# Mechanical Properties of Fly Ash Reinforced Al-Si Alloy Based MMC

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**Abstract-** On theexplore and augmentation of the engineering industrial sectors, this paper emphasizes the production of metal-matrix AlSi alloy with fly ash composites by the continuous stir-casting method. samples are prepared as per the standard and finally tested by hardness using Brinell hardness machine, impact strength by using Charpy-V-Notched machine, Compression test by using Universal Testing Machine, For sample preparation, LM6 as the base alloy and two fly ash samples A and B having different morphology are taken. MMC- A and MMC- B were produced by reinforcing fly ash A and fly ash B respectively in LM-6 by stir casting process. Several tests were done to know the impact strength, compressive strength and micro hardness of both base alloy and the new composites prepared. An attempt was made to analyze and compare the results of the experiments i.e. comparison of three properties of composites A and B, with each other and with the base alloy. It was observed that addition of fly ash to Al-Si metal matrix composite improved the above properties of LM-6.

**Index Terms-** Keyword1, keyword2, keyword3 (Separate Index Terms with semicolon).

## 1. INTRODUCTION

Metal Matrix Composites (MMCs) have been a topic of technological and commercial significance, over the two decades
(Miracle.2005). MMCs are advanced engineering materials consisting of one or more reinforcements in a metal matrix to get a tailored set of properties. The matrix phase has following roles:

- Protection of reinforcement materials.
- Distribution of stress to the reinforcement materials.
- Provision final shape of the composite part.

The reinforcement phase has following roles:

- Provision of high mechanical properties to the composite.
- Reinforcement of matrix in preferential directions [M.Kok. 2004-20].

Most of the MMCs possess higher specific weight, specific strength, better thermal stability, fatigue properties and wear resistance over the base metal [Anilkumar H.C, et al. 2013]. Areas of aerospace, defence, automotive, sporting goods, medical, marine etc. are potential application fields for MMCs [Emmanuel Gikunoo.2004-56].

Although there are different types of MMCs, Aluminium based MMCs have received a lot of attention [H.C. Anilkumar, 2011]. Aluminium is the 3rd most abundant element and the most abundant metal in the earth's crust. Light weight, many desirable set of properties, and the ease of their production has led to their broad usage [Mr.P.K. Suragimath et al]. In this experimental work, we have taken eutectic Aluminium-Silicon alloy LM6 (British specification- BS 1490-1988 LM6) as the base alloy with fly ash as reinforcement. From Al-Si phase diagram, it can be seen that LM6 is a eutectic alloy and have the lowest melting point. LM6 is widely used in automotive engines because of its good mechanical properties, high strength to weight ratio, wear resistance and low coefficient of expansion [N. Suresh et al, 2010, *S.* Sulaiman et al, 2010].

Fly ash is a by-product of combustion of coal. There are two types of fly ash, namely, precipitator (solid particle) and cenosphere (hollow particle) [T.P.D. Rajan et al 2007]. Fly ash a mixture of oxides rich in silicon (SiO2), iron (Fe2O3), and aluminium (Al2O3). Fly ash poses threat to atmosphere by contaminating both land and water bodies. Huge land area is needed for its dumping. Utilization of fly ash as reinforcement has many benefits commercially and environmentally [Baljeev Kumar et al, 2012]. Moreover it is a low density and low cost waste material available abundantly [N. Suresh et al, 2010]. Fly ash as reinforcement, improves the wear resistance, damping properties, hardness and stiffness and reduces the density of aluminium alloys [T.P.D. Rajan et al 2007]. Stir-casting technique is used for the synthesis of fly ash reinforced Al-Si metal matrix composites.

Fabrication techniques should ensure uniform distribution of the material being reinforced in the matrix and the formation of good bond between base matrix and reinforcing material in order to obtain MMCs with enhanced properties and hence, they act as one of the sensitive parameters responsible for affecting the distribution of the reinforcing materials, interfacial bond condition between reinforcing phase and matrix and the microstructure of the composite so formed [Hashim et al., 1999]. Stir Casting is a composite material fabrication method of liquid state type, i.e. dispersed phase is mixed with a molten metal matrix by means of mechanical stirring. The liquid composite material is thereafter cast either by conventional casting methods or conventional metal forming technologies. [Ankush Sachdeva et al, 2013]. It has been reported that the stir casting method so used for preparing the composites is capable of producing uniform distribution of the reinforced fly ash particles depending on the choice of matrix and reinforcing agent by [H.C. Anilkumar, 2011].As stir casting offers a wide selection of materials and processing conditions, relatively inexpensive and also due to stirring action the disperse particles into melts, and hence it produces better matrix particle bonding which makes it eligible to be used widely as a promising process [K. Kalaiselvan, 2011]. Stir casting is a reliable route for the synthesis of AMCs (Aluminium Matrix Composites) because of its scalability and simplicity. However, this technique has inherent problems such as when providing a good wetting between the particulate reinforcement and the liquid aluminium alloy melt [Sandeep Kumar Ravesh, 2012]. A set up of stir casting was developed [Sahin, 2003] with a bottom tapping facility and evaluated three methods for mixing of the reinforcement .He achieved a complete homogenous distribution of the particles in the matrix alloy. [M. Kok, 2005] overcame the problems of ceramic particles not being wetted by the liquid metal matrix and their sinking or floating depending on their density relative to the liquid metal which caused uneven dispersion of the ceramic particles. The mixture was melt stirred at high mixing speed (900 rev $min^{-1}$) and by preheating of the ceramic particles for improvement in wettability before their implementation into the metal matrix alloy.

## 2. EXPERIMENTAL PROCEDURE

Major headings should be typeset in boldface with the words uppercase.

### 2.1. *Composite Preparation*

The first section is composite preparation, second section is specimen preparation for different experiments and the third section is experiment (Matthews and Rawlings, 1997, 24). Composites A and B used in the process were produced by reinforcing fly ash A and B in LM6 by stir casting method. Particles fly ashes A were cenospherical, whereas particles of fly ash B were irregular in shape. Composition of LM6 is shown in the table 1.

The fly ash A and B were first collected and shieved separately with Shieve number 240 to get the fly ash of same size. Then both the samples were preheated in electrical furnace for an hour in order to demoisturise and to reduce the carbon content in them. Then the fly ash A was added to molten LM-6 by continuous stirring in electrical furnace operating at 660$^o$c. After stirring it for considerable time i.e. 4 minutes, the mixture was poured into a die for casting. The die used was first cleaned and was painted with $Al_2O3$ so that the metal matrix composite after solidification can be removed easily. Then the die was preheated to finalize the die preparation. After solidification, MMC was taken out and was used for preparation of samples for different test. The fly ash sample B was added to LM-6 in same procedure to produce MMC-B then experiments were carried out to compare the properties of LM-6, MMC-A & MMC-B.

3.1.1 *Mechanical Testing*

Typeset sub-subheadings in medium face and capitalize the first letter of the first word only.

**2.2.** *Impact Strength test*

if a sudden force or load is applied on a body for a very short period then the body is said to undergo impact. Impact strength is the property by virtue of which the material possesses the strength to overcome the impact loading. Impact Strength test is done by IZOD V Notch pendulum impact testing machine. The square bar test specimens is applied on a simply supported beam. A Specimen is adjusted by square cross section 10 mm x 10mm x 55mmin length with 45-degree v notch at center. Single blow of hammer is given at mid span of specimen. The blow should be sufficient to bend or break the specimen at center. The striking energy should be 310 ±10 joules. The energy spent in bending or breaking the specimen is taken as IZOD impact testing machine.

**2.3.** *Compression test*

Compression test is done in the Universal Testing Machine (UTM). The cylindrical test specimens are mounted on the base plate of the UTM. The specimens here used had same diameter as that of height (15 mm). The load is applied on the specimen gradually until the sample is compressed to a height of 14mm. With the application of load, the displacement increases, but the displacement reduces drastically, as it cannot be compressed any more.

*2.4 Micro hardness*

Micro hardness test was done in Vickers Micro Hardness Testing Machine. The specimen used had a highly finished surface and was held perpendicular to the indenter. Vickers Micro hardness testing machine gives an allowable range of load for testing with a diamond indenter. The resulting indentation is measured and converted to a hardness value. During the test, a constant load was maintained i.e. 0.98 N.

**3. RESULTS AND DISCUSSION**

**3.1 Impact Strength**

An impact strength reading gives the energy absorbed by a material during fracture which in turn shows the toughness of materials.

Table:1

| Co | Si | Fe | Cu | Mn | Ti | Zn | Ni | Pb | Sn | Cr | Ca | V | Al |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.01 | 12.24 | 0.43 | 0.08 | 0.16 | 0.06 | 0.09 | 0.02 | 0.05 | 0.06 | 0.01 | 0.008 | 0.01 | 86.7 |

From Table no 2 it is clear that, IZOD impact strength value, of LM6 was 0.5 J and of both MMC-A and MMC-B was 1.5J. It is seen that, fly ash reinforced composites have better impact strength than their base alloy

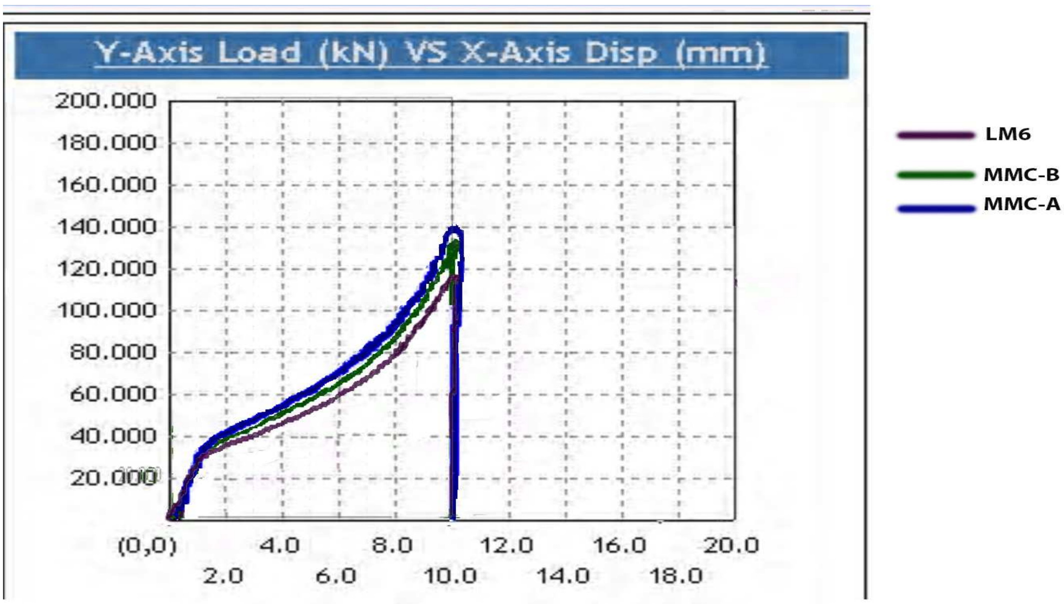
Table no.-2

| Sample No | Sample name | Impact strength test IZOD V notch | | | Mean in joule |
|---|---|---|---|---|---|
| | | Trial-1 | Trial-2 | Trial-3 | |
| 01 | LM-6 | 0.5 | 0.5 | 0.5 | 0.5 |

| | | | | | |
|---|---|---|---|---|---|
| 02 | MMC A | 1.5 | 1.5 | 1.5 | 1.5 |
| 03 | MMC B | 1.5 | 1.5 | 1.5 | 1.5 |

**3.2 Compressive Strength**

The compressive properties of the synthesized MMCs and LM6 can be understood by studying stress-strain curve. For LM6, the ultimate compressive strength was determined to be 0.712 KN/mm2 at an ultimate compressive load of 114.680KN. The deflection at the ultimate load was found to be 9mm, whereas maximum deflection was 10mm. At an ultimate compressive load of 138.870KN, the ultimate compressive stress for MMC-A was found to be 0.892KN/$mm^2$. Deflection at ultimate load was found to be 10mm, and maximum Deflection was 10.1mm. In case of MMC-B the ultimate compressive strength was found to be 0.858KN/mm2 at an ultimate compressive load of 132.110KN. Both the maximum deflection and deflection at ultimate load was found to be 10.1mm. It is clear from the results that the compressive strength of MMCs were greater than that of LM6. This is because of hardening of base alloy by fly ash particles [R.M.Pilai et al,2004, Lim Ying Pio et al, 2005]. MMC-A has greater compressive strength than MMC-B. The difference in their compressive properties could be attributed to the differences in particle structures of fly ash reinforced in LM6.




**3.3 Micro Hardness**

The micro hardness of the LM6 and the MMCs can be studies from the table no 3. Three trials were made for each of the each of the composites and the mean micro hardness was calculated. It is clear from the table that, MMC-B and LM6 exhibit highest (74.9 HV) and lowest (63.25 HV) micro hardness values respectively. MMC-A showed micro hardness of 71.925 HV. The micro hardness of MMC-A and MMC-B was greater than LM6, because of hardening of base alloy by fly ash particles and may be due to the formation of SiC Due to the irregular sized particle reinforcement in MMC-B, it displays better micro hardness than MMC-A. Because, irregular particle size promotes better bonding between base metal and reinforcement than that of cenospheres.

Table No.-3

| Sample No | Sample name | Micro Hardness in HV | | | Mean in HV |
|---|---|---|---|---|---|
| | | Trial-1 | Trial-2 | Trial-3 | |
| 01 | LM-6 | 64.50 | 62.50 | 62.75 | 63.25 |
| 02 | MMC A | 71.58 | 72.34 | 71.85 | 71.925 |
| 03 | MMC B | 75.2 | 75.9 | 73.6 | 74.9 |

## 4. CONCLUSION

### 4.1 Impact Strength

Results of the test for LM-6, MMC-A, MMC-B were found to be 63.55 J, 67.94 J, and 70.75 J respectively. This shows that, impact strength of MMC-A is greater by 6.9% than that of LM-6. Similarly, increment was noticed in the impact strength of MMC-B over LM-6 by 10.2%. However, MMC B showed better impact strength than MMC A by 4.13%.

### 4.2 Compression Strength

The test carried on the UTM shows that MMC-A & MMC-B have better compressive strength than LM-6.For e.g.; result of MMC-A was found to be 138.87 KN (21.09% more than LM-6) and of MMC-B was 132.11 KN(15.19% more than LM-6). When MMC A was compared with MMC B its compressive strength was found greater (5.11%) than MMC B.

### 4.3 Micro Hardness

Test results show that, micro hardness of MMC-A (71.925 HV) is 13.71% more than that of LM-6. Also for MMC-B it is (74.9 HV) 18.41% more than that of LM-6. Micro hardness of MMC B is 4.13% greater than MMC-A.

## References

1. D.B. Miracle, 2005. Metal Matrix composites- From science to technological significance, *Composites Science and Technology*, 65, 2526-2540.
2. M. Kok, Production and mechanical properties of Al2O3 particle reinforced 2024 aluminium alloy composites, Journal of Materials Processing Technology.
3. R. Teti, Machining of Composite Materials University of Naples Federico II, Italy.
4. Anilkumar H.C, IJMSE Volume 3, Issue 1 February 2013 PP. 6-13,"Effect of Particle Size of Fly ash on Mechanical and Tribological Properties of Aluminium alloy (Al6061) Composites and Corelations.
5. Emmanuel Gikunoo 2004- 56 ,Effect of Fly Ash Particles on the MechanicalProperties and Microstructure of Aluminium Casting Alloy A535.
6. Mr. Prashant Kumar Suragimath, Dr. G. K. Purohit, A Study on Mechanical Properties of
7. Aluminium Alloy (LM6) Reinforced with SiC and Fly Ash, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE).
8. N. SURESH, S. VENKATESWARAN, S. SEETHARAMU, influence of cenospheres of fly ash on the mechanical properties and wear of permanent moulded eutectic Al-Si alloys, Material Science-Poland, vol28, No. 1, 2010.
9. H.C. Anilkumar, International Journal of Mechanical and Materials Engineering (IJMME), Vol.6 (2011), No.1, 41-45.
10. *S*. Sulaiman□, M. Sayuti, R. Samin, Mechanical properties of the as-cast quartz particulate reinforced LM6 alloy matrix composites, journal of materials processing technology 2 0 1 ( 2 0 0 8 ) 731–735.
11. T.P.D. Rajan , R.M. Pillai , B.C. Pai , K.G. Satyanarayana , P.K. Rohatgi ,Fabrication and characterization of Al–7Si–0.35Mg/fly ash metal matrix composites processed by different stir casting routes, Elsevier. Composites Science and Technology 67 (2007) 3369–3377.
12. Baljeev Kumar, Rajeev Garg, Upinderpal Singh, Utilization of fly ash as filler in Hdpr/Fly ash polymer composites: A review, IJAER Vol-7, No.-11 2012.
13. Hashim et al., [1999]-reference of chaptr2 [Thesis].
14. Ankush Sachdeva et al., IJEST, ISSN: 0975-5462, Vol. 5, No.10, Oct 2013.
15. K. Kalaiselvan, N. Muruganand, and P. Siva, "Prod. And characterization of AA6061–B4C stir cast composite," Materials and Design, vol. 32, pp. 4004–4009, 2011.
16. Sandeep Kumar Ravesh, IJERA, ISSN: 2248-9622,Vol. 2, Issue 6, November- December 2012, pp.727-731,"Prepration & Analysis For Some Mechanical Property Of Aluminium Based Metal Matrix Composite Reinforced With Sic & Fly Ash".
17. Sachin.Y, Preparation and some properties of SiC reinforced aluminium alloy composites, 24, 2003, 671-679.161 (2005) 381–387, 2004-20.
18. R.M.Pilai, K.S.Biju Kumar, B.C. Pai, A simple inexpensive technique for enhancing density and mechanical properties of Al-Si alloys, Journal of

Materials Processing Technology 146 (2004) 338–348

19. Lim Ying Pio, Shamsuddin Sulaiman, Abdel Majid Hamouda, Megat Mohamad Hamdan Megat Ahmad, Grain refinement of LM-6 Al-Si alloy sand casting to enhance mechanical properties, Journal of Materials Processing Technology 162–163 (2005) 435–441