Effect on Mechanical Properties of Aluminium Alloy Composites on Adding Ash as Reinforcement Material

Mohd ZAFARUDDIN KHAN[1*], Mohd ANAS[2], Ather HUSSAIN[3], Md IRSHADUL HAQUE[4] and Kamran RASHEED[5]

[1]*Department of Mechanical Engineering, University Polytechnic Integral University, Lucknow, Uttar Pradesh, India*
[2,3,5]*Department of Mechanical Engineering, Integral University, Lucknow, Uttar Pradesh, India*
[4]*Mechanical Engineer Mushrif trading & contracting Co. Kuwait*

Abstract

To produce Al-matrix cast particle composites, wettability of the ceramic particles by liquid Al is essential. To improve wettability of the solution, few elements such as Mg and Si are added into Al melt to incorporate the ceramic particles. The present investigation has been focussed on the utilization of abundant available industrial waste such as fly ash and bagasse ash in useful manner by dispersing it into Eutectic Al-Si alloy LM6 Containing 10.58% Si to produce composites by liquid casting route. The mechanical properties such as Brinell Hardness and Ultimate tensile strength has been investigated. The test results of the mechanical properties have indicated that the ultimate tensile strength varies from 112.6 kN/mm^2 to 180 kN/mm^2 with maximum value at 10wt % fly ash +10wt % bagasse ash and hardness varies from 52 BHN to 80 BHN with maximum value at 10wt% fly ash + 10wt% bagasse ash as reinforcement in the matrix metal. It was concluded that 10wt% fly ash +10wt% bagasse ash can be used as reinforcement in aluminium composites and the produced composites could be used in automobile industry for the production of lighter & strong engine blocks, pistons and other components.

Keyword : Aluminium Matrix Composite, Fly ash, Bagasse ash, Mechanical Properties.

DOI : 10.14456/jmmm.2015.9

Introduction

The composite materials have been adopted as advanced engineering material due to improvement in mechanical properties of material. The advancement in material science and demand of metals having specific properties has led to researches in this field.

The study by Singla M. et al. (2009) on metal matrix composites (MMCs) for aluminium based silicon carbide particulate with an objective to develop a low cost method of producing MMCs and to obtain homogeneous dispersion of ceramic materials. His attempt with two step mixing method of stir casting technique and conducting experiment with varying weight fraction of SiC while keeping all other parameters constant has shown good results of uniform dispersion of reinforcement in the matrix. The hardness and impact strength increases with the increase in weight percentage of SiC was noticed. The ageing behavior of Al-Cu-Mg/Bagasse ash particulate composite with 2-10wt% bagasse ash particles was studied by Aigbodion V.S et al. (2010). It was noticed that the bagasse ash being the major parameter in ageing behavior followed by the ageing temperature. The product had shown decreased hardness and increased ageing time. The work of Verma D. et al. (2012) reviewed properties, applications and processing of bagasse ash fibre and composites. Similarly, the study on composite material by Subrahmanyam A.P.SV.R et al (2015) on the reinforcement of Rice husk ash and Fly ash in 5%-10% and 15% respectively in aluminium alloy (Al-Si10Mg) has shown improved tensile strength , hardness and percentage elongation.

Metal matrix composites (MMCs) represent a new generation of engineering materials in which a strong ceramic reinforcement is incorporated into a metal matrix to improve its properties including specific strength, specific stiffness, wear resistance, excellent corrosion resistance and high elastic modulus. MMCs combine metallic properties of matrix alloys (ductility and toughness) with ceramic properties of reinforcements (high strength and high modulus), leading to greater strength in shear and compression and higher working-temperature capabilities.

*Corresponding author E-mail : mdzafar@iul.ac.in

Aluminium based MMCs have received increasing attention in recent decades as engineering materials with most of them possessing the advantages of high strength, hardness and wear resistance. Aluminium is widely used as a structural material especially in the aerospace industry because of its light weight property. However, the low strength and low melting point were always a distinct problem. Aluminium alloys reinforced with ceramic particles exhibit superior mechanical properties to unreinforced Al alloys and hence are candidate for engineering applications. The stir casting method is widely used among the different processing techniques available. Stir casting usually involves prolonged liquid reinforcement contact, which can cause substantial interface reaction. The most conventional method of production of composites by casting route is vortex method, where the liquid aluminum containing 2-5% Mg is stirred with an impeller and ceramic particles are incorporated into vortex formed by stirring of the liquid metals. Addition of Mg into the liquid metal reduces the surface tension and there by avoids the rejection of the particles from the melts. Without addition of Mg recovery of the particles into the melt is quite low. Hence 2-5% Mg is generally added into the Al melts before incorporation of the particles. However, the chemistry of the particles of an Al alloy is changed with addition Mg that can be deleterious to the mechanical properties of the composites.

Fly ash is one of the residues generated in the combustion of coal. It is an industrial by-product recovered from the flue gas of coal burning in electric power plants. Depending upon the source and makeup of the coal being burned, the components of the fly ash produced vary considerably, but all fly ash includes substantial amounts of silica (silicon dioxide, SiO_2) (both30 amorphous and crystalline) and lime (calcium oxide, CaO). In general, fly ash consists of SiO_2, Al_2O_3, Fe_2O_3 as major constituents and oxides of Mg, Ca, Na, K etc. as minor constituent physical properties of fly ash mainly depend on the type of coal burned and the burning conditions.

Bagasse is a by-product from the sugar industry and it is usually burnt at the mill to provide process power or steam that provides energy for process machineries. The use of sugar cane bagasse as a source of energy, because of its appreciable calorific value, leads to production of ash as waste which has no specific economic application. A new reuse process of these wastes has to be established because these wastes, their ashes and gases are environmental burdens. Reinforcing aluminium metal with bagasse ash as a source of silica and alumina particulate will yield a material that displays combination of physical and mechanical properties of both the metal matrix and the silica.

Most of the previous studies carried out on processing of aluminium–fly ash composites have utilized different size of reinforcement, different amount of reinforcement, different types of fly ash. Almost no work found on mixing different weight percentages of fly ash and bagasse ash and its effect on the characteristics of AMCs. Therefore, an attempt has been made to mix different weight percentage of fly ash and bagasse ash as reinforcement to fabricate the AMCs and a comparative analysis is presented in terms of their mechanical properties.

Materials and Experimental Procedures

Eutectic Al-Si alloy LM6 containing 10.58% Si was used as a matrix and it was further designated as base alloy in the paper and is purchased from the nearby market. Fly ash was taken from Panki Thermal Power Plant, Kanpur, Uttar Pradesh and Bagasse ash was collected from Kisan Sahkari Chini Mills Limited, Oudh, Mahmudabad, Sitapur, Uttar Pradesh. The chemical composition of the base alloy is given in Table I. The chemical compositions of different samples after reinforcement have been such as base alloy+ 20wt% Fly Ash, Base alloy+10wt%Bagasse Ash and Base alloy + 10wt%Fly Ash+10wt%Bagasse Ash are listed in Table

Table 2.1

Division	Compound	Base alloy Wt. %	Base alloy+20wt%Fly Ash	Base alloy+10wt%Bagasse Ash	Base alloy+10wt%Fly Ash+10wt%Bagasse Ash
Elements in major quantities	Si	10.58	12.0023	12.678	13.895
	Fe	0.73	0.81	1.12	0.303
Elements in small quantities	Cu	0.247	0.177	0.151	0.02
	Pb	0.168	0.085	0.106	0.038
	Ni	0.021	0.039	0.062	0.009
	Ga	0.013	0.011	0.012	0.016
	Zn	0.02	0.319	0.363	0.024
	Mn	0.327	0.092	0.118	0.06
	Mg	0.368	0.343	0.364	0.353
	Cr	0.06	0.068	0.141	0.022
	Sb	0.015	0.0099	0.017	0.0079
	P	0.01	0.0099	0.012	0.012
	Ti	0.016	0.015	0.017	0.0063
	Ca	-	-	0.011	0.0027
	Cd	-	-	0.011	-
	V	-	-	0.0093	0.0028
	Sn	-	-	0.0077	-
	Hg	-	-	-	0.0039
	Ce	-	-	-	0.0015
Elements in minute quantities i.e. Less than 0.0001%- Cd, Zr, Sr, Na, Li, In, Co, Ba, Be, Sn, B, Ag, Bi					

This involves incorporation of ceramic particulate into liquid aluminium melt and allowing the mixture to solidify. Here, the crucial thing is to create good wetting between the particulate reinforcement and the liquid aluminium alloy melt. For increasing wettability, Mg is added that means it decreases the surface tension of the ash. The simplest and most commercially used technique is known as vortex technique or stir casting technique. The vortex technique involves the introduction of preheated ceramic particles into the vortex of the molten alloy created by the rotating impellar.

Table 2.2. Preparation of Samples

Sample	Composition
S1	Base Alloy
S2	Base Alloy with 10% Fly Ash by weight
S3	Base Alloy with 20% Fly Ash by weight
S4	Base Alloy with 30% Fly Ash by weight
S5	Base Alloy with 10% Bagasse Ash by weight
S6	Base Alloy with 20% Bagasse Ash by weight
S7	Base Alloy with 30% Bagasse Ash by weight
S8	Base Alloy with 10% Fly Ash by weight and 10% Bagasse Ash by weight
S9	Base Alloy with 15% Fly Ash by weight and 15% Bagasse ash by weight
S10	Base Alloy with 20% Fly Ash by weight and 20% Bagasse Ash by weight

Several samples are prepared for the test. The specimens were casted in the form of cylindrical bars having diameter 35 mm and length 190 mm. The size of all the specimens is uniform. Further the specimens were machined according to the machine standard. Sample 1 is the base alloy for which three specimens are prepared. Sample 2 is Base alloy with 10% fly Ash by weight, for which 3 specimens are prepared for testing. Similarly Sample 3 has Base alloy with 20% fly Ash by weight, for which 3 specimens are prepared for testing.

The above samples of aluminium ash metal matrix are prepared by Stir casting method i.e. 500 gm of base metal is taken with required amount of bagasse ash and fly ash particles. The ash particles are preheated to remove moisture content. The base alloy converted to molten form at 660°C in the open hearth furnace and stirred with the help of mild steel stirrer for 5-7 minutes at 200 rpm. The dispersion of fly ash particles is achieved by the vortex method. The melt with reinforced particulates is poured into the sand mould at 620°C. Ceramic particulate are incorporated to solidify For increasing wettability, Mg is added to decreases the surface tension of the ash

Testing

Tensile Strength Test

For Tensile strength test the above prepared specimens were machined on a lathe machine to proper machine standard i.e. Gauge Length -56 mm, Neck Diameter- 11.5mm, Collar Diameter- 27 mm and Total length of the specimen -166 mm. An Ultimate Tensile Machine was used to measure the tensile strength of the AMC specimens. The UTM specimens were loaded between two grips that are adjusted manually. A constantly increasing force was applied to the specimen by electronic control means. The load was continuously recorded. The UTS was then calculated and shown in table 4.1

Hardness Test

Hardness is the measure of how resistant solid matter is to various kinds of permanent shape when a force is applied. There are three types of tests used with accuracy by the metals industry. But in our present work we considered only Brinell hardness test. Brinell hardness measurements were carried out in order to investigate the influence of particulate weight fraction on the matrix hardness. Load applied was 500kgs for 20 seconds and ball indenter was used with 10 mm diameter. The hardness of the AMC specimens is shown in table 4.

Results and Discussion

Mechanical Properties

The tensile properties were listed in Table 4.1. The tensile strength were recorded to be the highest for AMC prepared with Base Alloy +10wt% Fly Ash +10wt% Bagasse Ash as compared to the other samples. Base Alloy + 20wt% Fly Ash and Base Alloy + 10wt% Bagasse Ash also shows good tensile strength but in comparison with above composition there values are relatively low. Table 4.1 presents the hardness values for different samples prepared. The average value of hardness recorded was found to be the highest for AMC prepared with the Base Alloy +10wt% Fly Ash+ 10wt% Bagasse Ash

Table 4.1. Tensile Strength Test / Hardness Test

Sample	Tensile Strength in KN/mm^2/ Brinell Hardness Number (BHN)					
	Test-1		Test-2		Test-3	
S1	112.6	53	116.2	48	114.4	52
S2	136.2	58	138.8	62	134.6	59
S3	158.8	66	164	63	160.4	69
S4	146.2	60	144.2	65	146.2	64
S5	168.6	71	172.4	73	170	75
S6	144.2	70	148.6	69	142.4	70
S7	138.2	65	138	66	136.8	64
S8	176.8	76	174.8	78	180	80
S9	152.8	64	154.6	62	156	64
S10	138	60	140	58	138	59
Mean	**1472.4**	**643**	**1491.6**	**644**	**1478.8**	**656**

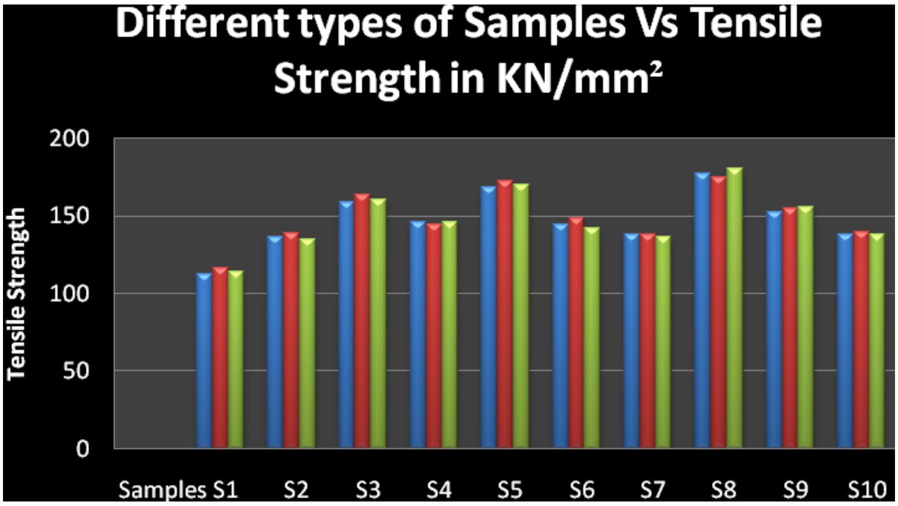

Figure 4.1. Showing the graph for Different Samples Vs Tensile Strength in kN/mm^2

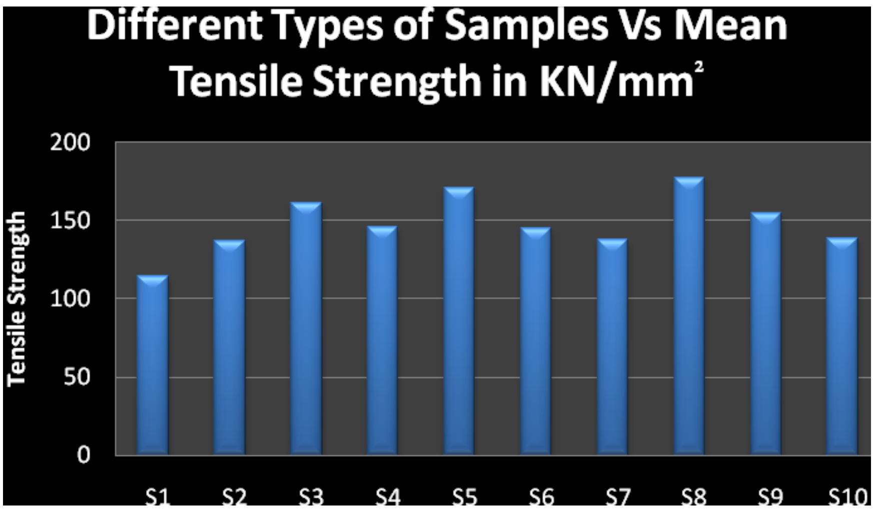

Figure 4.2. Showing the graph for Different Samples Vs Mean Tensile Strength in kN/mm^2

Discussion on Graphical Analysis

The graph 4.1 shows the Different types of Samples Vs Tensile Strength in kN/mm^2. It is observed that Sample 8 has highest value of Tensile Strength. As we have prepared 3 Samples from each configuration we obtain 3 readings for each Sample.The Mean Tensile Strength of Sample 8 is given in graph 4.2 i.e. 177.2 kN/mm^2 is relatively high than all the other Samples. It can be therefore concluded that by adding 10% Fly Ash by weight & 10% Bagasse Ash by weight we can obtain best results for the Tensile test. It is also observed that as the percentage of both the ashes is further increased we obtain a relatively low Tensile Strength.

For the graph 4.2 obtained, it represents the Mean Value of the Tensile Strength for each sample.

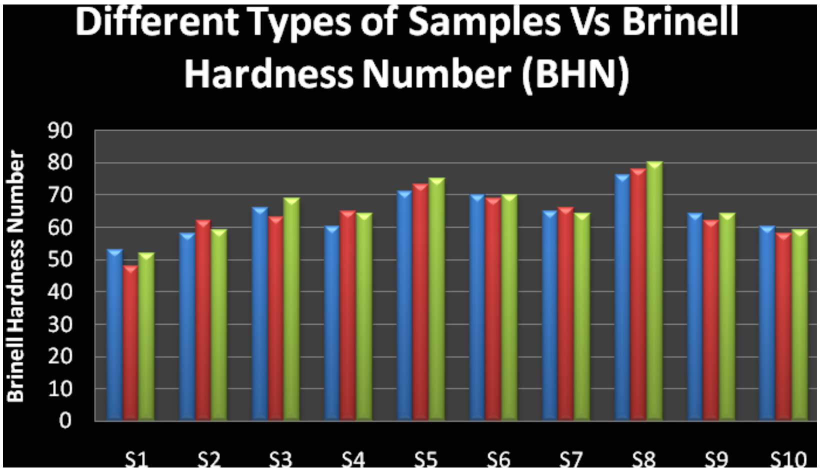

Figure 4.3. Showing the graph for Different Samples & Brinell Hardness Number

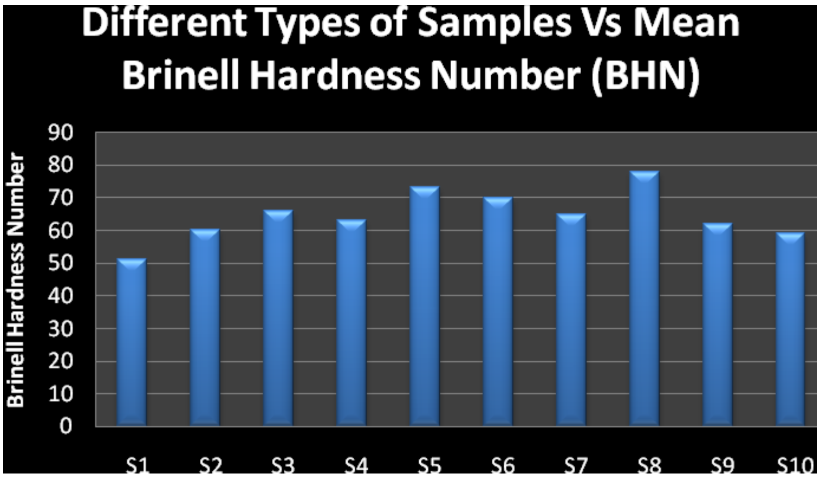

Figure 4.4 Showing the graph for Different Samples & Mean Brinell Hardness Number

Discussion on Graphical Analysis

The graph 4.3 shows the Different types of Samples Vs Brinell Hardness Number(BHN). It is observed that Sample 8 has realtively high value of Brinell Hardness Number. As we have prepared 3 Samples from each configuration we obtain 3 readings for each Sample. The Mean Brinell Hardness Number of Sample 8 is given in graph 4.4 i.e. 78 BHN is relatively high than all the other Samples. It can be therefore concluded that by adding 10% Fly Ash by weight & 10% Bagasse Ash by weight we can obtain best results for the Brinell Hardness Number. It is also observed that as the percentage of both the ashes is further increased we obtain a relatively low Brinell Hardness Number.

For the graph 4.4 obtained, it represents the Mean Value of the Brinell Hardness Number for each sample.

Conclusions

The continuous stir casting method used to prepare the composites could produce uniform distribution of the reinforced fly ash particles. In the present investigation, it was anticipated that all the composites will have the same wt% of the dispersed phases. The Tensile Strength and Hardness values were higher for AMC prepared with Base Alloy+10wt% Fly Ash+10wt% Bagasse Ash as compared to AMC prepared with other wt% of ash.

The experimental data reveals that selection of reinforcement is one of the important aspects in production of metal matrix composites especially when the enhanced mechanical properties are desired.

The following conclusions may be drawn from the present work:

- From the study it is concluded that we can use fly ash and bagasse ash for the production of composites and can turn industrial waste into industrial wealth. This can also solve the problem of storage and disposal of ash.
- 10wt%Flyash +10wt% Bagasse Ash can be successfully added to Al-Si alloy LM6 by stir casting route to produce composites.
- Addition of magnesium improves the wettability of ash with aluminium melt and thus increases the retention of the ash in the composite.
- Hardness of Al-Si alloy LM6 is increased from 51BHN to 78BHN with addition of ash and magnesium.
- The Ultimate tensile strength has improved by mixing Fly Ash and Bagasse Ash with each other by 10%wt.

Acknowledgment

The authors wish to acknowledge technical staff of Panki Thermal Power Plant, Kanpur, Uttar Pradesh, India and Kisan Sahkari Chini Mills Limited, Oudh, Mahmudabad, Sitapur, Uttar Pradesh for their help in collecting different samples of ash.

References

1. Singla, M., Dwivedi, D., Singh, L. and Chawla, V. (2009). Development of aluminium based silicon carbide particulate metal matrix composite. *J. Miner. Mater. Character. Eng.* **8(6)** : 455-467.

2. Aigbodion, V.S., Hassan, S.B., Dauda, E.T. and Mohammed, R.A. (2011). Experimental study of ageing behaviour of Al-Cu-Mg/bagasse ash particulate composites. *Journal of Tribologyin industry.* **33(1)** : 28-35.

3. Verma, D., Gope, P.C., Maheshwari, M.K. and Sharma, R.K. (2012). Bagasse fiber composites-A review. *J. Mater. Environ. Sci.* **3(6)** : 1079-1092.

4. A.P.S.V.R. Subrahmanyam, G. Narsaraju and Srinivasa Rao, B. (2015). Effect of rice husk ash and fly ash reinforcements on microstructure and mechanical properties of aluminium alloy (AlSi10Mg) Matrix composites. *IJAST.* **76** : 1-8.

5. Mohana Rao, D. and Bapi Raju Bandam M.E. (2014). Preparation and characterization of Al-Fly ash metal matrix composite by stir casting method. *IJISME.* **3(1)** : 1-5.

6. Usman, A. M., Raji, A., Hassan, M. A. and Waziri, N. H. (2014). A comparative study on the properties of Al-7% Si-Rice husk ash and Al-7% Si-Bagasse ash composites produced by stir casting. *IJES.* **3(8)** : 1-7.

7. Singla, Deepak and Mediratta, S.R. (2013). Evaluation of mechanical properties of Al 7075-fly ash composite material. *IJIRSET.* **2(4)** : 951-959.

8. Lokesh, G. N., Ramachandra, M., Mahendra, K.V., Sreenith, T. (2013). Characterization of Al-Cu alloy reinforced fly ash metal matrix composites by squeeze casting method. *IJEST.* **5(4)** : 71-79.

9. Madakson, P.B., Yawas, D.S. and Apasi, A. (2012). Characterization of coconut shell ash for potential utilization in metal matrix composites for automotive applications. *IJEST.* **4(3)** : 1190-1198.

10. Mahendra, K.V. and Radhakrishna, K. (2007). Fabrication of Al-4.5% Cu alloy with fly ash MMC and its characterization. *Mater. Sci. Poland.* **25(1)** : 57-68.