Study of Mechanical Behaviour of Silicon Carbide Reinforced Al7075 MMC

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Abstract- *Aluminium Al7075 alloy is mainly used in automobile applications of crank case, chain sprocket, and frame structures, etc. Automobile Engine's Crank case is the bottom most structure of the engine that has the purpose of energy absorption during low velocity impact. Crank case is also a structural component used to store the lubrication oil. Its failure leads to the failure of the engine. For this purpose, the improvement of its strength is important and the following work has been undertaken. In the present work, an attempt has been made to synthesize Al 7075 /SiC Aluminium metal matrix composites and to analyze the mechanical properties. Aluminium alloy (Al7075) is reinforced with SiC particles at varied compositions (0%, 4%, 8% by wt) with the stir casting machine. Along with that a constant volume (4% by wt) of copper is added. The study was carried out to understand the mechanical properties by tensile test, Hardness and Impact test and the dispersion of Silicon Carbide were found using the Optical Microscopy test.*

Keywords- Aluminium 7075, Stir casting, Silicon Carbide, Mechanical properties, Crankcase, Metal matrix composite, Copper

I. INTRODUCTION

Aluminium alloys are extensively used in engineering constructions and works where light weight or corrosion resistance is essential. Aluminium and Magnesium are the materials which are mostly used for the making of metal matrix composites due to their high reliability on manufacturing and machinability. Apart from that the aluminium is entering the major engineering applications because of its light weight. The mostly used cast aluminium alloy system is Al–Si, where the high levels of silicon (4.0–13%) contribute to give good casting characteristics. Metal matrix composites are the materials in which the addition of other metals is possible. The base metal can be reinforced with the various matrix materials in order to improve the strength and also the various other properties as per our requirement. There are also various methods for making the metal matrix composites like powder metallurgy, stir casting, squeeze casting, physical vapour deposition, chemical vapour deposition etc. Stir castingis the most economical method for manufacturing the metal matrix composites.

II. PROBLEM IDENTIFICATION

Automobile Engine's Crank case is the bottom most structure of the engine that has the purpose of energy absorption during low velocity impact. Crank case is also a structural component used to store the lubrication oil. Its failure leads to the failure of the engine. For this purpose, the improvement of its strength is important and the following work has been undertaken. In the present work, an attempt has been made to synthesize Al 7075 / SiC.It has major alloying elements Silicon, Copper, Zinc which contributes for better strength, machinability and cast ability. The chemical composition of aluminium 7075 is listed in Table 1.

Table 1 Chemical Composition of Aluminium 7075

Al	Mg	Cr	Cu	Fe	Mn	Si	Zn	Others
87.1 to 91.4 %	2.1 to 2.9 %	0.18 to 0.28 %	1.2 % to 2%	0.4 % max	0.3 % max	0.4 % max	6.1 % max	0.15 % max

III. EXPERIMENTAL WORK

In this paper, metal matrix composite is made with stir casting method at the various compositions of 0%, 4% and 8% of silicon carbide and in addition to that a constant volume of copper at 4% is added to all the compositions of Aluminium 7075.

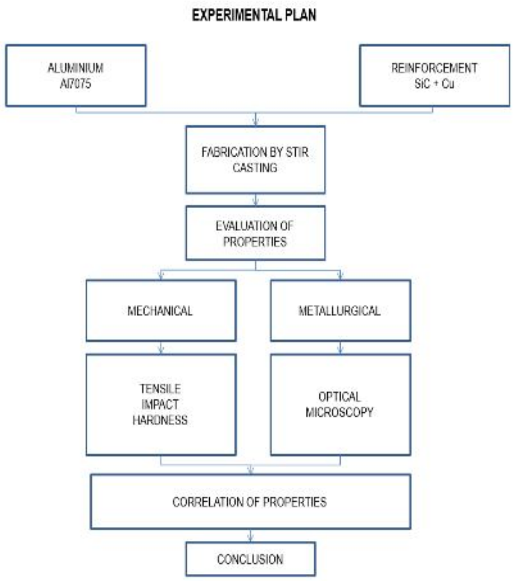


figure 1 Experimental Setup – Al7075 + sic + cu

The silicon carbide and copper are preheated in the powder form using a preheater and then mixed with molten aluminium 7075. The stirring temperature is maintained at 725 ^{o}C for around 6 minutes and poured at the same temperature.

A. COMPOSITE PREPARATION

The metal matrix composite is made with the variation in compositions as shown in the Table 2

Table 2 Composite Preparations

SAMPLE	MAGNESIUM AZ91B	COPPER	SILICON CARBIDE
1	96 %	4 %	0%
2	92 %	4 %	4%
3	88 %	4 %	8%

Following procedure was followed after the casting specimen

1. Specimens are made prismatic in shape with dimensions 20 mm x 10 mm x 10 mm for OM, tensile test specimen, impact test specimen of 55 mm x 10 mm x 10 mm and a specimen for hardness are made.
2. Hardness of specimen is measured on Rockwell hardness testing machine.
3. The microstructure analysis is done for the samples of all three compositions which are fabricated by using the stir casting machine in 100x magnification by using the Inverted Microscope.
4. The tensile strength is measured in universal testing machine to know the properties of the three MMCs.
5. Impact strength of the MMC is measured to know the toughness of the composites by using the charpy impact testing machine.

3.1.1 TENSILE TEST

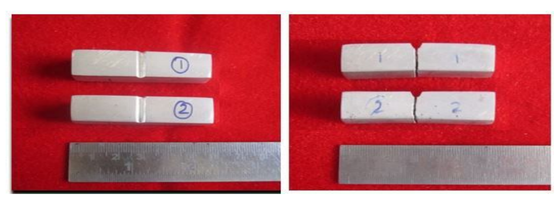
In this the sample are subjected to tension until failure. The Properties like ultimate tensile strength, maximum elongation and reduction in area are measured using the tensile testing. From this, Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics can also be determined. The tensile test has been taken through the universal testing machine for the specimens which we made. The tensile test specimen before testing is shown in fig. 2 (a) and the tensile test specimen after testing is shown in fig.2 (b).

(a) Before Test (b) After Test

figure 2 Tensile Test specimens

3.1.2 IMPACT TEST

The results of the charpy impact tests for Al 7075 - SiC composites fabricated with different processing weight percentages of composition are taken.



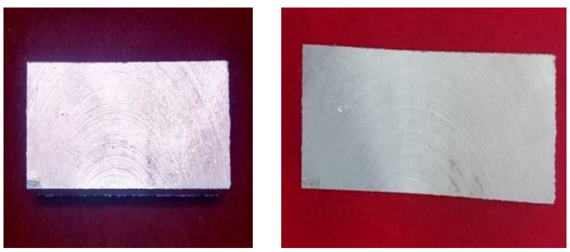
(a) Before Test (b) After Test

figure 3 Charpy Impact Test Specimens

The test results revealed that the impact energy of Al 7075 - SiC is mainly depends on the distribution of the particles in the matrix. It is interesting to note there is a little variation in the value for the different processing conditions. The impact values are slightly in-creases with increasing the compositions. The impact test specimen before testing is shown in fig.3 (a) and the impact test specimen after testing is shown in fig.3 (b).

3.1.3 HARDNESS TEST

Hardness tests were performed on the cast samples with a Rockwell hardness testing machine. The results of micro hardness test (HV) conducted on chilled MMCs samples revealed an increasing trend in matrix hardness with an increase in reinforcement content (up to 8 wt % SiC). Results of hardness measurements also revealed that copper chill has an effect on hardness of the composite. This significant increase in the hardness can be attributed primarily to presence of harder Silicon carbide particulates in the matrix, a higher constraint to the localized deformation during indentation due to their presence and reduced grain size. In this particle reinforced composite, there is generally a big difference between the mechanical properties of the dispersoid and those of the matrix. These results in incoherence and a high density of dislocations near the interface between the dispersoid and the matrix. Hardness increases with increase of the silicon carbide. The hardness test specimen before testing is shown in fig.4 (a) and the hardness test specimen after testing is shown in fig.4 (b).



(a) Before Test (b) After Test

figure 4 Rockwell Hardness Test Specimen

3.1.4 MICROSTRUCTURE

The mechanical properties of composite materials are powerfullyreliant on on micro structural parameters of the system. The evolution of microstructure depends mainly on the cooling rate during phase change. Though the microstructure evolution depends on many process parameters, the final structure is decided by the cooling conditions during solidification. The present investigation aims at producing cast Aluminium alloy- Silicon carbide particulate composites. The dispersoid being added ranges from 0 wt % to 8 wt % in steps of 4wt %.

IV. RESULTS AND DISCUSION

4.1 RESULTS

4.1.1 TENSILE TEST

The magnesium metal matrix composite of ASTM E8M standard has been inferred to the tensile testing in the Universal testing machine with the maximum load capacity of 30 KN and with the maximum elongation capacity of 1000 mm at the room temperature in the Commando Testing Lab at Coimbatore.

Table 3 Tensile Test Results

MATERIAL PROPERTIES	YIELD STRENGTH	ULTIMATE TENSILE STRENGTH	% OF ELONGATION	PEAK LOAD
Al 7075 + 0 % SiC + 4% Cu	22.325	38.924	4.2	2.13
Al 7075 + 4 % SiC + 4% Cu	104.98	131.54	2.72	6.74
Al 7075 + 8 % SiC + 4% Cu	123.1	155.4	2.0	7.82

From the table 3 it is inferred that the yield strength of the Al7075 + 4 % Copper is very less due to the defects like porosity and blow holes present in the casting. The 4% of the reinforcement gives the yield strength of 104.98MPa, which is 4 times greater than the 0% of reinforcement value. The 8% of the reinforcement of the silicon carbide gives 123.1 MPa of yield strength which is 17 % higher than the 4% reinforcement of the Silicon Carbide. On seeing the ultimate tensile strength the 0% reinforcement has only 40 MPa, whereas the 4% reinforcement has 131.54 MPa of Ultimate tensile strength. The 8% reinforcement of the silicon Carbide gives the ultimate tensile strength value of 155.4 MPa. The 8% reinforcement of silicon carbide gives 18% improvement in the ultimate tensile strength of the specimen.The Percentage of elongation in the 0% reinforcement of silicon carbide gives the value of 4.2% which is merely due the high ductile property of the Aluminium. Whereas the 4% of the Silicon Carbide has the Percentage of elongation of 2.72% and the 8% of the Silicon carbide reinforcement has the 2% of the Percentage of Elongation.The Peak Load with stand by the 0% reinforcement of the casting is 2.13KN, whereas the 4% reinforcement of the silicon carbide has 6.74KN which is 216% higher the 0% reinforcement and the peak load value of the 8% reinforcement of the silicon carbide has 7.82KN which is 267% higher than the 0% reinforcement and 108% higher than the 4% reinforcement of Silicon Carbide.

4.1.2 IMPACT TEST

The Aluminium Metal Matrix Composite of ASTM E23 standard has been intended to the Charpy Impact testing in the Impact testing machine which is available in the strength of materials laboratory at Government College of Technology, Coimbatore.

Table 4 Impact Test Results

S.NO	SAMPLE NAME	TRAIL 1	TRAIL 2	AVERAGE VALUE
1	Al 7075 + 0 % SiC + 4% Cu	2	2	2
2	Al 7075 + 4 % SiC + 4% Cu	2	2	2
3	Al 7075 + 8 % SiC + 4% Cu	2	4	3

The table 4 shows impact strength of the 0% reinforcement of Silicon Carbide is 2J. On reinforcing the 4% of the Silicon Carbide it gives the same value of 2J, but for the 8% reinforcement the impact strength gets increased to 3J, which is 50% improvement in the strength of the 0% and 4% reinforcements.

4.1.3 HARDNESS TEST

The hardness test for the aluminium metal matrix composite samples are taken at ASTM E18-2016 standard and tested by using the Rockwell Hardness test machine at the temperature of 26 °C in the Commando Testing Lab at Coimbatore. The hardness values are taken at the different places in the three different compositions of 0 %, 4 %, 8 % reinforcement of Silicon Carbide with the Aluminium 7075. And then the average values are listed in the table.

Table 5 Hardness Test Results

S.NO	SAMPLE NAME	AVERAGE HARDNESS VALUE HR15T
1.	Al 7075 + 0 % SiC + 4% Cu	66
2.	Al 7075 + 4 % SiC + 4% Cu	68
3.	Al 7075 + 8 % SiC + 4% Cu	75

The table 5 shows the hardness value for the 0% reinforcement is 66 which gets improves beacause of the addition of the copper. The 4% reinforcement of silicon carbide is 68 which is 3% improvement in the hardness. Whereas the 8% reinforcement has hardness value of 75 which is 10% greater than the 4% reinforcement and 13% higher than the 0% reinforcement of silicon carbide.

4.1.4 OPTICAL MICROSCOPY

The microstructure differences of the three compositions are taken and are differentiated below

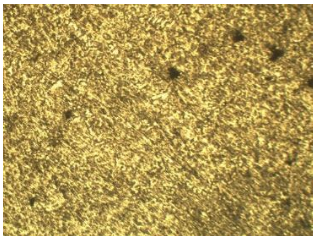


Figure 5 Optical Microstructure Of 0 % Sic + 4% Cu MMC

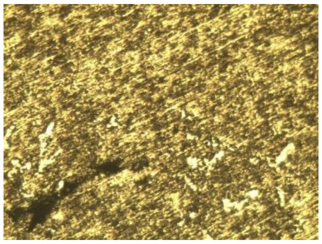


Figure 6 Optical Microstructure Of 4% Sic + 4% Cu MMC

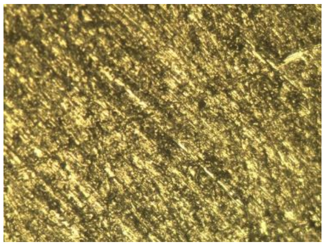


Figure 7 Optical Microstructure Of 8% Sic + 4% Cu MMC

From the fig. 5, 6, 7 the eutectic structure of the various compositions of 0 %, 4 %, and 8 % SiC reinforced Al 7075 is shown with the variations. Also the level of SiC is varied and it is increased from one composition to another.

4.2 DISCUSSION

All the results obtained from testing the MMC is clearly reported above tables 5, 6, 7. So from the bar chart figure 8 the observed mechanical properties are clearly displayed.

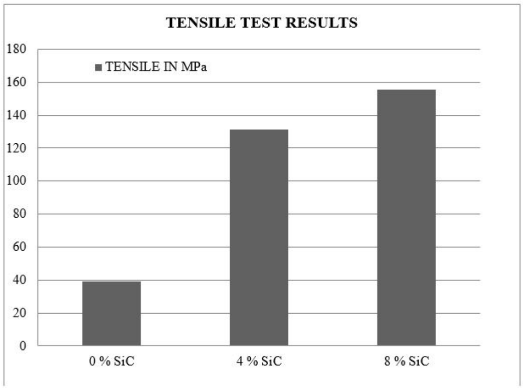


Figure 8 Comparision Chart Of Tensile Properties

As the shown in the bar chart the SiC reinforced Aluminium metal matrix composite has higher tensile properties. Because the tensile strength and the yield strength of the Silicon carbide particles are very higher than the base material, due to the reinforcement the Silicon carbide particles have mixed well in the matrix. This results in the enrichment of the tensile properties. Particularly the tensile properties of the 8 % SiC is higher while compared, so this gives the better results.This shows that the addition of Sic improves the strength of the Aluminium.

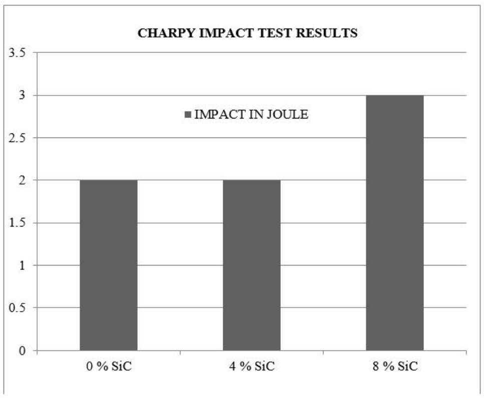


Figure 9 Comparision Chart Of Charpy Impact Test Results

The fig.9 shows the impact test results of the casting of SiC reinforced Aluminium metal matrix composites. It is clearly indicated that the impact test value of the all composites are similar and the 8% reinforcement of Sic is higher than all other reinforcements. This is because the Aluminium is a light weight material and SiC has high toughness, when they are mixed together to form a composite it gives low impact strength. This results in the enhancement of the toughness values in the composites.

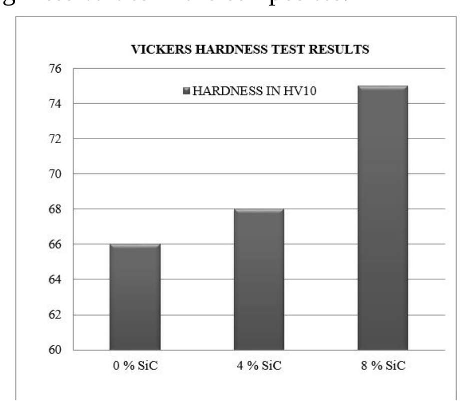
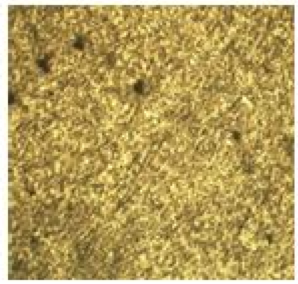
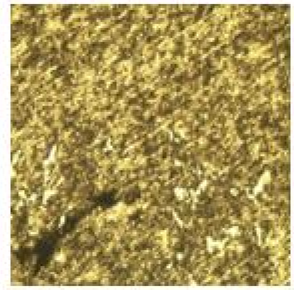


Figure 10 Comparision Chart Of Vickers Hardness Test Results

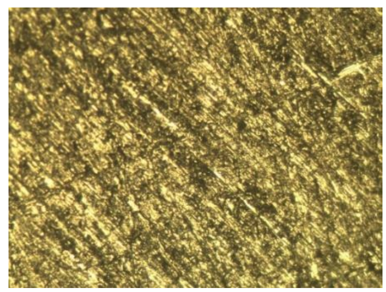
The hardness of the composites made by the reinforcement of SiC with the Al 7075 MMC is increased while comparing with the as cast material.It is also shown in figure 10 that the hardness of the 0 % SiC and 4 % SiC is relatively higher than the as cast material. But the 8 % SiC reinforcement gives the best hardness value of 13 % high. This shows the improvement of Sic improves the Strength of the Aluminium.



(a) 0 % SiC REINFORCEMENT



(b) 4 % SiC REINFORCEMENT



c) 8 % SiC REINFORCEMENT

Figure 11 Optical Microscopic Images On 100x Scale

The optical microstructure of the composites at various compositions 0 %, 4 % and 8 % SiC is shown in the fig.11 clearly. It shows that composites have close microstructures while comparing with each other. And the amount of SiC is more in the 8 % SiC reinforcement than the 4 % reinforcement. Even in the 12%, it indicates that the Silicon Carbide reinforcement particles are homogeneously dispersed in the Aluminium metal matrix composites.

V. CONCLUSION

Silicon Carbide and Copper reinforced Aluminium 7075 metal matrix composite is fabricated successfully by using stir casting process. From this study the following mechanical properties and microstructure are observed.

- Tensile strength of composite material is enhanced as the result for the addition of SiC particles and the result found that strength of composite material is higher than that of the 0 % of reinforcement. Exclusively reinforcement of 8 % SiC gives higher tensile strength while comparing with the other compositions.

- Impact strength of composite material has been increased in addition of SiC. Hence, the toughness of the Aluminium MMC is enriched than the base material.
- Hardness of the composite material is increased than the base material especially the composition of 8 % SiC has high hardness while comparing with the other two compositions of 0 % SiC and 4 % SiC.
- So the 8 % reinforcement of SiC is the best composition while compared with the other compositions.
- The microstructure study shows that there is homogeneous mixture and the SiC and copper is dispersed well in MMC. So it results in augmentation of mechanical properties such as tensile strength, toughness, and hardness.

REFERENCES

[1] Prof.S.RNimbalkar, MhaseVijay , ManojSatpute, 2015, "Aluminiumalloy Al-7075 reinforcement and Stir casting -a Review", IPASJ International Journal of Mechanical Engineering (IIJME), Volume 3, Issue 11.

[2] ZiyangXiu , Wenshu Yang , Ronghua Dong , MuridHussain , Longtao Jiang , YongXing Liu , Gaohui Wu , 2015, "Microstructure and Mechanical Properties of 45 vol.% SiCp/7075Al Composite", Journal of Materials Science & Technology.

[3] Mohd. Suhail, MahmoodAlam, Reyaz Ur Rahim, 2015, "The Effect of Process Parameter on Metal Matrix Composite (Al+4%Cu+5%Sic) By Stir Casting", International Journal of Engineering Trends and Applications (IJETA) – Volume 2 Issue 1.

[4] ChintaNeelima Devi, V.Mahesh and N.Selvaraj, 2014, "Tensile and Impact behaviour of Al-Sic-Zn-Cu Metal Matrix Composite", Research Journal of Engineering Sciences Vol. 3(2), 17-22.

[5] Ali Kalkanlı ,SencerYılmaz, 2007, "Synthesis and characterization of aluminum alloy 7075 reinforced with silicon carbide particulates", Materials and Design 29, 775–780.

[6] M.Sreenivasa Reddy, Soma V. Chetty, SudheerPremkumar, 2012, "Effect of reinforcements and heat treatment on tensile strength of Al-Si-Mg based hybrid composites", Int. Journal of Applied Sciences and Engineering Research, Vol.1,No. 2.

[7] Pradeep, B.S Praveen Kumar and Prashanth B, 2014, "Evaluation Of Mechanical Properties Of Aluminium Alloy 7075 Reinforced With Silicon Carbide And Red Mud Composite", International Journal of Engineering Research and General Science Volume 2, Issue 6.

[8] Vinitha B. S. Motgi, 2014, "Evaluation of Mechanical Properties of Al 7075 Alloy, Flyash, SiC and Redmud Reinforced Metal Matrix Composites", IJSRD - International Journal for Scientific Research & Development| Vol. 2, Issue 07.

[9] R.Keshavamurthy ,SadanandaMageri , Ganesh Raj , B.Naveenkumar , Prashant M Kadakol and K.Vasu , 2013, "Microstructure and Mechanical Properties of Al7075-TiB2 in-situ composite", Research Journal of Material Sciences Vol. 1(10), 6-10.

[10] I. Estrada-Guela, C. Carre˜no-Gallardoa, D.C. Mendoza-Ruiza, M. Miki-Yoshidaa, E. Rocha-Rangel, R. Martínez-Sáncheza, 2009, "Graphite nanoparticle dispersion in 7075 aluminum alloy by means of mechanical alloying", Journal of Alloys and Compounds 483 (2009) 173–177.