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Study of Impact Strenght, Hardnedss and Tensile Strenght of Lm6 Aluminum Alloy Metal Matrix Composites Reinforced with Silicon Carbide and Aluminum Oxide

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***Abstract* – Aluminium metal matrix composites will be very helpful in the fabrication or manufacturing of the lightweight spare parts or components of the automotive vehicle as aluminium metal matrix composites have high specific mechanical attributes and low density. In the present manuscript,LM6 Aluminium alloy has been reinforced with varied weight proportion of silicon carbide and alumina oxide. The aluminium material matrix composites has been synthesised via two step stir casting method. Investigation has been done with regards to the mechanical properties such as Impact Strength, Hardness and Tensile Strength.**

***Keywords*- Metal Matrix Composites, Two Step Stir Casting, LM6/SiC, LM6/AL_2O_3, LM6/SiC/Al_2O_3,.**

I. INTRODUCTION

Nowadays, fuel economy is the main aspire of the automotive industry and which can be accomplish by means of reduction in the weight of the components of automotive vehicles and improvement in efficiency of the engine. Improvement in the efficiency of the engine and reduction in the weight of the components can be achieved by employing the aluminium alloys in the frame or body components and in spare parts of engines. By all odds, the use of the aluminium and magnesium castings in automotive industry will be helpful in the design and production of more fuel efficient cars. Aluminium metal matrix composites has 67% low density and three times more thermal conductivity in comparison with other material. Aluminium metal matrix composites have very good strength and wear resistance which is equal to strength and wear resistance of the cast iron. [1]

1. Reason for Revolution of Aluminium in Industry [2]

a) By virtue of last five year of trend of the using up of aluminium has been increased so the global aluminium market may be foreseen the growth rate of 5.9 percent annually.
b) The fuel economy is the main aspire of the automotive industry and which can be attained by improvement in efficiency of the engine and reduction in the weight of the components. Improvement in the efficiency of the engine and reduction in the weight of the components can be achieved by employing the aluminium alloys in the frame or body components and in spare parts of engines.
c) Nowadays, aluminium has a number of applications in the emerging sector and, solar system, electronics, and telecommunications also.
d) Aluminium has competence of recyclability, so the aluminium is becoming a more famous or prominent material.
e) Aluminium has convincing quality as a construction material, and today over 20 percent of aluminium use up in the building and construction industry.

2. Why Industry Moves to Aluminium [2]

There are firm reasons behind the change-over of industry in to the favour of the aluminium alloys reason of aluminium's increased scope in industry as detailed in table I as under:

Table I:
Reason of aluminium's increased scope [2]

Benefits	Drawback
Light Weight	Higher Cost
Recyclability	Inherent Strength
Flexibility	
Malleability	
Corrosion Resistance	
Environmental Impact	

3. Aluminium Use Increased in the Automotive Industry [2]

The using up of aluminium has been increased in the automotive industry in area of the automotive manufacturing and aviation industry.

By reason of the manufacturer can reduce the weight of component without affecting the durability of product by use up the aluminium alloys in the production of the components, which is very helpful for automotive manufacturers in the designing and production of the light weight component.

4. Application of Aluminium in Construction [2]

Aluminium using up also has been drastically increased from last few years. The reason of increase in the application of aluminium in the building and construction due the following advantages as under: [2]

1) Reduction in maintenance cost.
2) Durability.
3) Environmental benefits.
4) The main advantage is light strength to weight ratio, sustainability, recyclability and versatility.
5) Corrosion resistance.

5. Use of Aluminium in Emerging Industries [2]

The demand for the aluminium has been augmented in emerging industry such as telecommunication, oil and gas drilling, transportation, solar energy, electronics due to the following reason as under:

1) Low density.
2) Conductive properties.
3) High corrosion resistance.

6. Good for Environment [2]

By reason of aluminium can be recycle very easily so it is favourable for the environment**.** Oak ridge national laboratory (ORNL) has been studied with regard to emission impact and revealed that the aluminium constituted vehicles performed better than in comparison with steel constituted vehicles because there is less emission impact has been found out in the aluminium constituted vehicles in comparison with steel or iron constituted vehicles during their life cycle.

7. Tight Tolerances and Longevity [2]

By reason of aluminium have better capabilities of tight tolerance and longevity in the comparison with the cast iron and steel, so the automotive manufacturing industries have been changed over to aluminium from the cast iron and steel.

8. Thermal properties [2]

Thermal properties is one more feature which makes the aluminium popular in the industry, as it has thermal conductivity about 205 watts per meter Kelvin (W/(m*k)).This value is quite higher in comparison with stainless steel (thermal conductivity about 20 W/(m*k)) and other similar metals.

II. Metal Matrix Composite [3]

Metal Matrix Composite is generally contained the low density metals like aluminium or magnesium, and generally ceramic material's fibre or particulates which can be employed for reinforcement with base alloy such as silicon carbide, boron carbide ,graphite and alumina and etc. These material matrix composites have higher specific strength and stiffness in comparison with base metal or unreinforced material. Reinforced alloys can withstand higher temperature and higher wear rate much more in the comparison of unreinforced material.

III. Objectives Of Present Work

The problem is to investigate the impact strength, hardness and tensile strength of aluminium metal matrix composite of Al/SiC, Al/Al_2O_3 and a hybrid of Al/SiC/Al_2O_3.Aluminium alloy of grade LM6 has been chosen as base matrix and reinforced with silicon carbide (SiC) of mean 150 mesh size particles and Alumina (Al_2O_3) of mean 150 mesh size particles, respectively. Fabrication of samples has been done by two step stir casting technique with the following composition as under:

1) LM6: SiC (100:2,100:4,100:6 and 100:8) by weight of LM6.

2) LM6: Al_2O_3 (100:2,100:4,100:6 and100:8) by weight of LM6.

3) LM6: SiC : Al_2O_3 (100:2:2, 100:4:4, 100:6:6,100:8:8) by weight of LM6 respectively.

a) While the AA2618 alloy selected as base matrix and silicon carbide (SiC) nano particulates elected as reinforcement. The study has been prearranged with the addition of varied weight ratio proportion of silicon carbide (SiC) nano particles (such as 5%, 10%, 15%, 20%, 25% and 30% by weight of base matrix) to the base matrix alloy (AA2618) by Ede[4] and he found upturn in hardness, ultimate tensile strength, density, Young's modulus and yield strength with adding up of varied percentage of silicon carbide (SiC) reinforcement particles to base matrix.

b) Another trial has been performed by Puneeth[5] in which the author selected the A356.1 aluminium alloy selected as base matrix and silicon carbide particulates elected as reinforcement. The study has been prearranged with addition of the varied volume % of silicon carbide (SiC) particle such as 5%, 10% and 15% by weight of base matrix. The specimen has been synthesized via stir casting technique. The composites have been portraying by scanning electron microscope (SEM) and the investigation has been done with respect to the mechanical properties such as hardness, impact strength, and wear test under: different conditions.

The results reported that with addition of the varied volume % of silicon carbide (SiC) particle such as 5%, 10% and 15% into the base matrix an upturn in mechanical properties.

IV. EXPERIMENTAL PROCEDURE

A. Detail of composition of Aluminium alloy LM6 which has been used up in the present experiment in table II as under:

Table II :
Chemical Composition of Aluminium alloy LM6 [6]

Iron	0.6
Manganese	0.5 max
Nickel	0.1 max
Zinc	.01 max
Tin	.05max
Titanium	0.02
Aluminium	Remainder

B. Two step stir casting process.

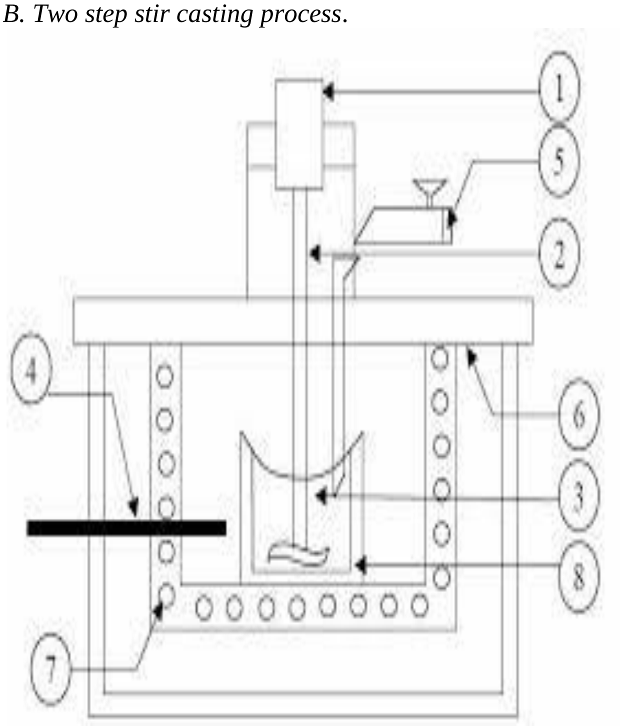

Figure 1 : Schematic view of setup of Stir Casting [7]

1. Motor
2. Shaft
3. Molten Aluminum
4. Thermocouple
5. Particle Injection Chamber
6. Insulation Hard Chamber
7. Furnace
8. Graphite crucible

Aluminium alloy thawed in a crucible by placed it in a muffle furnace at 700°C for two to three hours . For the removal of moisture content from the silicon carbide and alumina particles,both have been preheated at 950°C respectively for four hours,then the furnace temperature kept heightened above the liquids temperature of aluminum near about 700 °C to melt then allowed it to cooresulted in down completely and than kept the temperature at 630 °C to form the semi-solid state of slurry and then the preheated SiC particles and Al_2O_3 particles added into the base matrix.The smelted aluminum alloy slurry has been striired with help of radial drill machine at speed of 300 rpm for 10 minutes and then semi-solid state of slurry has reheated at temprature of 700 °C to again form the smelted aluminum alloy slurry . In the second step of stirrering has been empoyed in liquid state for the five minutes. Two-step stirring techniques facilitate the better wettabilty.

C. Input Parameters

The quantity of base matrix and reinforcement material which has been employed in present study for the fabrications of samples of aluminum material matrix composites of Al/SiC, Al/Al_2O_3 and a hybrid of $Al/SiC/Al_2O_3$ has mentioned in detailed in the table III.

Table IV :
Composition of Samples

Sample No.	Aluminium(LM6) (gm)	SiC (gm)	Al_2O_3 (gm)	Remarks
1	1500	-	-	Weight of sample=1500 gm
2	1500	30	-	SiC= 2 % of LM6
3	1500	60		SiC= 4 % of LM6
4	1500	90	-	SiC= 6 % of LM6
5	1500	120	-	SiC= 8 % of LM6
6	1500	-	30	Al_2O_3= 2% of LM6
7	1500	-	60	Al_2O_3= 4% of LM6
8	1500	-	90	Al_2O_3= 6% of LM6
9	1500	-	120	Al_2O_3= 8% of LM6
10	1500	30	30	SiC+Al_2O_3= 2% + 2% of LM6
11	1500	60	60	SiC+Al_2O_3= 4% + 4% of LM6
12	1500	90	90	SiC+Al_2O_3= 6% + 6% of LM6
13	1500	120	120	SiC+Al_2O_3= 8% + 8% of LM6

V. Result And Disscussion

A. Impact Test [8]

This type of test is a standardized high strain energy test which has been used to examine the energy absorbed by the specimen's material amid the fracture**.**This test is generally known charpy impact test.

The measurement of energy to be absorbed through the specimen v-notch toughness,genearlly use to the tset the vessles and bridges In the current study, the specimen has been manufacatured according to ASTM E23 specification as shown in the figure no.2 and the result detailed in tableIV.

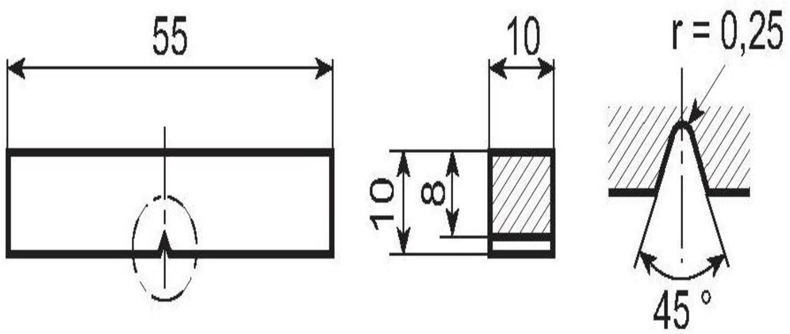

Figure 2 : Charpy (Simple-Beam) Impact Test Specimen as per ASTM E23[9]

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Table V :
Results of Impact Test

Sample No.	Sample Name	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Mean(J)
1	LM 6	5.9	5.7	5.7	5.9	5.9	5.8
2	2 % SiC	6.5	6.6	6.4	6.2	6.3	6.4
3	4% SiC	7.4	7.1	6.9	7.3	7.1	7.1
4	6% SiC	7.9	7.5	7.4	7.3	7.2	7.6
5	8% SiC	7.9	8.2	8.5	8.6	7.9	8.2
6	2% Al_2O_3	6	5.8	5.9	5.7	6.1	6
7	4% Al_2O_3	6	6.4	6.4	5.9	6.3	6.3
8	6 % Al_2O_3	6.5	6.6	6.6	6.7	6.4	6.5
9	8%Al_2O_3	6.6	6.9	6.8	6.6	6.9	6.8
10	2SiC+2%Al_2O_3	7.3	7.1	7.2	7.3	7.4	7.3
11	4% SiC+4 Al_2O_3	7.7	7.5	7.9	8.1	8.3	7.9
12	6%SiC+6%Al_2O_3	8.2	8.1	8.4	8.3	8.6	8.3
13	8%SiC+8%Al_2O_3	8.5	8.6	8.9	8.8	8.7	8.7

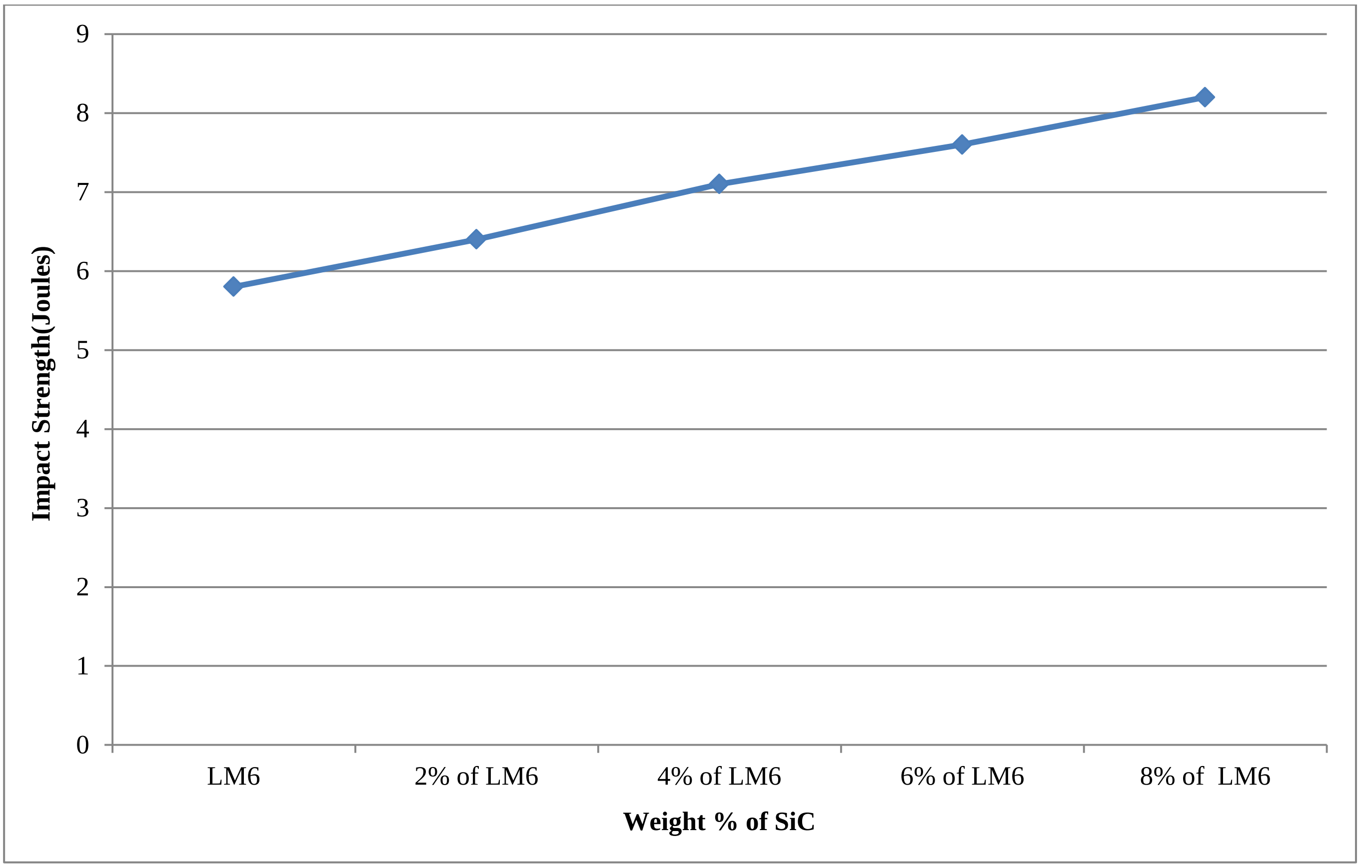

Figure 3 : Comparison of Impact Strength with weight % variation of SiC

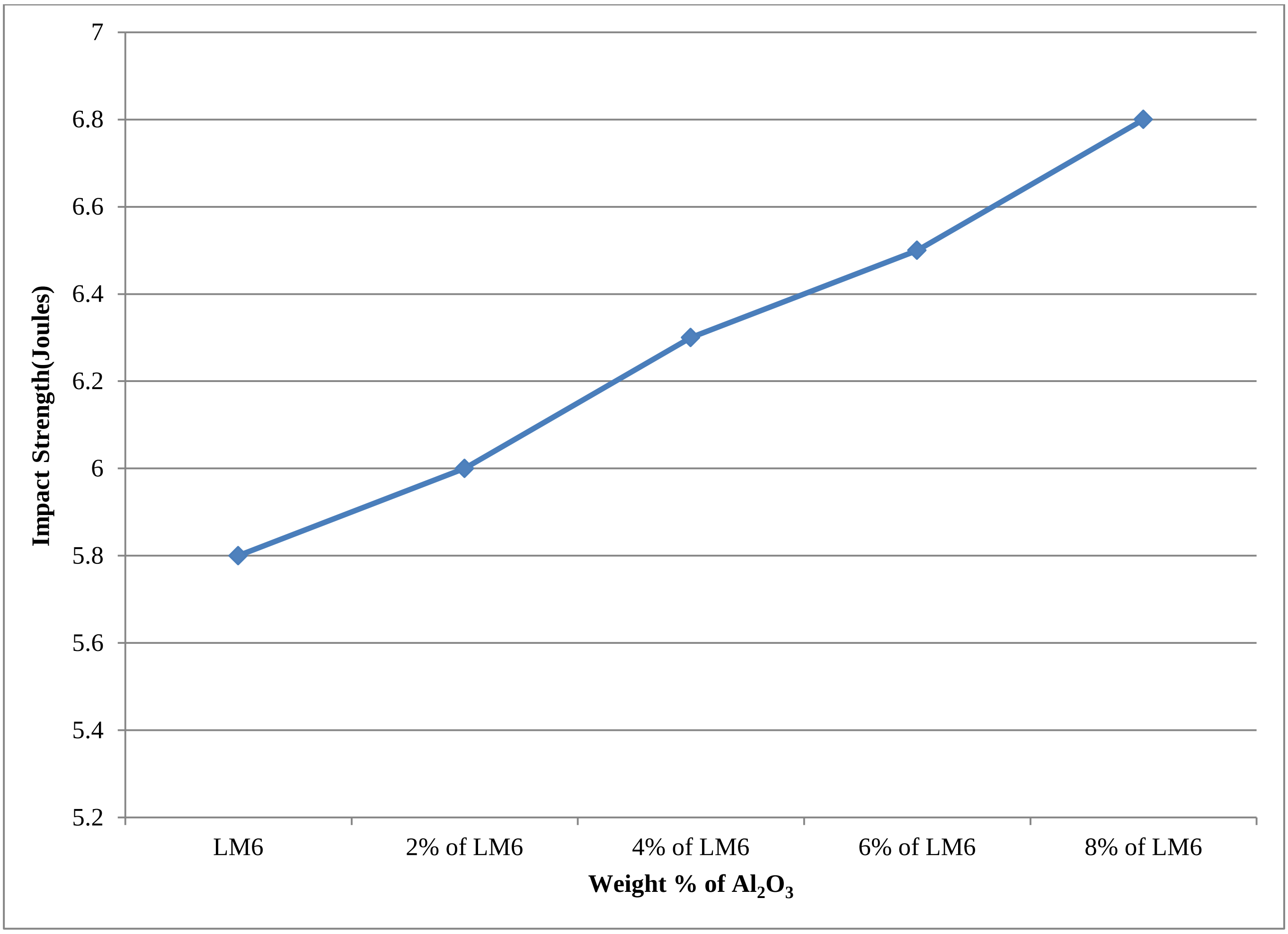

Figure 4 : Comparison of Impact Strength with weight % variation of Al_2O_3

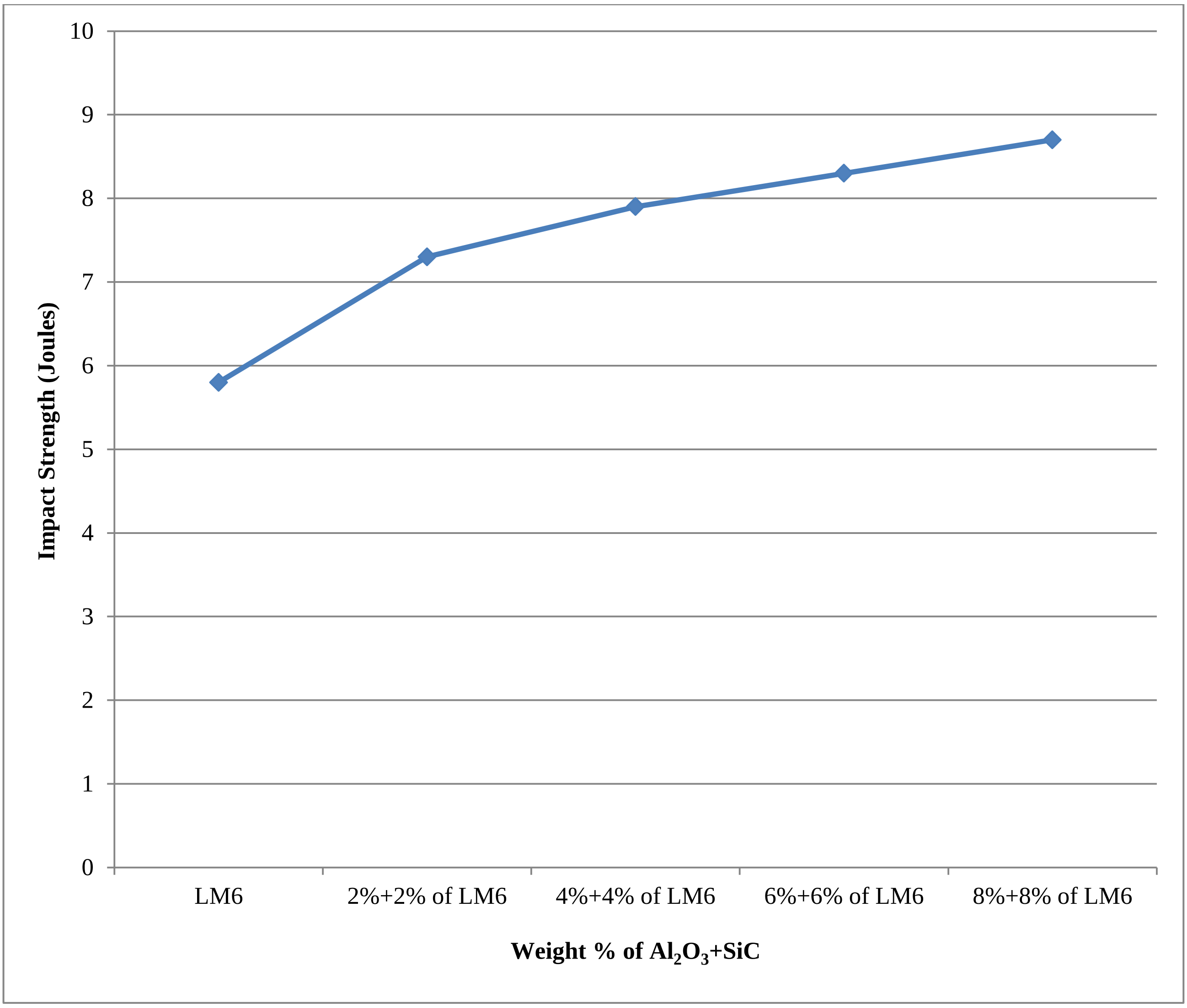

Figure 5 : Comparison of Impact Strength with weight % variation of Al_2O_3+SiC

From figure no.3 to5, it is clear that the impact strength has been got an upturn in comparison with base metal with the adding up of varied weight % of SiC and Al_2O_3 content into the base matrix because of the dissemination of reinforced material's particles into base matrix and by hindering the action of the dislocation.

B. Brinell Hardness Test [8]

It is a resistance of the material against the penetration or abrasion beneath the locally enforced load. Whenever we scratch a CD with the nail of the finger or file our nail with the help of the nail file, hardness always comes into play. Hardness applied to check the following resistance generally as under:

1) Scratching
2) Cutting
3) Indenting

Brinell hardness test specification and procedure comes under: the ASTM E10, according to Binrell hardness test, a load apply through a steel ball with a 10-millimeter diameter for the duration of a definite period of the time as per under:

Time to be Applied (sec)- 30 sec

Applied Load - 500 kg

The specimen requires a pre-condition of a metallographic finish which has been obtained by use up the 100,220,400,600 and 1000 grit size emery paper. Binrell hardness test results have been detailed in the tableV.

Table VI
Results of Hardness Test

Sr. No.	Sample Name	Trial 1 (BHN)	Trial 2 (BHN)	Trial 3 (BHN)	Trial 4 (BHN)	Trial 5 (BHN)	Mean (BHN)
1	LM 6	51.7	52.4	51.9	51.8	52.8	52.1
2	2 % SiC of LM6	53.4	54.6	55.4	53.8	55.3	54.5
3	4% SiC of LM6	60.4	58.1	57.9	59.3	60.1	59.5
4	6% SiC of LM6	70.9	71.5	71.4	67.3	67.2	69.5
5	8% SiC of LM6	77.9	78.2	78.5	77.6	77.9	78
6	2% Al_2O_3 of LM6	70.6	66.8	68.9	69.7	67.5	68.7
7	4% Al_2O_3 of LM6	75.6	76.1	78.2	75.9	76.3	76.4
8	6 Al_2O_3 of LM6	80.5	79.6	78.3	81.2	80.4	80
9	8%Al_2O_3 of LM6	84.6	85.9	82.8	83.6	81.5	83.6
10	25 SiC+2% Al_2O_3 of LM6	62.3	64.1	65.2	64.3	63.4	63.9
11	4% SiC+4 %$Al_2O_3$of LM6	77.7	77.5	74.9	74.51	78.3	76.6
12	6% SiC+6 %Al_2O_3 of LM6	88.2	88.1	89.4	91.3	90.6	89.5
13	8% SiC+8% Al_2O_3 of LM6	98.5	98.6	94.9	97.8	96.7	97.3

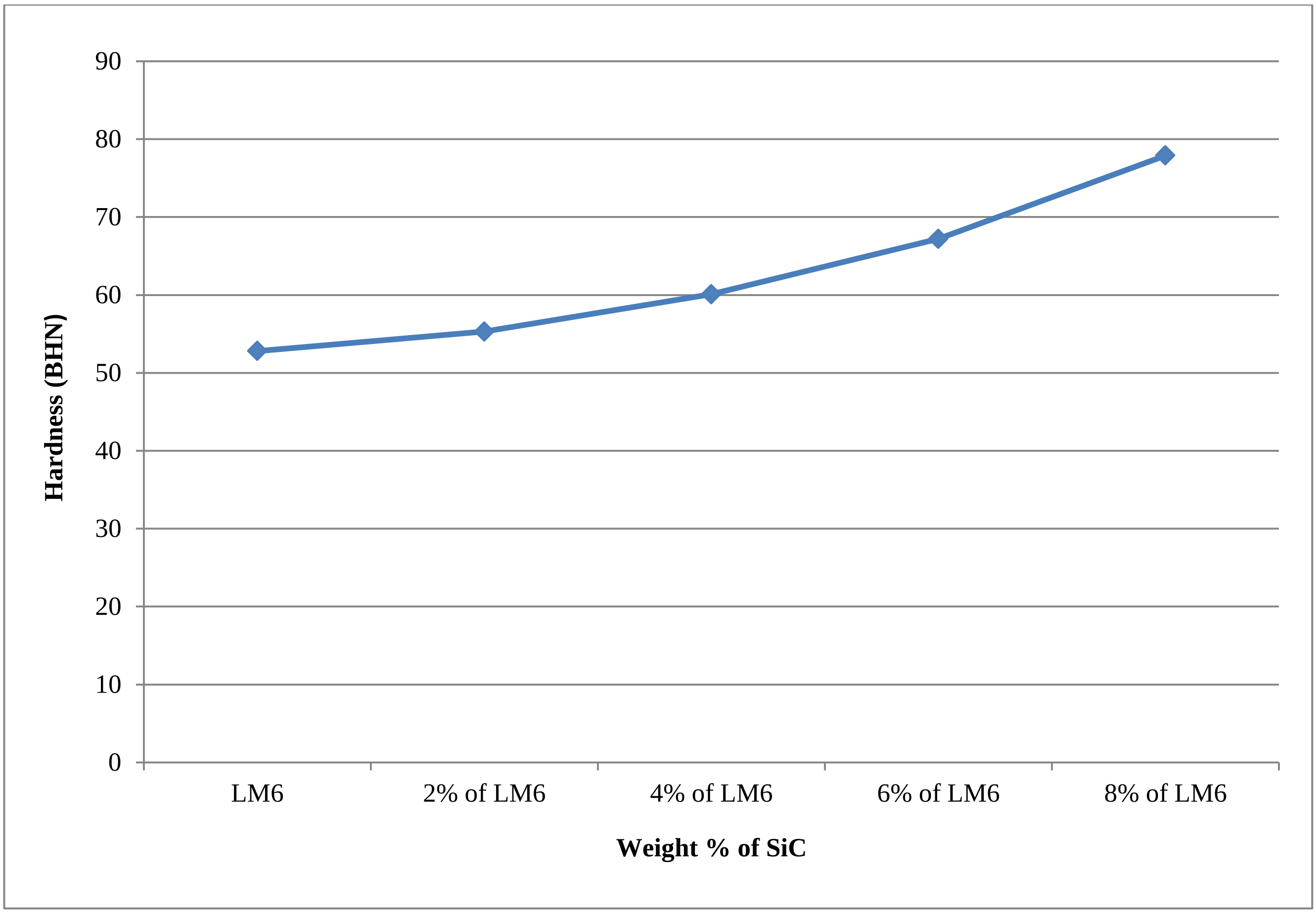

Figure 6 : Comparison of Hardness with weight % variation of SiC

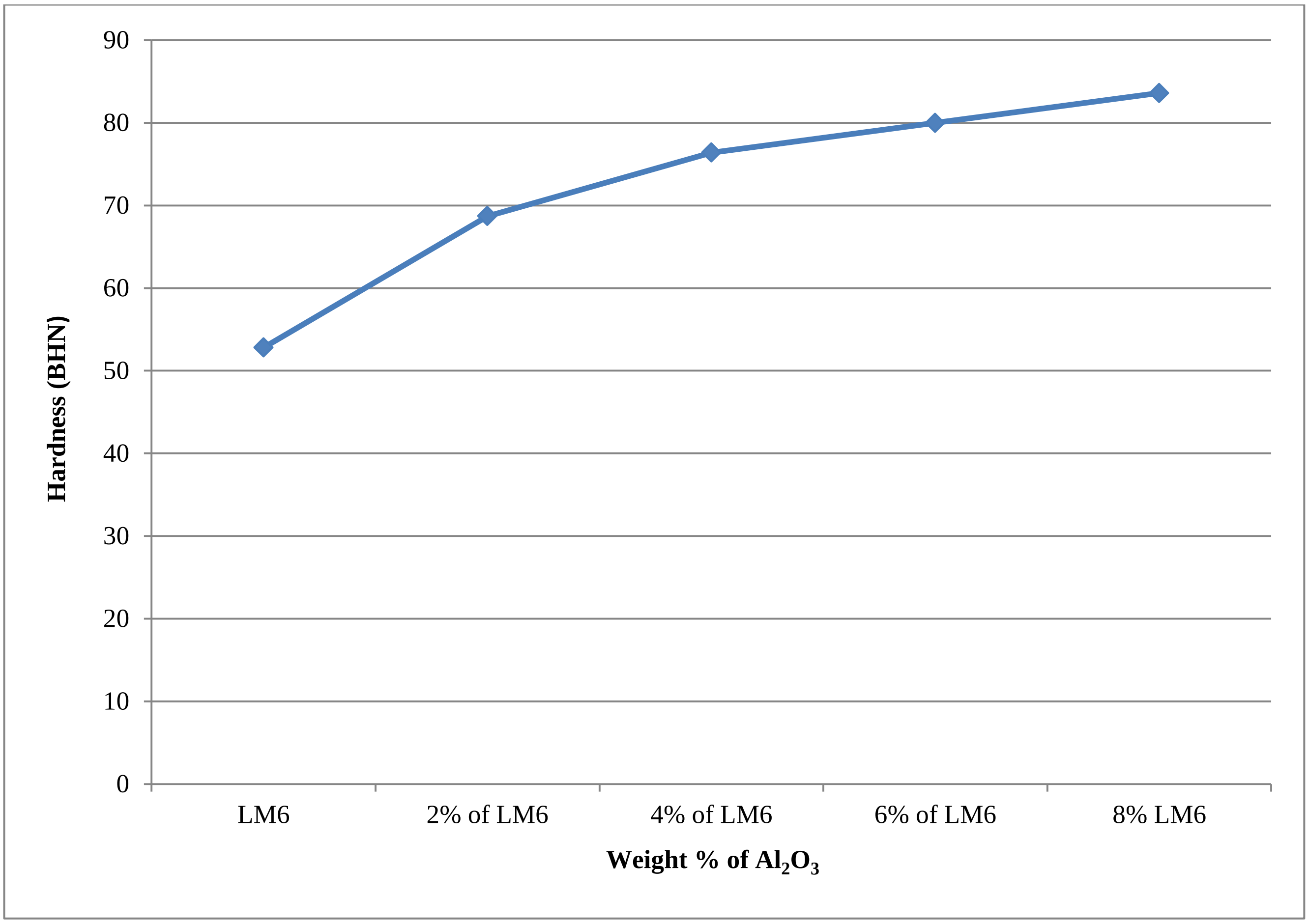

Figure 7: Comparison of Hardness with weight % variation of Al_2O_3

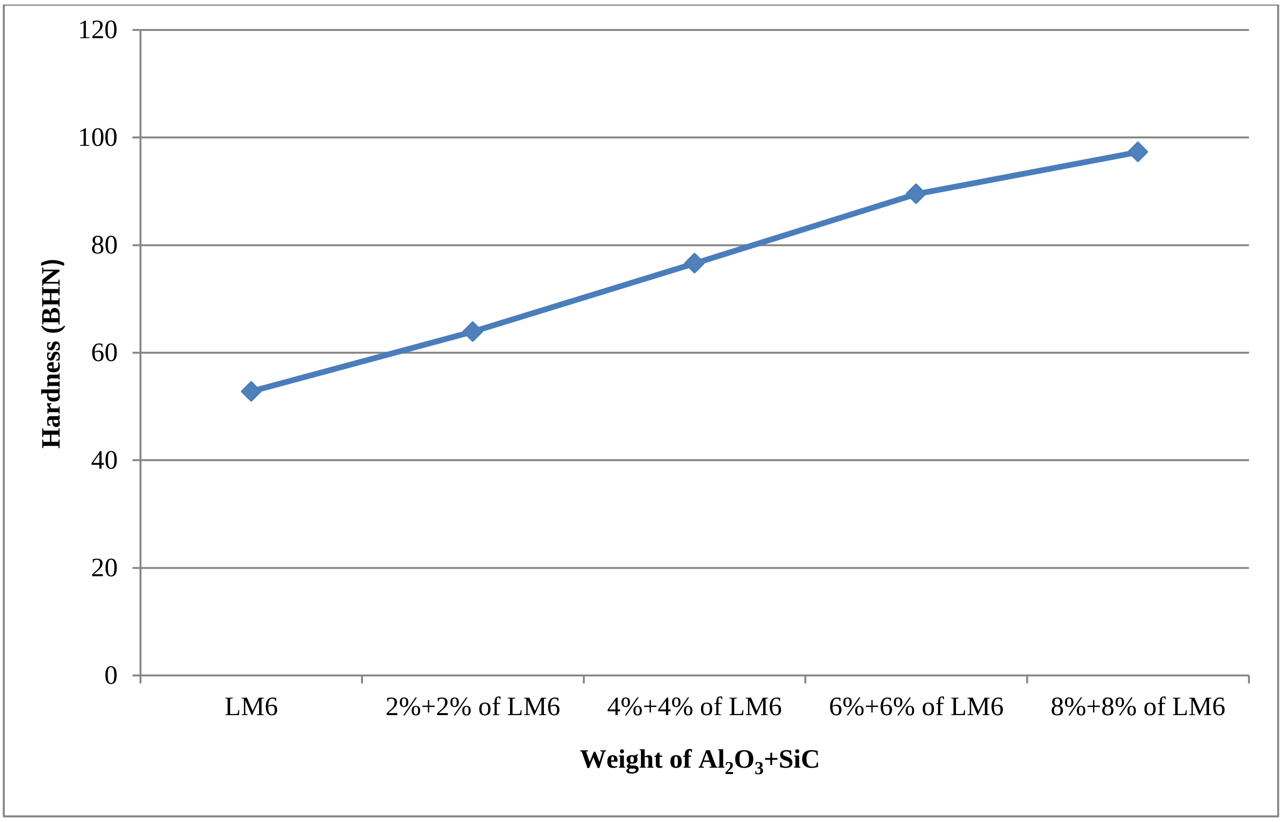

Figure 8 : Comparison of Hardness with weight % variation of Al_2O_3+SiC

It is clear from figure 6 to 8 that the hardness has been got an upturn in comparison with base metal with the adding up of varied weight % of SiC and Al_2O_3 content into the base matrix because of the dissemination of reinforced material's particles into base matrix and by hindering the action of the dislocation.

C. Tensile Strength Test [9]

It is capability of a substance to endure the load which tends to elongate In the tension testing sample is deal with to a continuously increase in the uniaxial tensile force as same time reading of the experiment get note down. The experiment may be sustained as far as the sample get break down within the two parts and this is known as test to destruction. The test is generally can be done by employing a universal testing machine that can be use for both tensile and compressive test. The sample of a substance always manufactured according to standard dimension.

In the current study or trial the tensile test has been done in the universal testing machine (UTM) and results are examined to calculate the tensile strength of composite specimen.

The dimension of the specimen has been made according to ASTM B557 M-94, (30x30x10) mm has been shown in the figure 9: Tensile specimen as per ASTM B557 M-94, G is gage length, W is width, T is thickness, R is radius of fillet, L is overall length, A is length of reduced section, B is length of grip section and C is width of grip section. It is also known as the standard test methods of tension testing wrought and cast aluminium- and magnesium-alloy products.[10]

Common points of activity when testing a material consist of: ultimate tensile strength or peak stress; offset yield strength which can perform at a point just above the onset of permanent deformation; and the rupture or fracture point where the specimen split into pieces. Tensile test results have been detailed in the table VI.

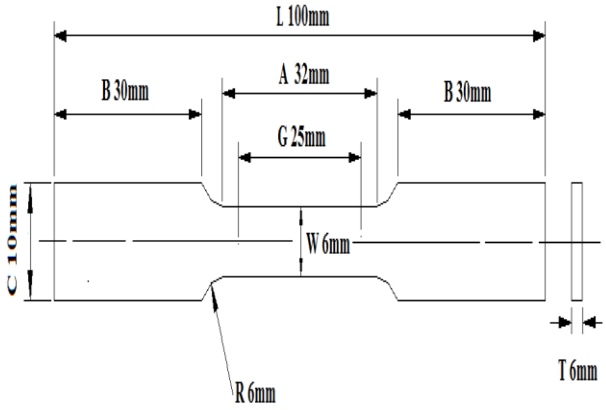

Figure 9 : Tensile Specimen as ASTM B557 M-94[10]

Table VII :
Results of Tensile Strength Test

Sr. No.	Sample Name	Yield strength (N/mm^2)	Ultimate strength (N/mm^2)	Elongation (%)
1	LM6	62	165	7.4
2	2 % SiC of LM6	69	185	6.8
3	4% SiC of LM6	77	205	5.2
4	6% SiC of LM6	92	225	2.5
5	8% SiC of LM6	122	275	1.7
6	2% Al_2O_3 of LM6	62	160	6.8
7	4% Al_2O_3 of LM6	73	178	5.2
8	6 Al_2O_3 of LM6	86	220	2.4
9	8%Al_2O_3 of LM6	110	266	1.7
10	2 SiC+2%Al_2O_3 of LM6	80	204	5.5
11	4%SiC+4%$Al_2O_3$of LM6	106	282	3.1
12	6%SiC+6%Al_2O_3 of LM6	130	302	1.8
13	8%SiC+8%Al_2O_3 of LM6	156	351	1.3

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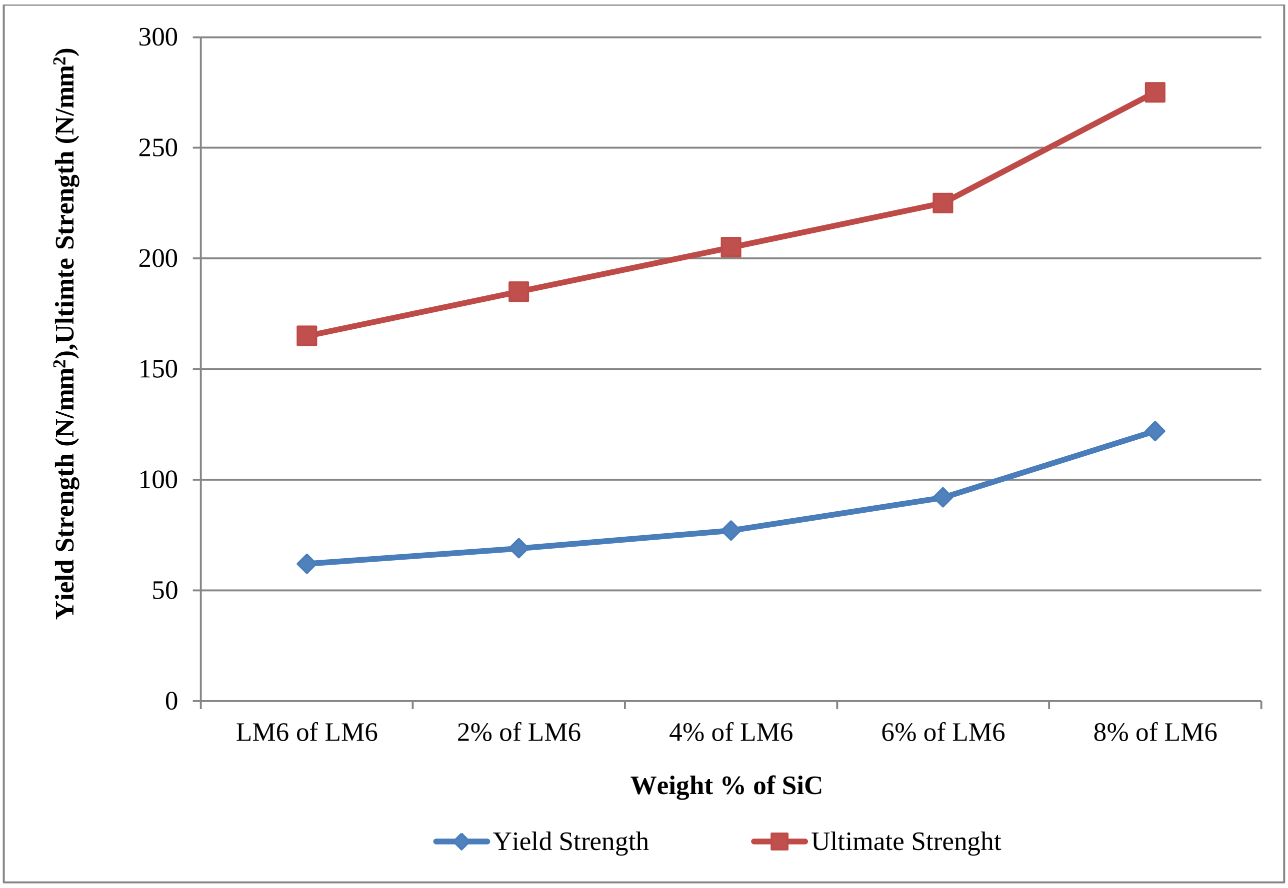

Figure 10 : Comparison of Tensile Strength with weight % variation of SiC

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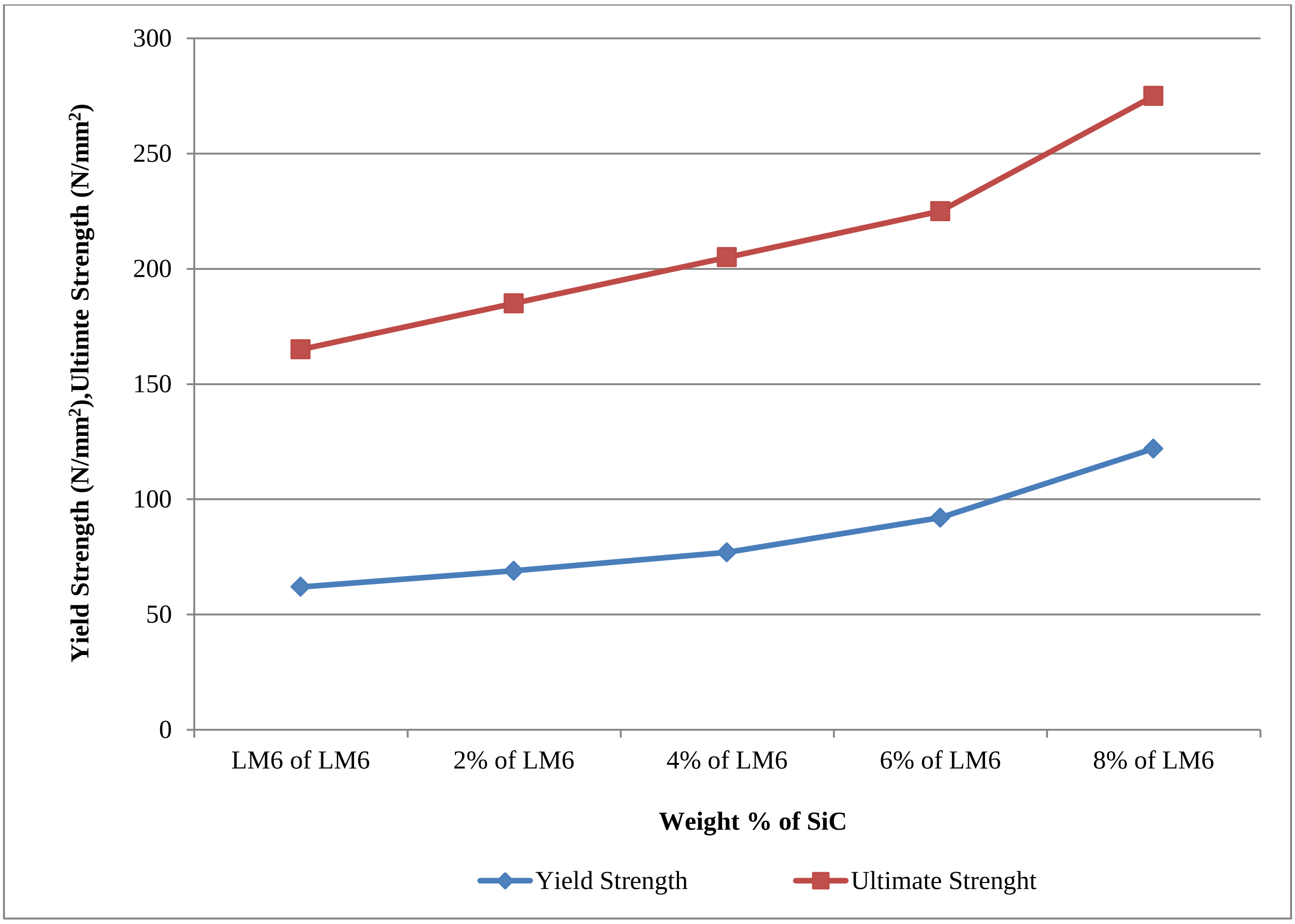

Figure 11: Comparison of Tensile Strength with weight % variation of Al_2O_3

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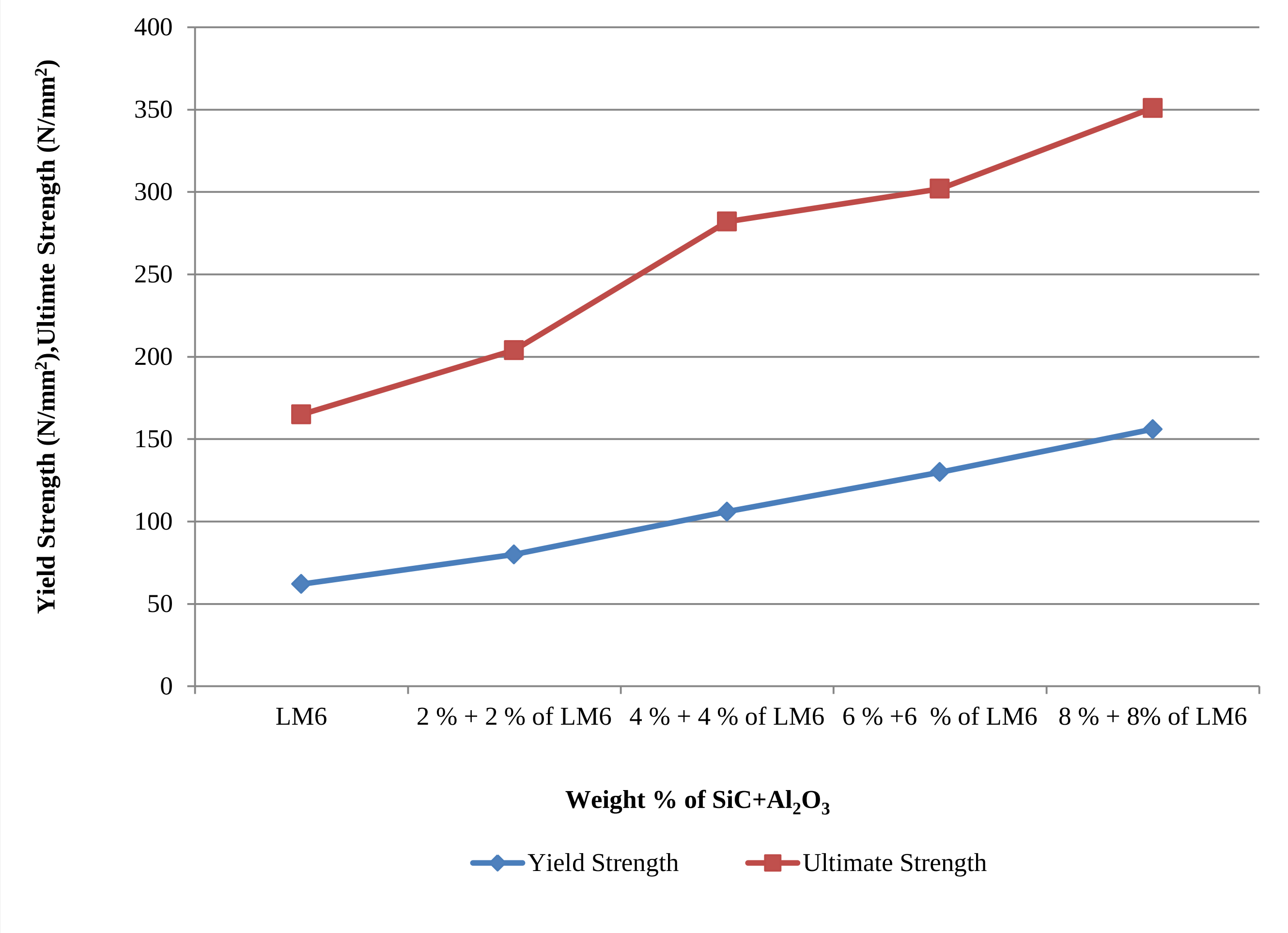

Figure 12: Comparison of Tensile Strength with weight % variation of $SiC+Al_2O_3$

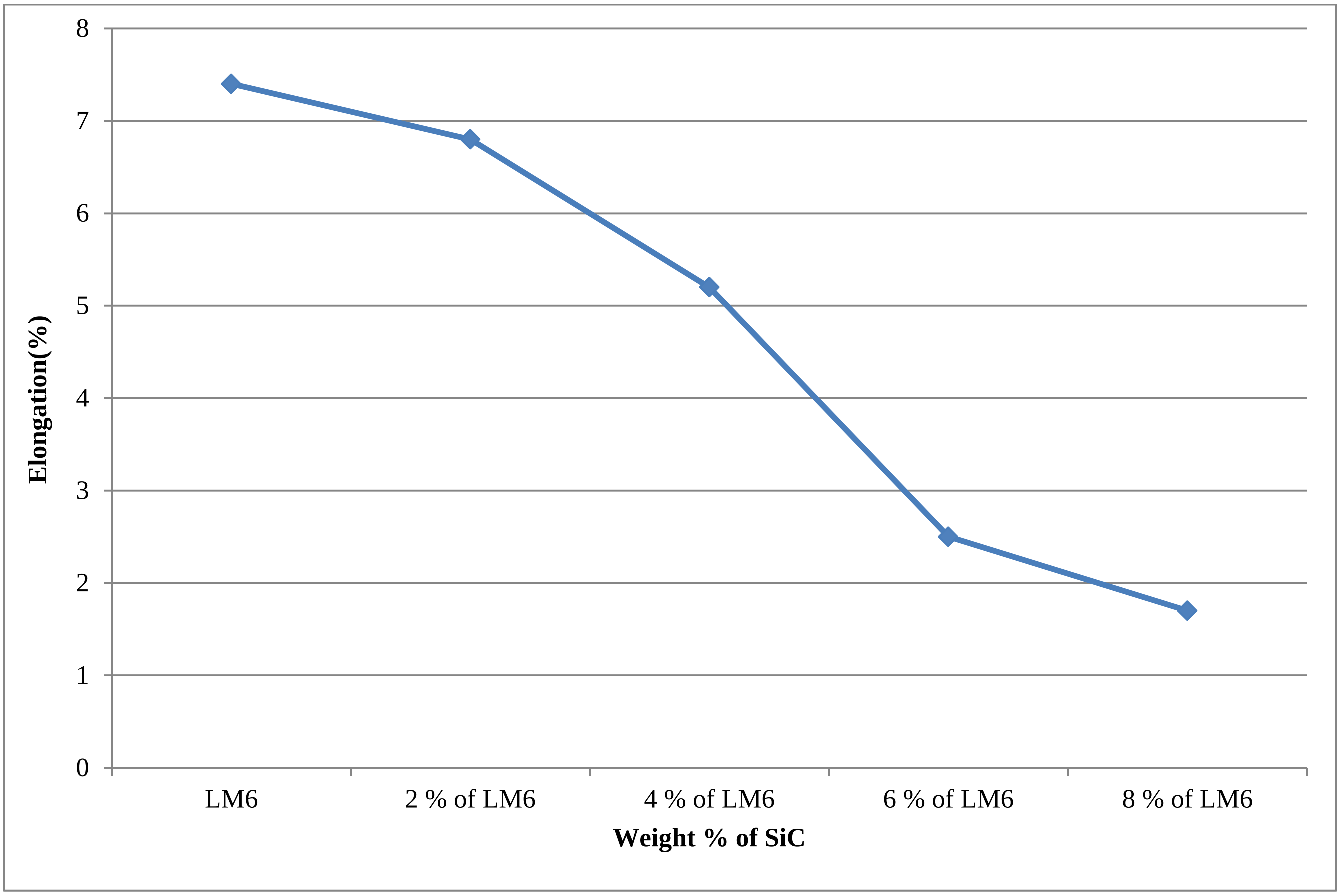

Figure 13 : Comparison of Elongation % with weight % variation of SiC

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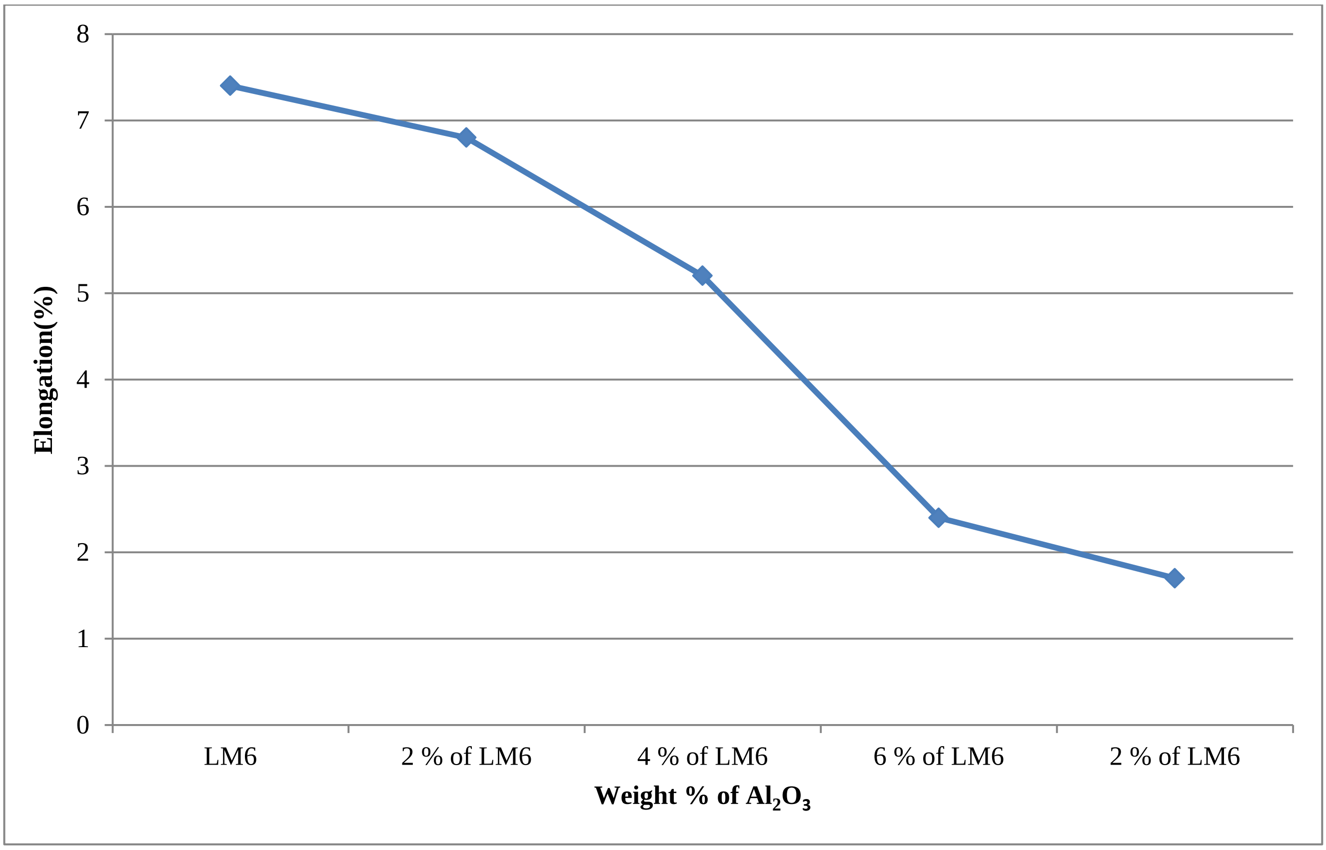

Figure 14 : Comparison of Elongation % with weight % variation of Al_2O_3

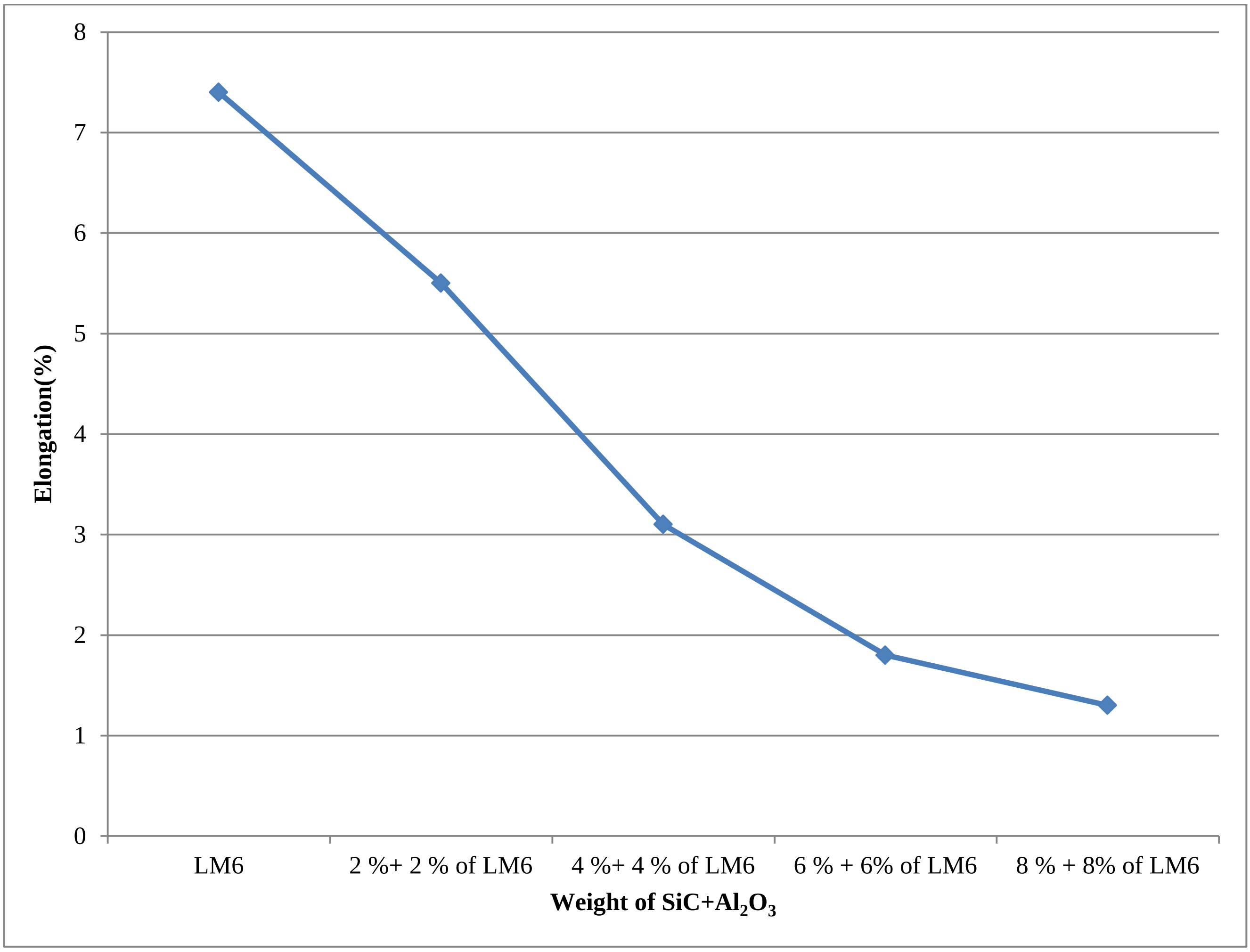

Figure 15 : Comparison of Elongation % with weight % variation of $SiC+Al_2O_3$

It has been concluded from figure no.10to12 that the ultimate strength and yield strength has been got an upturn in comparison with base metal with the adding up of varied weight % of SiC and Al_2O_3 content into the base matrix because of the dissemination of reinforced material's particles into base matrix and by hindering the action of the dislocation. It has been concluded from figure no.13 to 15 that the elongation % has been declined as the brittleness has been enhanced with adding up of varied the SiC and Al_2O_3 into to base matrix.

VI. CONCLUSIONS

The conclusion has been found out from the current exploration are detailed as under:

1. The consequence revealed that aluminium material matrix composites of aluminium alloy LM6 and SiC/Al_2O_3 is obviously better to base Al alloy LM 6 in the comparison of tensile strength, impact strength as well as hardness.
2. It is revealed that elongation percentage have a tendency to dwindle with adding up the particles weight percentage of the reinforcement material (such as silicon carbide and alumina), which corroborate that silicon carbide and alumina addition to the base matrix enhance brittleness.
3. It revealed from the investigation that mechanical properties such as impact strength, hardness, tensile strength and yield strength have an upturn with addition of the weight percentage of SiC and Al_2O_3 into the base matrix.

6.2 Scope of Future Work

1. Different grain size can use for improvement.
2. Variation in proportion of composition of matrix and reinforcement material.
3. By employing different fabrication process.

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