrix composites Increased with incorporation of silica carbide. Higher amount of silica carbide shows more influence on properties those values are feed into FEA of BHN test.
3. The maximum stress is increased in both the cases like experiment and FEA, The BHN results are also increased with increased SiC in both cases and results are correlated and deformation have been decreases with increased SiC in experiment and FEA results are correlated and these results are obtained from the ABAQUS software followed the standard procedure.
4. The reinforcement of SiC uniformlydistribution in metal matrix composite and this is confirmed by using the SEM, EDX and XRD analysis.

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