Comparison of Hardness and Strength of Fly Ash and Bagasse Ash Al-MMCs

Mohd. Anas[1], Mohd Zafaruddin Khan[2]
Department of Mechanical Engineering
[1, 2] Integral University, Lucknow, Uttar Pradesh, India

Abstract- *Metal matrix composites (MMCs), for couple of decades have found worldwide applications, constitutes an important class of design and weight efficient structural materials that are encouraging every sphere of engineering applications. Composites containing low density and low cost reinforcements have found wide importance. Among various discontinuously dispersed solids used, ash is one of the most inexpensive and low density reinforcement available in large quantities as solid waste byproduct. Hence, composites with ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. To produce Al matrix cast particle composites, wettability of the ceramic particles by liquid Al is essential. In the present investigation, to improve wettability, elements such as Mg and Si are added into Al melt to incorporate the ceramic particles. The focus is also 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 produced composites by liquid casting route. The mechanical properties such as Brinell Hardness and Ultimate tensile strength have been investigated. The results of the mechanical properties tests showed that the ultimate tensile strength varies from 112.6 KN to 180 KN 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 engine blocks, pistons, among others.*

Keywords- Aluminium Metal Matrix Composite, Fly ash, Bagasse ash , BHN, Ultimate Tensile strength

I. INTRODUCTION AND LITERATURE SURVEY

The growth of Indian population and its dependence on agricultural products for cooking purpose and the ease of having high living standard due to technological developments, have increased the waste materials generated through industrial, mining and agriculture activities etc. As The waste materials are hard to dispose and thus a prime concern to environmental pollution [1]. Utilization of waste materials to reduce contamination not only meets spaces for disposal but at the same time leads to manufacturing of new engineering materials. One such composite is Aluminium alloy matrix, using different %age of various types of ashes [2]. Thus, recycling the waste material by converting it into green material for application in automobile and construction industries is a prime concern among the current researchers. A composite such as Aluminium metal matrix (Al-MMCs) was produced mainly for reducing material usage since metal is quite expensive due to its limited availability in future and also the fabrication cost which is lower than conventional cost. Composites material is have already proven their worth as weight-saving materials. The efforts to produce economically attractive composite from easily available raw materials to enhance innovative manufacturing techniques for industries. Metal Matrix composites (MMCs) generally, represent a new class of engineering materials, which has been incorporated with ceramic reinforcement for having improved properties such as specific strength, specific stiffness, wear resistance, excellent corrosion resistance and high elastic modulus [3, 4].

Aluminium is widely used as a structural material in the aerospace industry because of its light weight inherent property. However, the low strength and low melting point is always a problem. 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 [5]. 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 [6]. 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. The addition of hard or stiff ceramic has been established to improve the modulus behaviour and strength properties in the metallic matrices [7, 8].

However this improvement varies from one ceramic material to another depending on the physical and chemical properties of the ceramic material. These properties include hardness, stiffness, and their interaction between each other and to the matrix material. Hence different ceramic material give different improvement properties of matrix material and the selection of reinforcing material depends on the basic requirements of the components during usage [9]. Reinforcing aluminium metal with rice husk or bagasse ashes as a source of silica particulate yields a material which has combination of physical and mechanical properties of both the metal matrix and the silica and alumina from the ashes. In our previous work Usman et al. [10] the silica and alumina potentials of rice husk ash and bagasse ash were determined while in other works [11], the density and some mechanical properties of composites produced by reinforcing aluminium alloy with rice husk ash and bagasse ash, respectively were determined.

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 [12].

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. All fly ash in general includes substantial amounts of silica (silicon dioxide, SiO2) (both30 amorphous and crystalline) and lime (calcium oxide, CaO) [13]. In general, fly ash consists of SiO2, Al2O3, Fe2O3 as major constituents and oxides of Mg, Ca, Na, K etc. as minor constituent. The largest application of fly ash is in the cement and concrete industry, though, creative new uses for fly ash are being actively sought like use of fly ash for the fabrication of MMCs. Aluminum–fly ash composites have potential applications as covers, pans, shrouds, casings, pulleys, manifolds, valve covers, brake rotors, and engine blocks in automotive, small engine and the electromechanical industry sectors [14, 15]. The fly ash reinforced AMCs are also termed as „Ash alloys".

The aim of present study is to utilise the abundant agro-industrial waste (fly ash and bagasse ash) from Indian agricultural dominating areas, where major waste is ashes, for its reinforcement in aluminium matrix composites, determining and comparing the properties of these composites. The economic utilisation of these agro-residue and scraps can only enhance the energy problem of the country and provide alternative engineering material for composites and ceramics applications, providing source of income to farmers and masses thereby escalating rural developments and reducing environmental pollution. Most of the previous work carried out on processing and manufacturing of aluminium–fly ash composites have utilized different size of reinforcement, different amount of reinforcement, different types of fly ash [1, 2, 14]. Almost no work found on mixing different weight percentages of fly ash and bagasse ash to examine the effect on the characteristics of AMCs. An attempt is 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. The details of experimentation and results are discussed in subsequent sections below.

II. SELECTION OF MATERIALS

Processing techniques using for the production of the composite materials are broadly classified into solid state and liquid state processing. The selection of the processing technique mainly depends on the application and state of the matrix and reinforcement materials. In this work, liquid state

TABLE I:
Chemical Composition of Al-Si Alloy
[Wt. %] Designated as Base Alloy

Compound	% by weight	Compound	% by weight
Al	86.8	Ga	0.013
Si	10.58	Sb	0.015
Fe	0.73	P	0.010
Cu	0.247	Co	0.0015
Mn	0.327	Sn	0.0025
Mg	0.368	V	0.0077
Pb	0.168	B	0.0023
Ni	0.021	Hg	0.0035
Zn	0.02	Bi	0.0010
Ti	0.016	Ca	0.0038
Cr	0.060	Cd	0.0018
Zr	0.011	Ce	0.0015

**the other elements which are in minute quantity with less than .1% by weight are Ag, Be, Sr, Ba, Na, Li, In*

processing is preferred for the manufacturing of the desired composite material. The Eutectic Al– Si alloy LM6 which has a composition of 10.58% Si is used as a matrix and it is further designated as base alloy in this paper. Fly ash was brought from Panki Thermal Power Plant, Kanpur, Uttar Pradesh and Bagasse ash was collected from Kisan Sahkari Chini Mills Limited, Oudh, Mahmudabad, Sitapur, ttar Pradesh. The chemical compositions of the base alloy are given in Table I. The chemical compositions of different samples after reinforcement is as Base alloy+ 20wt% Fly Ash, Base alloy+10wt%Bagasse Ash and Base alloy + 10wt%Fly Ash+10wt%Bagasse Ash are listed in Table II , Table III and TABLE IV respectively.

Several samples are prepared for the test. Sample 1 is the base alloy. Sample 2 is Base alloy with 10% Fly Ash by weight. Similarly Sampel 3 has Base alloy with 20% Fly Ash by weight and so on. For each sample 3 specimens are prepared (Table V)

TABLE II:
Chemical Composition of Base Alloy+20wt%Fly Ash

Compound	%wt	Compound	%wt
Al	85.98937	Cd	0.0014
Si	12.0023	Ce	0.0015
Fe	0.81	Co	0.0015
Cu	0.177	Bi	0.0010
Mn	0.092	V	0.0075
Mg	0.343	Ag	0.002
Cr	0.068	B	0.0019
Ni	0.039	P	0.0099
Zn	0.319	Hg	0.0040
Ti	0.015	Sb	0.0099
Ga	0.011	Sn	0.0032
Pb	0.085	Ca	0.0045

**the other elements which are in minute quantity with less than .1% by weight are Zr, Sr, Na, Li, In, Ba, Be*

The above samples of alluminium ash metal matrix are prepared by Stir casting method i.e 500gm 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 660oC in the open hearth furnace and stirred with the help of mild steel stirrer for 5-7 minuts at 200rpm. The dispersion of fly ash particles is achieved by the vortex method. The melt with reinforced particulates is poured into the sand mould at 620o C. Ceramic particulate are incoorpurated to solidify For increasing wettability, Mg is added to decreases the surface tension of the ash.

TABLE III:
Chemical Composition of Base Alloy+10wt%Bagasse Ash

Compound	Wt%	Compound	Wt%
Si	12.678	Ce	0.0015
Al	84.783	Hg	0.0030
Fe	1.12	Co	0.0025
Cu	0.151	Ga	0.012
Mn	0.118	Cd	0.011
Mg	0.364	Bi	0.0020
Cr	0.141	Na	0.0010
Ni	0.062	P	0.012
Zn	0.363	Pb	0.106
Ti	0.017	Sb	0.017
Ag	0.0003	Sn	0.0077
B	0.0030	Zr	0.0021
Ca	0.011	V	0.0093

**the other elements which are in minute quantity with less than .1% by weight are Sr, Li, In, Ba, Be*

TABLE IV:
Chemical Composition of Base Alloy +10wt%Fly Ash+10wt%Bagasse Ash

Compound	Wt%	Compound	Wt%
Si	13.895	Ce	0.0015
Al	85.2161	Bi	0.0010
Fe	0.303	Ca	0.0027
Cu	0.020	Ga	0.016
Mn	0.060	Hg	0.0039
Mg	0.353	V	0.0028
Cr	0.022	Sn	0.0010
Ni	0.0090	P	0.012
Zn	0.024	Pb	0.038
Ti	0.0063	Sb	0.0079
B	0.0022		

**the other elements which are in minute quantity with less than .1% by weight are Cd, Zr, Sr, Na, Li, In, Co, Ag, Ba, Be*

Figure 1: Specimen casted and machined for proper shapes before testing

IV. RESULTS AND DISCUSSION

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. A 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 V

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 10mm diameter. The hardness of the AMC specimens is shown in tableV.

Various plots are plotted to observe the strength and hardness profiles in figure 2 to figure 6. The highest value of strength is 164kN/mm^2 when 10% Bagasse Ash is added. However as the bagasse Ash"s %wt is increased, strength decreases.

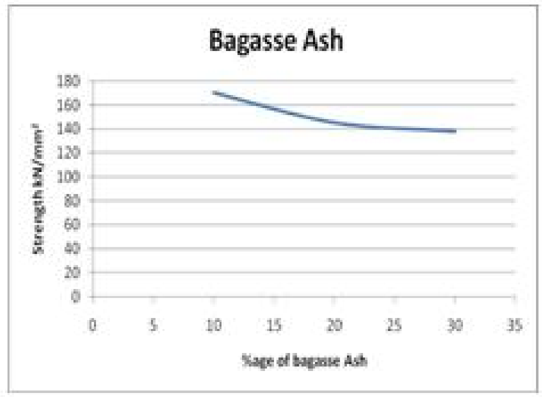

Figure2: Strength profile of Base Alloy with %wt of Bagasse Ash

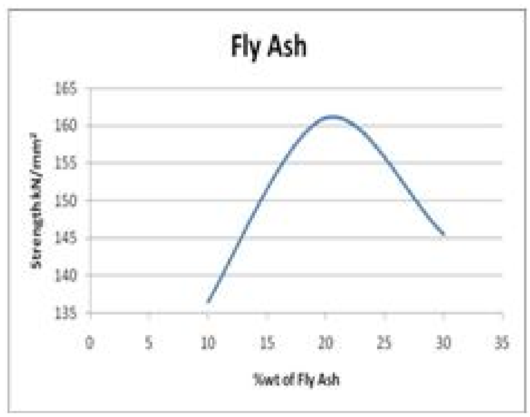

Figure 3: Strength profile of Base Alloy with %wt of Fly Ash

Mechanical Properties

The tensile properties were listed in Table V. 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 V also 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.

The hardness profiles are presented in figure 5 and 6. Figure 5 shows after a limited %wt addition of Fly and Bagasse Ash the curve almost overlaps at higher %wt ashes.

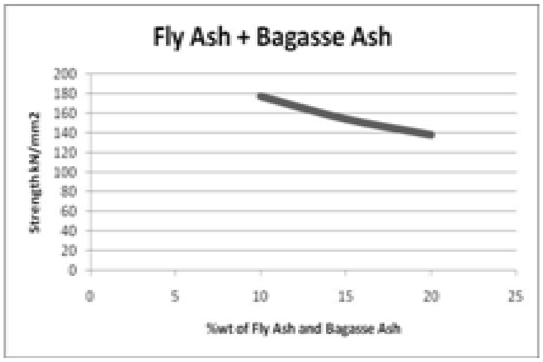

Figure 4: Strength profile of Base Alloy with %wt of Bagasse Ash and Fly Ash

Table V: Mean value of Brinnel Hardness Number and Tensile Strength for various samples

Samples	Brinnel Hardness Number	Tensile Strength
Base Alloy	51	114.4
Base Alloy+10wt%Fly Ash	60	136.5
Base Alloy+20wt%Fly Ash	66	161.06
Base Alloy+30wt%Fly Ash	63	145.5
Base Alloy+10wt%Bagasse Ash	73	170.33
Base Alloy+20wt%Bagasse Ash	70	145.06
Base Alloy+30wt%Bagasse Ash	65	137.7
Base Alloy+10wt%FA+10wt%BA	78	177.2
Base Alloy+15wt%FA+15wt%BA	62	154.47
Base Alloy+20wt%FA+20wt%BA	59	138.67

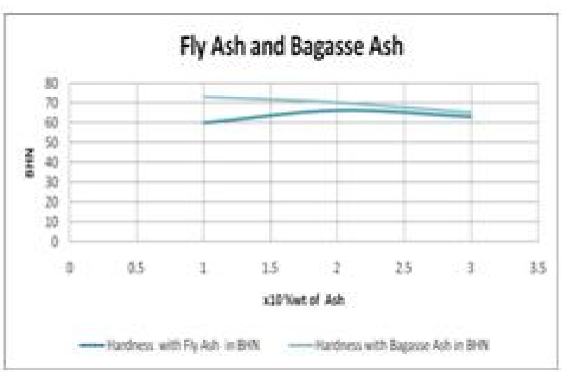

Figure 5: Comparison of Hardness profile of Fly Ash and Bagasse Ash with Base Alloy

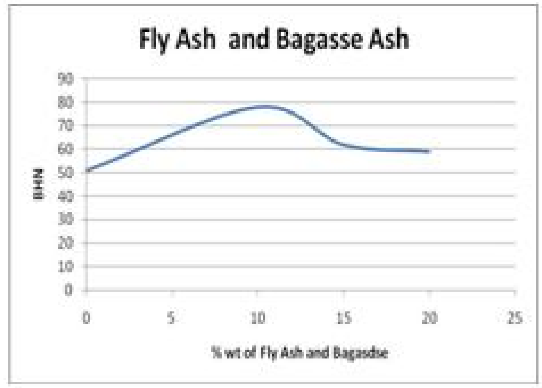

Figure 6: Hardness profile of Fly Ash and Bagasse Ash mixed with with Base Alloy

V. CONCLUSION

In the present investigation, it is observed that all the composites have Tensile Strength and Hardness values, 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 ;

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 casting route to produce composites of different properties like Hardness is increased from 51BHN to 78BHN with addition of ash and magnesium. The Ultimate tensile strength has increased by mixing Fly Ash and Bagasse Ash with each other by 10%wt.

REFERENCES

[1] L. Lancaster, M. H. Lung, and D. Sujan Utilization of Agro-Industrial Waste in Metal MatrixComposites: Towards sustainability International Journal of Environmental, Ecological, Geological and Geophysical Engineering Vol:7, No:1, 2013

[2] Ajit Kumar Senapati et al. Use of Waste Flyash in Fabrication of Aluminium Alloy Matrix Composite International Journal of Engineering and Technology, Vol: 6 No: 2, 2014, pp. 905-913

[3] Vengatesh.D and Chandramohan.V. Aluminium Alloy Metal Matrix Composite: Survey Paper. International Journal of Engineering Research and General Science ISSN 2091-2730 Volume 2, Issue 6, October-November, 2014 . pp 792-796.

[4] Oluwagbenga Babajide Fatile, Joshua Ifedayo Akinruli and Anthony Akpofure Amor. Microstructure and Mechanical Behaviour of Stir-Cast Al-Mg-Sl Alloy Matrix Hybrid Composite Reinforced with Corn Cob Ash and Silicon Carbide. International Journal of Engineering and Technology Innovation, vol. 4, no. 4, 2014, pp. 251-259.

[5] A. M. Usman, A. Raji, M. A. Hassan1 and N. H. Waziri. A Comparative Study on the Properties of Al-7%Si-Rice Husk Ash and Al-7%Si-Bagasse Ash Composites Produced by Stir Casting. The International Journal Of Engineering And Science (IJES) Volume 3 Issue 8 Pages 01-07 2014 ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805.

[6] Deepak Singla And S.R. Mediratta, evaluation of mechanical properties of al 7075-fly ash composite material, International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 4, April 2013,pp 951-959

[7] Zuhailawati, H.; Samayamutthirian, P. and Mohd Haizu, C. H. (2007). Fabrication of Low Cost Aluminium Matrix Composite Reinforced With Silica Sand. Journal of Physical Sciences, 18(1), 47-55.

[8] Froyen, L. and Verlinden, B. (July, 2013). Aluminium Matrix Composites Materials "Training in Aluminium Application Technologies (TALAT)" Eropean Aluminium Association, Belgium.

[9] Usman, A. M., Raji, A. and Waziri, N. H. (2014). Characterisation of Girei Rice Husk for Silica Potential. IOSR Journal of Environmental Science, Toxicology and Food Technology., 8(1) Version V, 68-71.

[10] Usman, A. M., Raji, A., Waziri, N. H. and Hassan M. A. (2014). A Study on Silica and Alumina Potential of the Savannah Bagasse Ash. IOSR Journal of Mechanical and Civil Engineering, 11(3) Version V (May-June, 2014), 48-52.

[11] Usman, A. M., Raji, A., Waziri, N. H. and Hassan M. A. (2014). Aluminium Alloy - Rice Husk Ash Composites Production and Analysis. Leonardo Journal of Practices and Technologies, 25(2), XX-XX. (submitted)

[12] Usman, A. M., Raji, A., Hassan M. A. and Waziri, N. H. (2014). Production and Characterisation of Aluminium Alloy - Bagasse Ash Composites. IOSR Journal of Mechanical and Civil Engineering, 11(4) Version III, 38-44.

[13] Rohatgi P.K,Weiss D, and Gupta Nikhil, “Applications of Fly Ash in Synthesizing Low-Cost MMCs for Automotive and Other Applications”, Journal of the Minerals, Metals and Materials Society, vol 58,(2006): pp 71-76

[14] D. Mohana Rao, Bapi Raju Bandam M.E, Preparation and Characterization of AL-Fly AshMetal Matrix Composite by Stir Casting Method, International Journal of Innovative Science and Modern Engineering (IJISME), Volume-3 Issue-1, December 2014

[15] Dhadsanadhep, C.; Luangvaranunt, T.; Umeda, J. and Kondoh, K. (2008). Fabrication of Al/Al2O3 Composite by Powder Metallurgy Method from Aluminum and Rice Husk Ash. Journal of Metals, Materials and Minerals, 18(2), 99-102.

[16] Sudarshan, and M. K. Surappa, “Synthesis of fly ash particle reinforced A356 Al composites and their characterization,” Material Science and Engineering- A, vol. 480 (1-2), pp. 117-124, 2008.