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"Study and analysis of tensile strength of aluminium alloy lm-12 reinforcement with sic and comparision of displacement with finite element analysis"

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ABSTRACT: To develop the Al alloy metal matrix composite (MMC's) by using stir casting technique successfully and ensured the reinforced of SiC uniformly distributed in the metal matrix composites. The filler material of SiC is varying with weight percentage of 0%, 5%, 10%, 15%, and 20%wt. The production cost is at better in price compare to other production technique with less in wastages and environmental friendly.
The Al alloy metal matrix composites are fabricated the sample specimens for tensile test as per the ASTM standard by using of some machining operations. And for the Finite element analysis created the model by using CAD applications as per the standards.
To conduct the mechanical characterizations MMC's by followed the standard testing procedure while conducting the experiments and founded all experimented mechanical results, were founded developed with increased of reinforcement in MMC's. And suggest to the end users which is best compositions of MMC's is suitable to industrial sectors.

I. INTRODUCTION

The composite materials are defined as combining the two or more different materials by using metallurgical technique or stir casting process to produces the MMC's. The casted MMC's is homogenous it means obeying the same properties and develop the some strength like, mechanical, chemical, thermal and physical properties (2) etc.

The Al alloys were using many applications industrial sectors like, automobile industries are used in Piston material in IC engine and high pressurized hydraulic brake pads, in the field of aircraft many more parts are used, electrical field and used to daily utilities. Due to this material is high strength and it possess high ductility with low weight ratio, highly corrosion resistance in nature and widely available in nature with cheap price. Those Al alloys can make easy machining operations.

The pure Al alloys are having low strength as compare with reinforced Al Alloys. To make high strength of Al alloys by using ceramic material is adding or filler or reinforced materials like, Sic, Ti,Gr& Ni etc(1).

The Metal matrix composites reinforced with hard ceramic particles are of interest due to several advantages in terms of mechanical properties and ease of fabrication. These materials are used in aerospace, aircraft, automotive and many other manufacturing and industrial fields.

In this case SiC used as reinforced filler material in weight percentage of (5%wt.- 20%wt.) every increment of SiC in 5%wt. These metal matrix composites are developed by using stir casting techniques with using of crucible furnace which is made of graphite material and made the moulds also same materials because these materials withstand of high temperature limits, this type of process is very minimum operation cost, time and obtained good surface finished and despised shape product obtained with no defects like, no blow holes, cracks and pin holes etc. Due to this process is very familiar for production of metal matrix composites.

II. LITERATURE REVIEWED PAPERS

1. **Bansal P Shubhranshu et.al:(2015)** with this paper Al359 alloy was reinforced with Silicon Carbide and Silicon Carbide/Graphite particles using stir casting process. To conduct the ultimate tensile strength against Silicon

Carbide reinforced composite, wear test was conducted at different loading with same speed.

2. **G.E Prakash Gadade et.al: (2013)**in this case study the engine piston is most complex part compared to other components in an automobile sector, regarding piston studied from this paper.
3. **WinterLisa et.al:(2018)** In this work the high cycle fatigue behaviour of a particulate reinforced 2124 aluminium alloy reinforced with SiC particles are characterized tensile and fatigue testing at room temperature.
4. **B.A.Devan et.al :(2015)** in this studied of paper, work is carried out to find out the thermal distribution on different piston materials used.
5. **S.A.Mohan Krishna et.al :(2014)** The term Metal Matrix Composites (MMCs) production and covers a very wide range of materials to simple reinforcements of castings with low cost refractory wool, to complex continuous fires lay-ups in foreign alloys.
6. **R Rajesh A M et.al:(2016)** Study of this paper studied of this technique is less expensive and very effective. The hardness test and wear test were performed on the specimens which are prepared by stir casting techniques.
7. **Prabhat R. Kumar et.Al:(2016**) Reference of this paper Aluminum matrix composites are widely used in various advance industries like aerospace, transportation, defense, marine and auto-mobile, piston cylinder and sports, due to their better corrosion resistance, good mechanical property and high strength to weight ratio. Attention is being paid by researchers towards increasing the mechanical properties, and also to provide the attractive aesthetic appearance of the existing material by adding various reinforcement particles. Hence, in the proposed work, silicon carbide and boron carbide is considered to improve the mechanical properties like Tensile strength, hardness, wear resistance and density of the casted aluminum alloy LM6.
8. **R. Akhil et.al:(2014)** In this study, the metal–matrix composites of an aluminum–silicon based alloy (LM6) composition evaluated the hardness, tensile strength and microstructure properties were examined.
9. **Shanawaz Patil et.al:(2018)** Study of this paper the MMC's have find wide applications in all the engineering fields due to their light weight and high strength parameters, especially in the field of automobile and mechanical industries The aluminum MMC have got wide applications due to their excellent mechanical properties.

III. ALUMINIUM ALLOY LM12 AND SIC

Chemical Composition and Mechanical Properties of LM12

S	Materials		Percen		
	Copper	Cu	9.0-11.0	0.2% Proof stress	140-170 N/mm^2
2	Magnesium	Mg	0.2-0.4	Tensile Stress	170 N/mm^2
3	Silicon	Si	2.5	Elongation	0.5-1.5%
4	Iron	Fe	1.0	Impact Resistance [Izod]	1.0 N-m
5	Manganese	Mn	0.6	BHN	85-90
6	Nickel	Ni	0.5	Endurance limit [5×10^7 cycles]	60 N/mm²
7	Zinc	Zn	0.8	Modulus of elasticity	71000 N/mm²
8	Lead	Pb	0.1		
9	Tin	Sn	0.05		
10	Titanium	Ti	0.2		
11	Aluminum	Al	Remind		

Table:1

Applications of Aluminium AlloyLM12

- This Al alloy used in pistons in Internal combustion engines
- This used in high hydraulic braking system due to possess maximum hardness.
- Used in electric iron sole plates.
- Used in utensils
- Aerospace applications

Applicable of light weight usages

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Silicon carbide

Properties of Silicon carbide	Size	Melting Temperature	Polycrystalline	Single crystals
	30 microns	2830° C	15 Gpa	27 Gpa
	Excellent Creep resistance, High heating element in furnace, Hard and strong and uniformly distribution means good bonding capacity, Unique Thermal and electronic uses.			

IV. OBJECTIVES OF CURRENT RESEARCH:

The Aluminium Alloy LM-12 is used in precipitation hardened condition piston in IC engine and aerospace etc. 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. Mechanical properties are to be determined like FE Analysis of tensile of strength of MMC's.

V. METHODOLOGY

Metal matrix composites can be produced by two processes:

(a) Liquid metallurgy Technique

(b) Powder Metallurgy (PM) Technique

Since the Aluminium alloy LM12 melts at low temperature (600-700°C), liquid metallurgy Technique with effective stirring can be employed for the production of the composite. Content of the reinforcement of SiC is varied from wt of 5% to wt of 20% in steps of wt5%.

- Melting the Aluminium alloy LM12 in furnace at temperature (700-750°C) for 3:0 Hrs
- Homogeneous mixing of SiC particles with Molten LM-12 alloy by Stirring Technique about 20mins at 500 rpm.
- Content of the reinforcement of SiC is varied from wt of 5% to wt of 20% in steps of wt 5% in the mixture.
- Specimens are casted by metal moulding method.
- Fabrication of specimen for particular experimental testing by turning, facing, parting and grinding operations.
- Conduct Tensile strength and FE ANALYSIS of Tensile strength.

STIR CASTING PROCESS

Stir casting technique is the process of stirring the molten metal continuously by a stirrer which is operated by an Electric motor. Stirrer is immersed into the molten metal which is heated in a Crucible. Furnace continuously supplies heat to the Crucible. The reinforcement (Silicon carbide in our case) is poured into the molten metal and the stirrer stirs thoroughly to mix the reinforcement material with the molten metal. Stirring speed is 600 rpm, stirring time is 10 minutes and molten metal temperature should be maintained at 900°C. Schematic representation of the Stir casting process is shown in below Fig-1, Fig-2 and Fig-3.

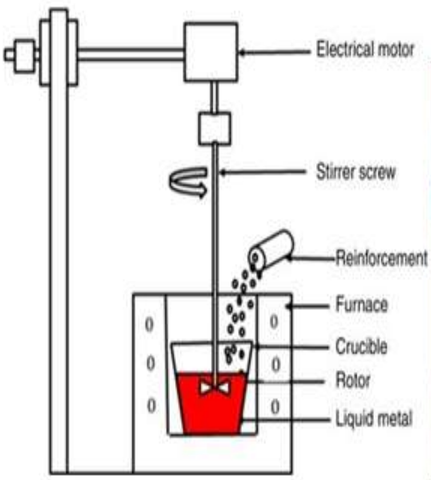

Fig-1 Stir casting setup**Fig-2** stirrer **Fig 3** crucible furnace

PREPARATION OF MMC's

Initially ingots of LM-12 aluminium alloy is 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. First prepared specimens of pure LM-12 alloy. Prepared moulds, and poured molten metal to get desire shape (cylindrical).

Fig-5.7 Moulds

Fig-Casted MMC's

Fig-pouring

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^{o}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 diameter and length of the specimen is obtained as shown below.

VI. FE ANALYSIS OF TENSILE STRENGTH

The tensile properties of MMC's of experimental results were correlated with FE analysis by using hyper mesh-Optistruct tool.

These mechanical properties MMC's as followed

- Considering the modulus of elasticity and Poisson's ratio of MMC's
- To possess the yield strength and ultimate tensile strength of MMC's
- Ductility properties, such as elongation and reduction in area.

In this case study, a simulation of a tensile test, which is a representative material test, is performed using a computer program (Hyper mesh CAE). Tensile test of Al -Sic MMC is performed and then analysed the stress–strain relationship using a computer program (Hyper mesh-Optistruct).

Finite Element Analysis

The finite element method is an important computation technique for analysing both complex geometries and for taking into consideration all the phenomena involved in the manufacturing process. One of the most delicate operations in this method is sub-dividing the continuum into elements since this discretization can have an influence both on the reliability of the results, and on computational requirements.

Hyper mesh as pre-processor

Pre-processing Software popularly known as Meshing Software. Hypermesh-13 used the FE analysis modules has been used to create the FE models.

Optistruct as solver

Optistruct is a set of the FE analysis modules, the modern structural analysis solver used for linear and nonlinear problems under the static and dynamic load conditions.

Experimentation details

The ASTM- E8 standard specimens are shown below figure and the modelling sample has taken.

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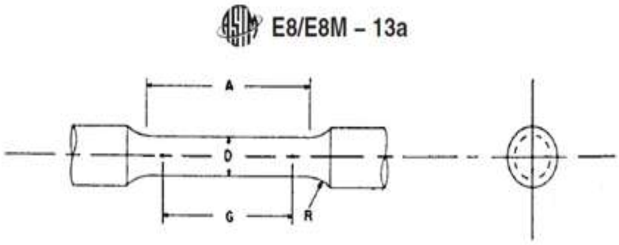
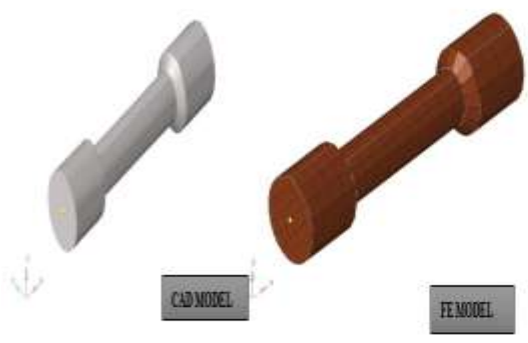


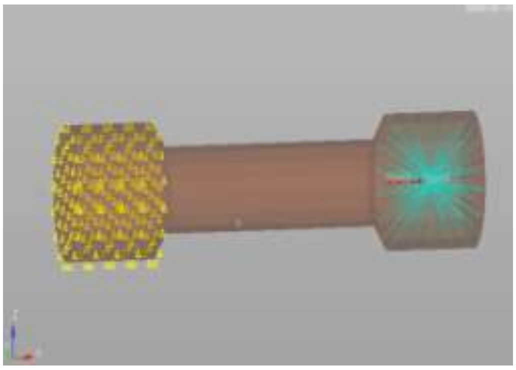
Dimensions, mm [in.] For Test Specimens with Gauge Length Four times the Diameter [E8]	Standard Specimen	Small-Size Specimens Proportional to Standard			
	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
G—Gauge length	50.0 ± 0.1 [2.000 ± 0.005]	36.0 ± 0.1 [1.400 ± 0.005]	24.0 ± 0.1 [1.000 ± 0.005]	16.0 ± 0.1 [0.640 ± 0.005]	10.0 ±0.1 [0.450 ± 0.005]
D—Diameter (Note 1)	12.5 ± 0.2 [0.500 ± 0.010]	9.0 ±0.1 [0.350 ± 0.007]	6.0 ± 0.1 [0.250 ± 0.005]	4.0 ± 0.1 [0.160 ± 0.003]	2.5 ± 0.1 [0.113 ± 0.002]
R—Radius of fillet, min	10 [0.375]	8 [0.25]	6 [0.188]	4 [0.156]	2 [0.094]
A—Length of reduced section, min (Note 2)	56 [2.25]	45 [1.75]	30 [1.25]	20 [0.75]	16 [0.625]

The following procedure have been followed to generate the components

1. To input the material properties as a border line conditions and forces are make the finite element model by using hyper mesh CAE software.
2. Create the CAD model as per the dimensions and shape given above.
3. Create the FE model for the part with solid elements and with element quality in optistruct solver deck.
3. Give the properties of the material in the material manager option. The properties that must be given are density, young's modulus, poison's ratio, and plastic strain.



4. In the Analysis Module, one end of the sample is made fixed. That is constrained. And the axial load is provided in the other end.



Applying boundary conditions (Constraints and Force)

5. Run the file with analysis set up & examines different Load v/s displacement, stress/s strain etc, select Result are plotted and explained below.

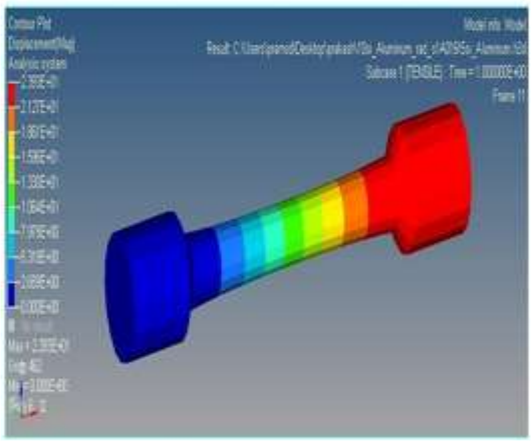


Fig: Applied Load to CAD Model

Experimental results of tensile test on UTM:

To conduct the tensile test of Metal matrix composites, the test samples are prepared as per the ASTM stand by using machine operations, Those MMC's tested by using UTM machine followed by standard procedure. The tensile test applied the load on MMC's in the direction of opposite (Fulling).

Length of the Specimen (L): 165mm Diameter of Specimen (D):19 mm Gauge Length of Specimen (l) = 50mm Gauge dia of Specimen (d) =13 mm

Fig: E8ASTM Tensile samples

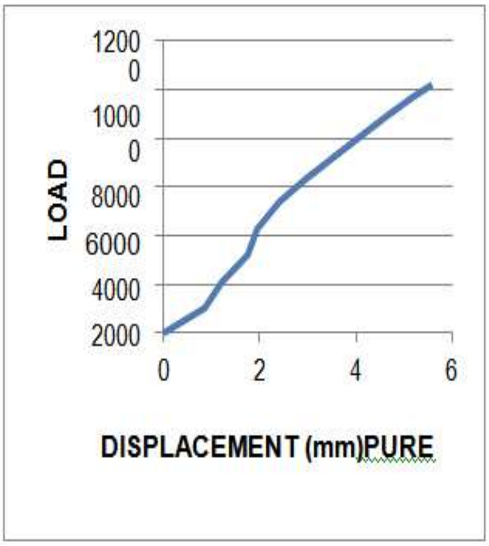
Tensile test experimented results Tabular column:

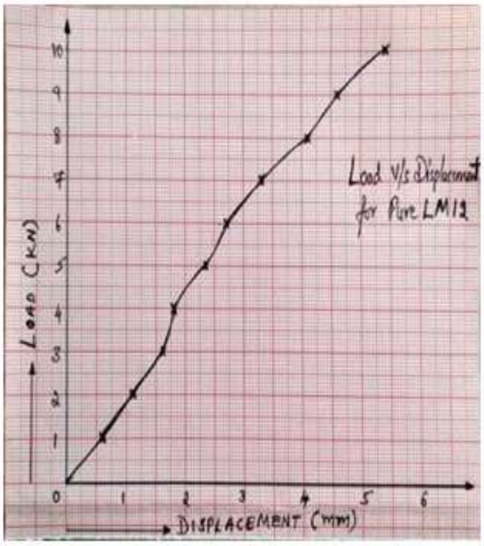
Sl. No.	Specimen	Load (KN)	Tensile strength (Stress) (KN/mm^2)	Strain	Modulus of Elasticity (KN/mm^2)	% of Elongatio n in mm
1	**LM12**	10.24	0.077	0.109	0.7090	5.4
2	**LM12+5%w SiC**	9.98	0.068	0.311	0.2185	5.1
3	**LM12+10%w SiC**	17.68	0.133	0.198	0.6731	4.4
4	**LM12+15%w SiC**	19.46	0.147	0.190	0.7721	3.5
5	**LM12+20%w SiC**	15.34	0.116	0.197	0.5876	3.1

DEFORMATION FE ANALYSIS OF TENSILE 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 compare with numerical and experimental results by giving the tensile strength as input load. The result variation is caused in the experimental analysis while deformation compares through the Hypermesh-13 software uses to deformation analysis, Load v/s displacement of different wt. % Sic of the experimental results were almost same with the numerically calculated values as shown in below figures.





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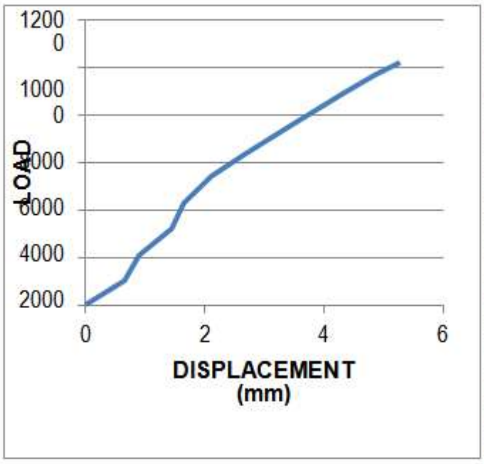

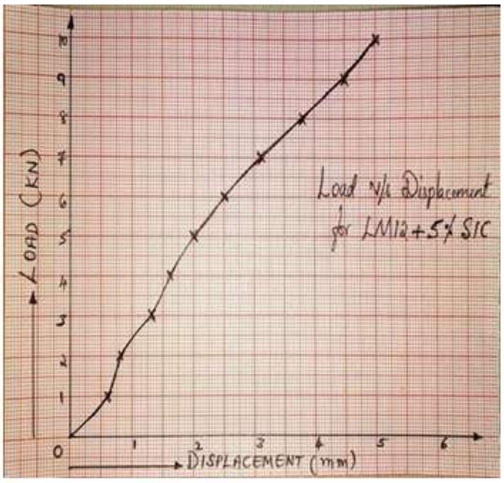

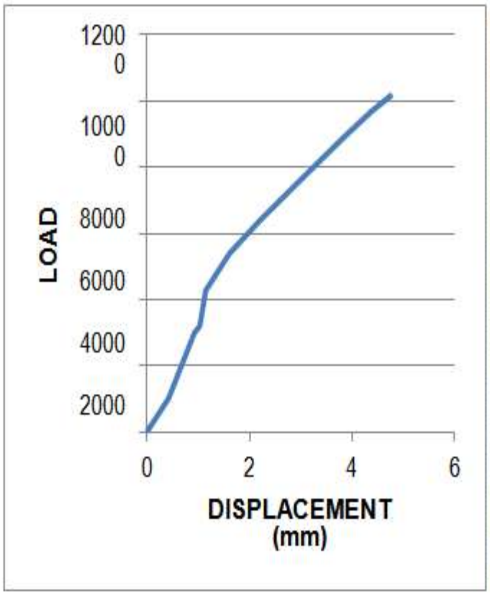

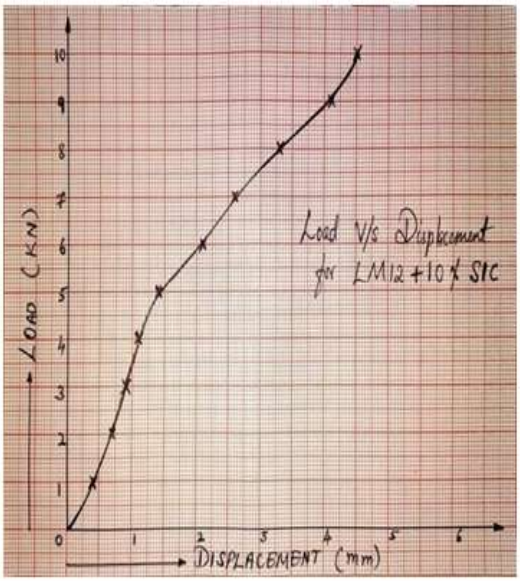

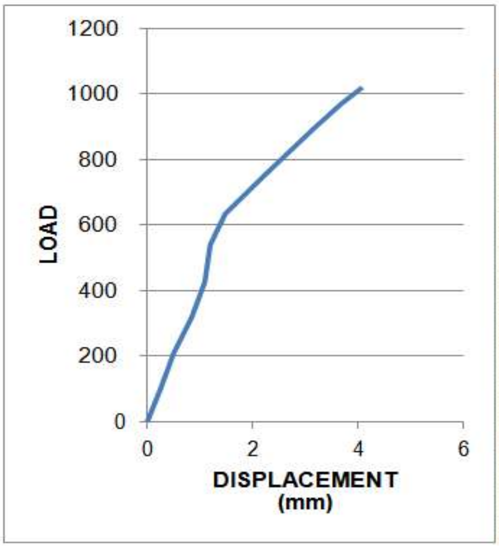

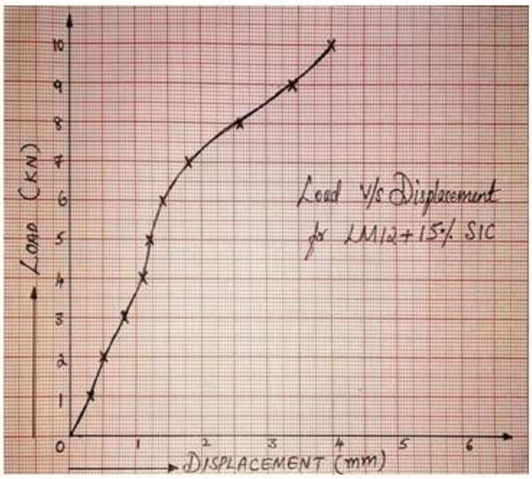

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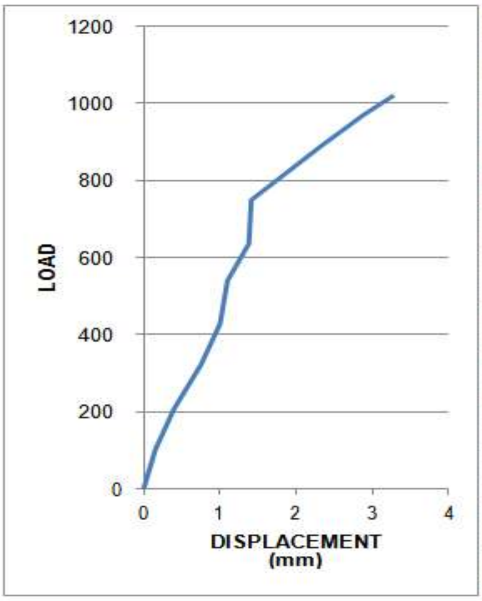
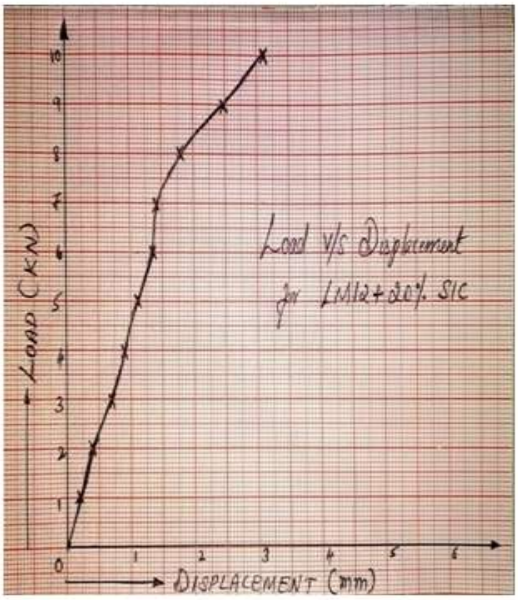
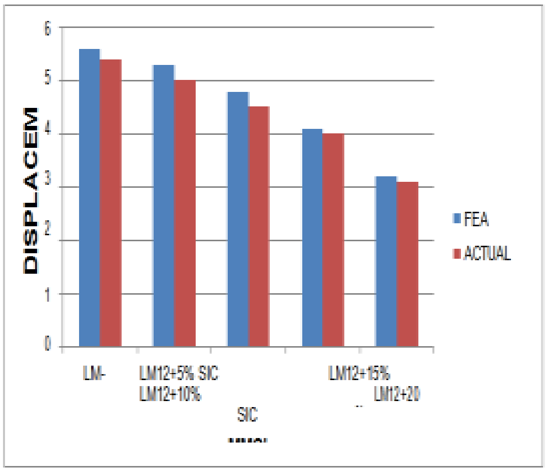




DISPLACEMENT COMPARISION

MMC	Displacement % in FEA	Displacement % in UTM
Pure LM12	5.5	5.4
LM12+5% SIC	5.2	5.1
LM12+10% SIC	4.6	4.4
LM12+15% SIC	4.0	3.5
LM12+20% SIC	3.2	3.1

Bar Graph Showing The Displacement Results For Mmc.



VII. CONCLUSION

FE analysis of Tensile strength is done to find the ductility of pure LM12 and MMCs. It is found that ductility reduced and elongation have been reduced with reinforcement of SiC is increased rate to the MMCs. The elongation rate of the MMC's is compared with actual tensile test results. It is found that as the content of SiC is increased in the MMC's, these materials are became more brittle due to this phenomena the ductility is reduced and elongation also reduced, those results were compare with FE analysis considering the lower tensile loads got improved, so hence LM12+10%SiC and LM12+15%SiC are betterment of usage.

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