International Journal on Emerging Technologies **3**(1): 178-184(2012) **ISSN No. (Print) : 0975-8364**
ISSN No. (Online) : 2249-3255

An Experimental investigation of Mechanical behavior of Aluminum by adding SiC and Alumina

Daljeet Singh*, Harmanjit Singh**, Som Kumar** and Gurvishal Singh***

Department of Mechanical Engineering,
**Amritsar College of Engg. & Technology,Manawala, (PB) India*
***R.I.E.I.T, Railmajra (PB), India*
****G.I.E.M.E.T, Batala Road, Sohian, (PB), India*

(Received 15 April, 2012 Accepted June, 2012)

ABSTRACT: Aluminum alloy are widely used in automotive sector due to their good mechanical properties, better corrosion resistance and wear, low melting point as compare to others. The most important property of these materials are relatively light in weight and having low production cost which make them attractive for different applications from technological point of view. The purpose of designing metal matrix composite is to add the desired attributes of metals and ceramics. This work is focused to study the change in behavior of aluminum by adding different %age amount of 'Sic' and 'Al_2O_3' composites. Then tensile test, hardness test, impact test performed on these samples which are produced by stir casting. Further it is concluded that as the weight %age of reinforcement goes on increasing the mechanical properties such as hardness, yield strength, ultimate strength also increases. But at the same time elongation decreases and the behavior of material changes from ductile to brittle.

Keywords: Aluminum alloys, stir casting, tensile test, hardness Test.

I. INTRODUCTION

The aim involved in designing metal matrix omposite materials is to combine thedesirable attributes of metals and ceramics. The addition of high strength, high modulusrefractory particles to a ductile metal matrix produce a material whose mechanicalproperties are intermediate between the matrix alloy and the ceramic reinforcement. Aluminum is the most abundant metal in the Earth's crust, and the third most abundantelement, after oxygen and silicon. It makes up about 8% by weight of the Earth's solidsurface. Due to easy availability, High strength to weight ratio, easymachinability,durable, ductile and malleability Aluminum is the most widely used non-ferrous metal in2005 was 31.9 million tons.

Advantages of Aluminum

1: Light Weight, Strong and Long-lasting

Aluminum is a very light metal with a specific weight of 2.7 gm. /cm^3, about a third that ofsteel. For example the use of aluminum in vehicles reduces dead-weight and energyconsumption while increasing load capacity. Its strength can be adapted to the applicationrequired by modifying the composition of its alloys.

II. Highly Corrosion Resistant

Aluminum naturally generates a protective oxide coating and is highly corrosion resistant.It is particularly useful for applications where protection and conservation are required.

III. Excellent Heat and Electricity Conductor

Aluminum is an excellent heat and electricity conductor and in relation to its weight isalmost twice as good a conductor as copper. This has made aluminum the mostcommonly used material in major power transmission lines.

II. COMPOSITE MATERIALS

Composites are materials in which two phases are combined, usually with stronginterfaces between them. They usually consist of a continuous phase called the matrix anddiscontinuous phase in the form of fibers, whiskers or particles called the reinforcement.Considerable interest in composites has been generated in the past because many of theirproperties can be described by a combination of the individual properties of the constituentphases and the volume fraction in the mixture.Composite materials are gaining wide spread acceptance due to their characteristics of behavior with their high strength to weight ratio. The interest in metal matrix composites (MMCs) is due to the relation of structure to properties such as specific stiffness orspecific strength. Like all composites, aluminum matrix composites are not a singlematerial but a family of materials whose stiffness, density and thermal and electricalproperties can be tailored**.** Composites materials are high stiffness and high strength.

N. Chawla [1] investigated the tensile strength processes in discontinuously reinforced aluminum(DRA).In this experiment author varies the average particle size (6-23 micro meter), Heattreatment is also given. Conclusion of this paper is that as particle size increases Tensilestrength decreases. Heat treatment increases the tensile strength.

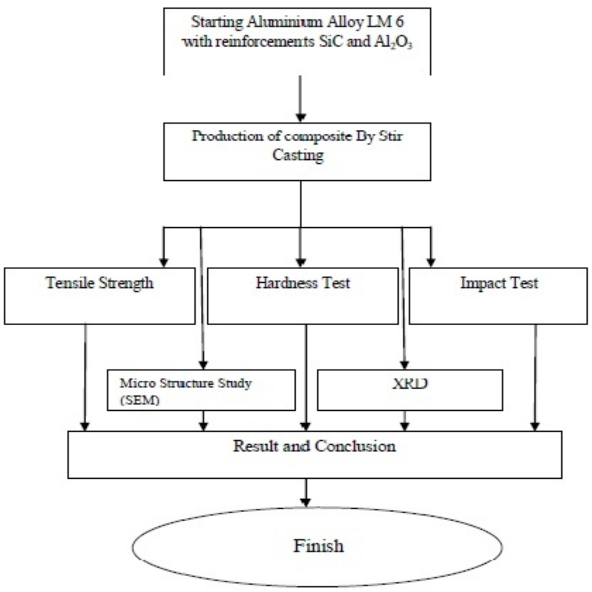
ManojSingla [2] studied to develop aluminum based silicon carbide particulate MMCs with anobjective to develop a conventional low cost method of producing MMCs and to obtainhomogenous dispersion of ceramic material. To achieve these objectives two method of stircasting technique has been adopted and subsequent property analysis has been made. Aluminum (98.41% C.P) and SiC (320-grit) has been chosen as matrix and reinforcementmaterial respectively. Experiments have been conducted by varying weight fraction of SiC(5%, 10%, 15%, 20%, 25% and 30%), while keeping all other parameters constant. Anincreasing trend of hardness and impact strength with increase inthe weight percentage of SiChas been observed. The best results (maximum hardness 45.5 BHN & maximum impactstrength of 36 N-m.) have been obtained at 25% weight fraction of SiC Ibrahim [3] In this review author studied the mechanical properties that can be obtained with metalmatrix composites by varying reinforcement percentage by 0, 10, 15, 20% and takingdifferent alloy AA 6061, AA 2014, AA 356. Conclusion of this paper is by increasingreinforcement % age yield strength, ultimate strength is increasing but elongation of an Alloydecreases.

S. Balasivanandha Prabu,L .[4] In the present study, high silicon content aluminum alloy–silicon carbide metal matrixcomposite material, with 10% SiC were successfully synthesized, using different stirringspeeds and stirring times. The microstructure of the produced composites was examined byoptical microscope and scanning electron microscope. The Brinell hardness test was performed. Increase in stirring speed and stirring time resulted in better distribution ofparticles. The hardness test results also revealed that stirring speed and stirring time have their effecton the hardness of the composite. The uniform hardness values were achieved at 600 rpm with 10 min stirring. But beyond certain stir speed the properties degraded again.

M. Kok [5] In this author examined AA 2024 aluminum alloy metal matrix composites (MMCs)reinforced with three different sizes and weight fractions of Al_2O_3 particles up to 30 wt. %were fabricated by a vortex method and subsequent applied pressure. The effects of Al_2O_3particle content and size of particle on the mechanical properties of the composites such ashardness and tensile strength were investigated. Scanning electron microscopic observationsof the microstructures revealed that the dispersion of the coarser sizes of particles was moreuniform while finer particles led to agglomeration of the particles and porosity. The resultsshow that the hardness and the tensile strength of the composites increased with decreasingsize and increasing weight fraction of particles.

G. B. Veeresh Kumar1 [6] examine the base matrix and the reinforcing phase for the present studies selectedwere AA 6061, AA 7075 and particles of Al_2O_3 and SiC of size 20 µm. It can be observedthat the densities of composites are higher than that of their base matrix, further the densityincreases with increased percentage of filler content in the composites. It can be observedthat the tensile strength of the composites is higher than that of their base matrix also it canbe observed that the increase in the filler content contributes in increasing the tensile strengthof the composite. In microstructure studies it can be observed that, the distributions ofreinforcements in the respective matrix are fairly uniform.

II. EXPERIMENTAL PROCEDURE



Preparation of Samples

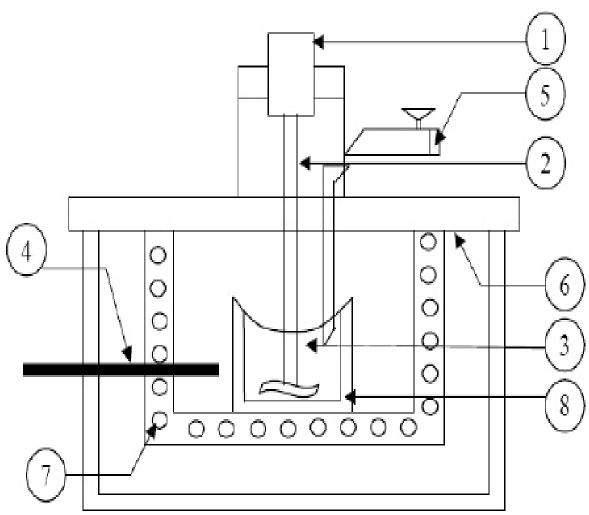


Fig.1. Schematic view of setup of Stir Casting.
1. Motor
2. Shaft
3. Molten Aluminum
4. Thermocouple
5. Particle Injection Chamber
6. Insulation Hard Chamber
7. Furnace
8. Graphite Crucible

Aluminum Alloy was melted in a crucible by heating it in a muffle furnace at 800°C forthree to four hours. The silicon carbide particles and Alumina particles were preheated at1000°C and 900°C respectively for one to three hours to make their surfaces oxidized. Thefurnace temperature was first raised above the liquids' temperature of Aluminum nearabout 750°C to melt the Al alloy completely and was then cooled down just below theliquidus to keep the slurry in Semi solid state. Automatic stirring was carried out with thehelp of radial drilling machine for about 10 minutes at stirring rate of 290 rpm. At thisstage, the preheated SiC particles and Alumina particles were added manually to the vortex. In the final mixing processes the furnace temperature was controlled within 700 ±10°C. After stirring process the mixture was pour in the other mould to get desired shape37of specimen as shown in Figure 4.10. The presence of reinforcement throughout thespecimen was inspected by cutting the casting at different locations and undermicroscopic examination. Same process was used for specimens with different compositions of SiC and Alumina.

III. RESULTS AND DISCUSSION

Impact Test Results

The Charpy impact test, also known as the Charpy v-notch test, is a standardized high strainratetest which determines the amount of energy absorbed by a material during fracture. Thisabsorbedenergyis measure ofgivenmaterial'stoughness.

Serial No	Composites	Trial						Average Force Nm
		1	2	3	4	5	Total Force Nm	
1	Aluminum Alloy (LM6)	6.2	6.1	5.9	5.6	5.5	29.3	5.86
2	LM6 + 2.5 % SiC	7.3	7.2	7.3	6.8	6.7	35.3	7.06
3	LM6 + 5 % SiC	8.2	8	7.5	7.8	7.6	39.1	7.82
4	LM6 + 7.5 % SiC	8.8	7.9	7.5	8.6	7.6	40.4	8.08
5	LM6 + 10 % SiC	8.5	8.7	8.8	9.7	9.2	44.9	8.98
6	LM6 + 2.5 % Al_2O_3	6.5	6.5	6.7	6.8	6.6	33.1	6.62
7	LM6 + 5 % Al_2O_3	6.7	6.8	6.9	7.0	7.0	34.4	6.88
8	LM6 + 7.5 % Al_2O_3	7.1	7.0	7.0	6.9	7.2	35.2	7.04
9	LM6 + 10 % Al_2O_3	7.5	7.2	7.1	7.2	7.1	36.1	7.22
10	LM6 + (2.5+2.5) % SiC+Al_2O_3	8.0	7.8	7.6	7.7	7.8	38.9	7.78
11	LM6 + (5+5) % SiC+Al_2O_3	8.2	8.5	8.9	9.2	9	43.8	8.76
12	LM6 + (7.5+7.5) % SiC+Al_2O_3	8.8	9.1	9.3	9.1	9.5	45.8	9.16
13	LM6 + (10+10) % SiC+Al_2O_3	9.2	9.3	9.4	9.0	9.9	46.8	9.36

Hardness Test:

The Rockwell testing machine usefor hardness measurement. The surface beingtested generally requires a metallographic finish and it was done with the help of 100, 220,400, 600 and 1000 grit size emery paper. Load used on Rockwell's hardness tester was 200grams at dwell time 20seconds for each sample. The result of Rockwell's hardness test forsimple alloy without reinforcement (Sample No.1) and the wt.% variation of differentreinforcements such as SiC/ Al_2O_3 and Al alloy LM6 (Sample No. 2-13) are shown in following Table

Sample No	Sample Name	Hardness Rockwell Hardness				Mean Hardness
	LM 6 +	Trial 1	Trial 2	Trial 3	Trial 4	
1	Pure	53.7	52.7	54.5	51.9	53.2
2	2.5 % SiC	56.7	59.5	56.1	60.1	58.1
3	5 % SiC	50	48	53	51	51.0
4	7.5 % SiC	86.3	89.3	85.8	89.8	87.8
5	10 % SiC	91.2	90.7	91.7	91.3	91.2
6	2.5 % Al_2O_3	76.5	74.3	75.2	75.6	75.4
7	5 % Al_2O_3	85.2	83.2	86.6	86.6	85.4
8	7.5 % Al_2O_3	89.9	89.4	91.6	87.6	89.6
9	10 % Al_2O_3	91.6	98.8	92.5	101.3	95.8
10	2.5 + 2.5 % T	69.8	69.8	71.5	67.1	69.2
11	5 + 5 % T	85.9	85.6	85.4	85.8	85.6
12	7.5 + 7.5 % T	107.2	106.1	109.4	110.5	108.2
13	10 + 10 % T	119.0	122.0	118.0	121.0	120.0

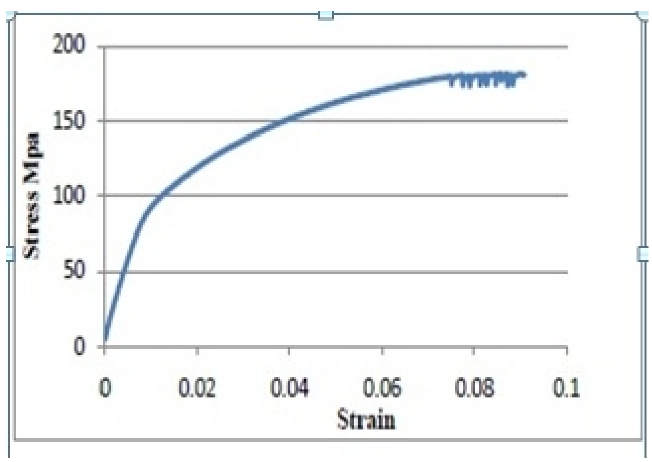
Tensile Strength Test:

Tensile tests were used to assess the mechanical behavior of the composites and matrix alloy. The composite and matrix alloy rods were machined to tensile specimens with a diameter of6mm and gauge length of 30 mm. Ultimate tensile strength (UTS), often shortened to tensilestrength (TS) or ultimate strength, is the maximum stress that a material can withstand whilebeing stretched or pulled before necking, which is when the specimen's cross-section starts tosignificantly contract.

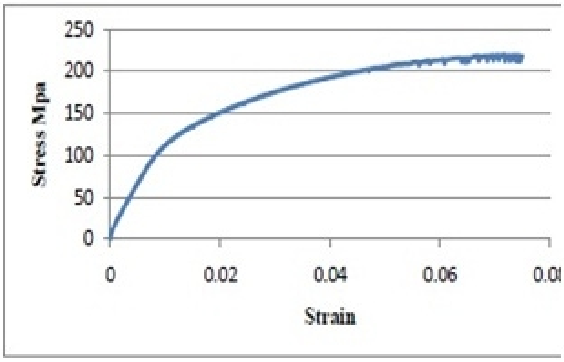
Alloy (LM6)	Yield Strength N/mm^2	UTS N/mm^2	Elongation (%)
Pure	65	180	9
2.5% SiC	78	220	7.5
5% SiC	85	245	5.5
7.5% SiC	112	250	3.2
10% SiC	150	310	2.1
2.5 % Al_2O_3	75	190	8.1
5 % Al_2O_3	88	201	6.5
7.5 % Al_2O_3	105	250	3.9
10 % Al_2O_3	140	290	2.8
2. 5% SiC + 2.5 % Al_2O_3	100	240	6.8
5% SiC + 5 % Al_2O_3	170	270	4.5
7. 5% SiC + 7.5 % Al_2O_3	190	320	3.1
10 % SiC + 10 % Al_2O_3	220	370	1.4

Stress vs. Strain Curves:

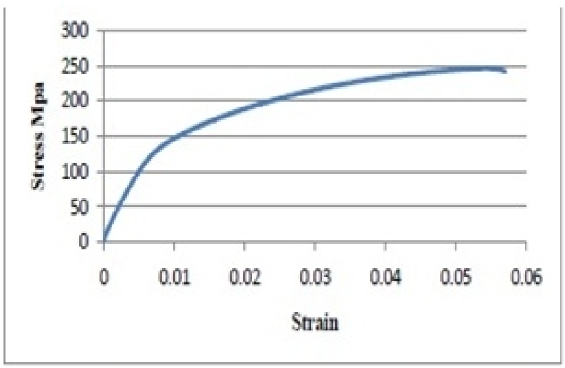
I. Stress vs. Strain Curves for Pure LM 6 Alloys



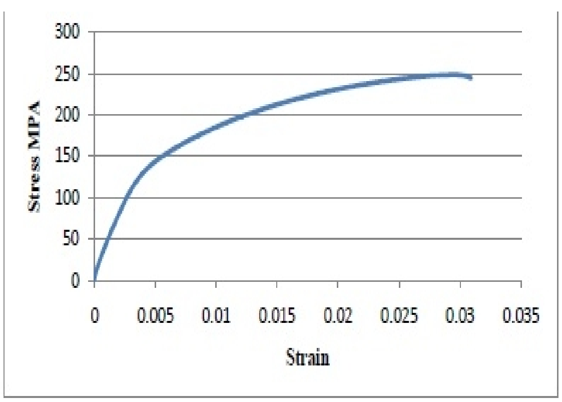
II. Stress vs. Strain Curves for LM 6 Alloys with 2.5% SiC



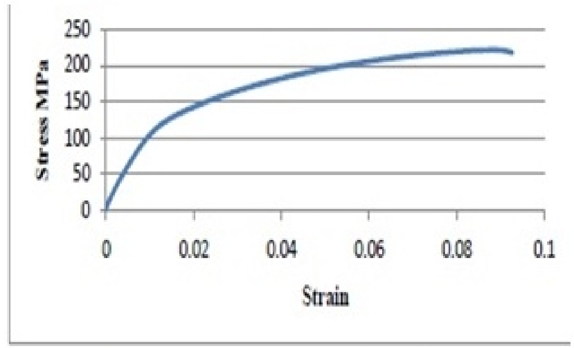
III. Stress vs. Strain Curves for LM 6 Alloys with 5% SiC



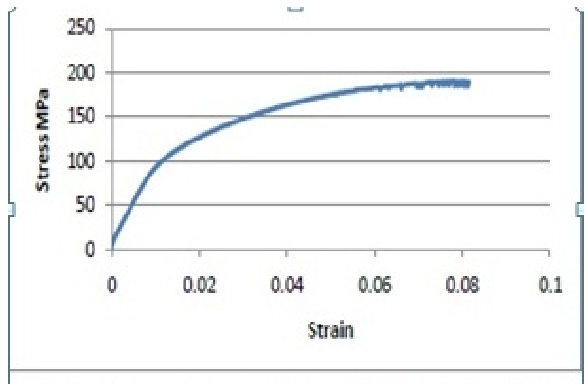
IV. Stress vs. Strain Curves for LM 6 Alloys with 7.5% SiC



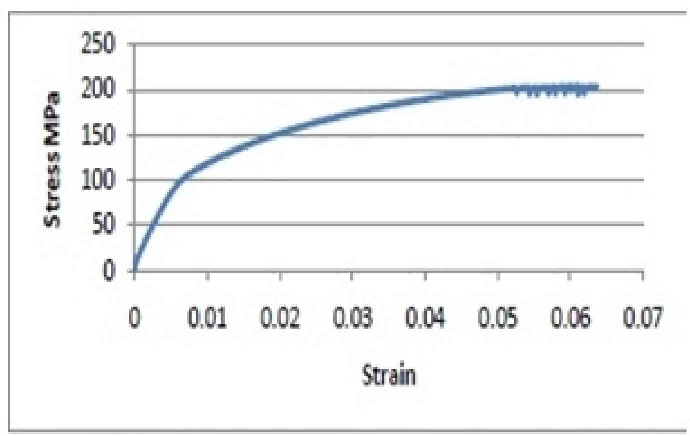
V. Stress vs. Strain Curves for LM 6 Alloys with 10% SiC



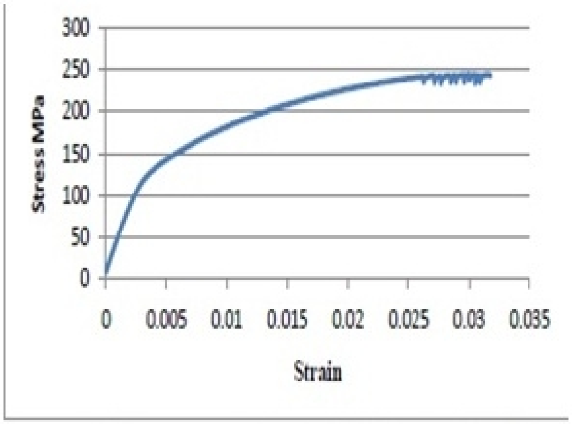
VI. Stress vs. Strain Curves for LM 6 Alloy with 2.5% Al_2O_3



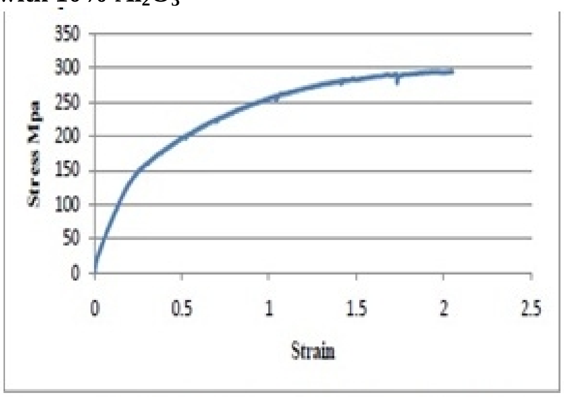
VII. Stress vs. Strain Curves for LM 6 Alloy with 5% Al_2O_3



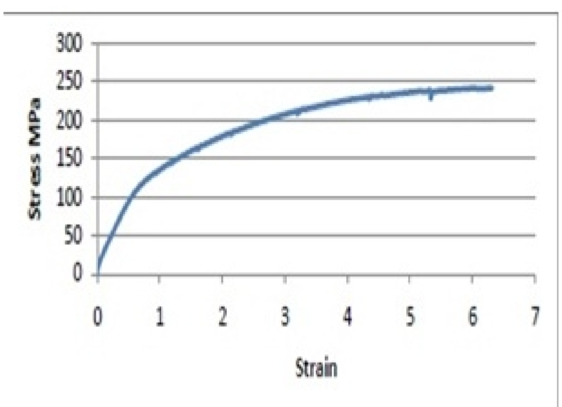
VIII. Stress vs. Strain Curves for LM 6 Alloy with 7.5% Al_2O_3



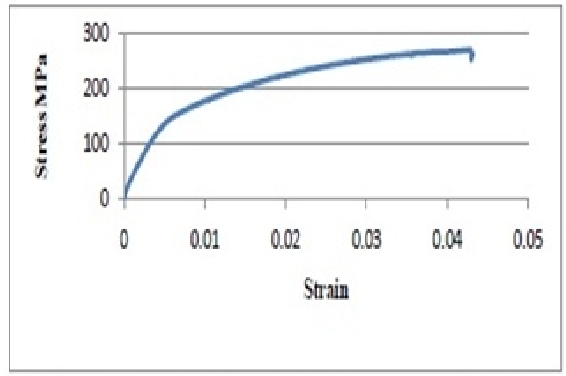
IX. Stress vs. Strain Curves for LM 6 Alloy with 10% Al_2O_3



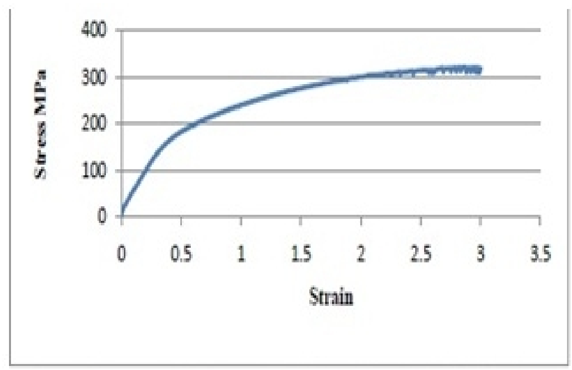
X. Stress vs. Strain Curves for LM 6 Alloy with 5% T (SiC & Al_2O_3)



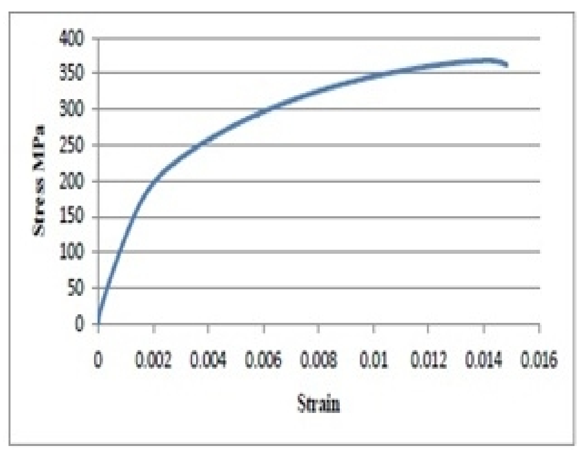
XI. Stress vs. Strain Curves for LM 6 Alloy with 10% (SiC & Al_2O_3)



XII. Stress vs. Strain Curves for LM 6 Alloy with 15% T (SiC & Al_2O_3)



XIII. Stress vs. Strain Curves for LM 6 Alloy with 20%T (SiC & Al_2O_3)



I.

It exhibits a very linear stress–strain relationship up to a well-defined yield point. The linearportion of the curve is the elastic region and the slope is the modulus of elasticity or Young'sModulus. As deformation continues, the stress increases on account of strain hardening untilit reaches the ultimate strength. Until this point, the cross-sectional area decreases uniformlybecause of Poisson contractions. The actual rupture point is in the same vertical line as thevisual rupture point. The work hardening rate increases with increasing volume fraction ofreinforcement (and decreasing matrix volume). The lower ductility can be attributed to theearlier onset of void nucleation with increasing amount of reinforcement.

IV. CONCLUSIONS

The conclusions drawn from the present investigation are as follows:

1. The results confirmed that stir formed Al alloy LM6 with SiC/Al_2O_3 reinforcedcomposites is clearly superior to base Al alloy LM 6 in the comparison of tensilestrength, Impact strength as well as Hardness.
2. Dispersion of SiC/ Al_2O_3 particles in aluminum matrix improves the hardness of thematrix material
3. It is found that elongation tends to decrease with increasing particles wt. percentage,which confirms that silicon carbide and alumina addition increases brittleness.
4. Aluminum matrix composites have been successfully fabricated by stir castingtechnique with fairly uniform distribution of SiC & Al_2O_3 particles
5. It appears from this study that UTS and Yield strength trend starts increases withincrease in weight percentage of SiC and Al_2O_3 in the matrix.
6. The Hardness increases after addition of SiC, Al_2O_3 particles in the matrix.
7. Impact strength is increase by adding SiC & Al_2O_3.

8.Stir casting process, stirrer design and position, stirring speed and time, particlepreheating temperature, particle incorporation rate etc. are the important processparameters.

REFERENCES

[1]. Chawla et al, "Tensile and fatigue fracture of Discontinuously Reinforced Aluminum, *Advances in Fracture Research*, (2001), pp. 1-6.

[2]. Manoj Singla, "Development of Aluminum Based Silicon Carbide Particulate MetalMatrix Composite", *Journal of Minerals & Materials Characterization & Engineering*, **8**(.6), pp-455-467, 2009.

[3] I.A. Ibrahim"Particulate reinforced metal matrix composites - a review", *Journal of materials science*, **26** (1991) 1137-1156.

[4] S. Balasivanandha Prabu, "Influence of stirring speed and stirring time on distributionof particles in cast metal matrix composite", *Journal of Materials Processing Technology* **171** (2006) 268–273.

[5] M. Kok, "Production and mechanical properties of Al2O3 particle-reinforced 2024aluminum alloy composites", *Journal of Materials Processing Technology* **161** (2005) 381–387.

[6] G.B. Veeresh Kumar, "Studies on Al6061-SiC and Al7075- Al_2O_3 Metal Matrix Composites", *Journal of Minerals & Materials Characterization & Engineering*, 9(1), pp.43-55, 2010.