International Journal of Manufacturing and Materials Processing
Vol. 3: Issue 1
www.journalspub.com

Analysis of Physical Properties and Fabrication of Silicon Carbide, Graphite and Fly Ash Reinforced Metal Matrix Composites

*Jaspreet Singh**
Department of Mechanical Engineering, Krishna Engineering College, Ghaziabad, India

ABSTRACT
In the present study, a modest effort has been made to produce aluminium based silicon carbide particulate MMCs with an objective to develop a conventional low-cost method of producing MMCs and to acquire homogenous dispersion of ceramic material. To achieve these objectives step-mixing method of stir casting technique has been adopted and subsequent property analysis is performed. Al 6351 has been reinforced by silicon carbide, graphite and fly ash material, respectively. Experiments were conducted by varying weight fraction of SiC (15%), Gr (6%) and fly ash (10%) and SiC (7.5%), Gr (3%) and fly ash (5%). The prime motive is to produce a MMC that has a good strength, less porosity, high tensile and compression strength with a reduction in weight and density, thus these above-mentioned materials has been selected.

Keywords: fly ash, graphite, metal matrix composites, silicon carbide, stir casting

***Corresponding Author**
E-mail: Jaspreet.deep123@gmail.com

INTRODUCTION

Particulate reinforced metal matrix composites (MMCs) are one of the advanced engineering materials which have attracted more and more interests. The integration of hard ceramic phase to a relatively soft matrix alloy, commonly Al, improves the strength, creep performance, and wear resistance of the alloy [1–3]. Moreover, they exhibit light weight which make these materials appropriate for many submissions such as automotive and aerospace applications. Aluminium matrix composites (AMCs) are replacing the conventional aluminium alloys due to improved strength to weight ratio, which is one of the most desirable characteristic in automotive engine pistons, brake pads, turbine blades, etc. to mention a few among the most common applications of AMCs. AMCs reinforced with soft reinforcement particles of Gr have been reported to be holding better wear characteristics owing to the reduced wear because of formation of a thin layer of Gr particles, which prevents metal to metal contact of the sliding surfaces. A linear relation between the wear volume and load is observed [4, 5] for laser processed Al–Gr composites. The investigation Al–Gr composite [6, 7] Gr indicates reduced wear rate with increase in particulate content. The investigation on machining of Al–Gr composites [6] has indicate considerable reduction of cutting forces and this has been attributed to the possible reduction of friction due to solid lubrication of Gr particulates. Thus, the addition of Gr facilitates easy machining and results in reduced wear of Al–Gr composites compared to Al alloy. The priorities to use fly ash as a filler or reinforcement in metal and polymer matrices is that fly ash is a by-product of coal combustion, available in very large quantities (80 million tonnes per year) at very low costs since much of this is currently land filled. Presently, the use of manufactured glass microspheres has limited applications mainly due to their high cost of production. Therefore, the material costs of composites can be reduced significantly by incorporating fly ash into the matrices of polymers and metallic alloys. However, very little information is available on to aid in the design of composite materials, even though attempts have been made to incorporate fly ash in both polymer and metal matrices. Chemosphere fly ash has a lower density than talc and calcium carbonate, but slightly higher than hollow glass. The cost of chemosphere is likely to be much lower than hollow glass. Chemosphere may turn out to be one of the lowest cost fillers in terms of the cost per volume. The high electrical resistivity, low thermal conductivity and low density of fly-ash may be supportive for making a light weight insulating composites. Fly ash as a filler in Al casting decreases cost, reduces density and increase hardness, stiffness, wear and abrasion resistance. It also advances the machinability, damping capacity, coefficient of friction, etc. which are needed in various industries like automotive, etc. As the production of Al is reduced by the consumption of fly ash. This reduces the generation of greenhouse gases as they are produced during the bauxite processing and alumina reduction [8–15].

EXPERIMENTS

The MMC test specimen is fabricated by Stir casting method. Particle reinforced metal–matrix composites have been considerably investigated in recent researches. Generally, this type of composites is produced using stir casting methods, and there have been fewer investigations on producing them by powder metallurgy techniques. In the stir casting process, the alloy is melted at a controlled temperature and the desired quantity of fly ash is added to the molten aluminum alloy. The molten alloy is stirred continuously to create a vortex to force the slightly lighter particles into the melt. Stirring continues to disperse the fly ash particles as uniformly as possible in a short time. The matrix is then transferred into a preheated and precoated transfer ladle. The material is stirred again and then poured into preheated permanent molds. It is then cooled, cut to shape, and surface cleaned. The Al/SiCp/Graphite/Fly Ash Metal matrix composite is manufactured by using stir-casting as the primary processing technique. Al 6351 aluminum alloy, whose chemical composition has been presented above, is used as the matrix material and a mixture of SiC, Graphite and Fly Ash with volume fraction of 15% SiC +6%Graphite+10%Fly Ash and 7.5% SiC +3%Graphite+5%Fly Ash is used as reinforced material. In the stir-casting process, first, the Al matrix material is melted in a Silicon Carbide crucible contained within a resistance-heated furnace and the liquid metal is heated to 930ºC. Next, mixture of Sic, Graphite and Fly Ash particles pre-heated to 650ºC are added into the molten Al material in nitrogen gas flow with a rate of 20 g/min. The SiC particles are stirred by a mixer at 300 rev/min. After completing the stirring process, the mixed material is cast into a metallic mold at 850–900ºC, and then quenched in water together with the mold. After that the MMC is cooled in air. The hardness of the composites is evaluated using Vicker's Hardness Tester [16–20]. Polishing has been done on both specimens and then Vickers Hardness testing was done for Both the specimens and then both specimens were machined in the form of dumbbell for tensile testing, as shown in Figures 1 and 2. Figure 3 shows the specimens after breakage (Tables 1–3).

Table 1. *Mechanical properties of Sic.*

Elastic modulus (GPa)	Density (g/cc)	Microhardness	Compressive strength (MPa)

410	3.10	3000	345

Fig.1. *l6351+3%Gr+7.5%SiC+5%Flyash.*

Fig.2.*Al6351+15%SiC+6%Gr+10%Flyash.*

Table 2. *Mechanical properties of graphite.*

Elastic modulus (GPa)	Density (g/cc)	Microhardness	Compressive strength (MPa)
150	2.7	1200	200

RESULT ANALYSIS

From the results of the experiment undertaken on the specimen of the 15% SiC +6%Graphite+10%Fly Ash and 7.5% SiC +3%Graphite+5%Fly Ash it could be clearly seen that not only there is a hike in the hardness of the material and well as the tensile strength also increases with it. Thus, by adding SiC, Graphite & Fly Ash the hardness of the MMC produced is higher than the base metal. Thus, an MMC plays an important role in improving the qualities of the base metal that could easily allow the use of the processed metal in any of the desired operation which requires the desired properties of the metal.

Comparison With Steel of Grade AISI 1008

The hardness of MMC has matched the hardness of Steel grade AISI 1010 and thus it could be used at its place. Thus, the MMC prepared could be used at the following places in place of the steel of this grade-

Automobile components, including auto bodies, connecting rods, transmission covers etc., Structural shapes, Carburized parts, Washers Nails, Rivets & Bushes

Table 3. *Physical and mechanical properties of Al6351 with Sic, Gr and Fly ash particulates.*

Specimen	Hardness (HV) 1	Hardness (HV) (2)	Hardness (HV) (3)	Average
Al6351	104	100	106	103
Al6351+ 3%Gr+7.5%SiC +5%Fly ash	121	118	125	121
Al6351+ 15%SiC +6%Gr+ 10%Fly ash	136	142	145	141

The hardness of composite with 3% graphite and 7.5% Silicon carbide as a reinforcement is 121 while the hardness with 6% graphite and 15% Silicon carbide as reinforcement is 141, respectively.

The increase in hardness for the composites is not dramatic and may be due to the increase in their brittleness or due to very fine particles of grain size 1000 mesh.

Fig. 3. *Specimens after breakage.*

The output of hardness test shows an increasing trend with the increase in fly ash wt%, this is because the fly ash particle shows some resistance to dislocation which in turn resists the deformation. And it is also because the fly ash particles have higher hardness than aluminium. Thus, by observing the above figures and tables we can conclude that, with the addition of fly ash and SiC mechanical properties like tensile strength, compressive strength and hardness can be increased up to some extent [21–27].

CONCLUSIONS

Based on the observation and results obtained through experiments the following conclusions can be drawn. From the study, it is concluded that we can use fly ash for the production of composites and clearing the fly ash storage issues [28, 29].

- The porosities of the obtained cast composite have found to be increased with the increase of graphite particulates. This is due to the vortex found because of the stirring action, which enhances the dissolution of gases and causes more bubbles to be formed inside the melt which decreases the hardness of Al-Gr composites.
- The hardness for Al-SiC–Gr–Fly ash (141) composites is more as compared to aluminium (102) and may be due to the increase in their brittleness or due to very fine particles of grain size 1000 mesh.
- % Reinforcement affects the mechanical properties like tensile strength and hardness, etc.
- Increase of load increases wear by reducing the role of tribolayer.
- Hardness of Al-15% SiC –10% Fly ash (141) composite is considerably improved against Al-7.5% SiC-5%Fly ash (121) composite due to the addition of SiC particulates.
- Al-Gr composites, due to increase in percentage of graphite particulates reduces the fracture toughness, which results in higher wear rate.
- Fly ash up-to 10% by weight can be successfully added aluminium 6351 alloy by stir casting route to produce composites.
- Hardness of aluminium (Al6351) is increased from 102 HV to 141 HV with addition of fly ash and silicon carbide and graphite.
- The ultimate tensile strength has improved with increase in fly ash content. Whereas ductility has decreased with increase in fly ash content.
- Compressive strength increases with increase in reinforcement wt%.

REFERENCES

[1] J.B. Yang, C.B. Lin, T.C. Wang. *Wear*. 2004; 257: 941–52p.

[2] K. Radhakrishna. *Hardness and Wear Characteristics of Al-4.5%CU (LM11) Alloy and FLY ash Composite (AMC)*, Prof of BMS College of Engineering, June, 2008.
[3] Beinias, *Microstructure and Corrosion Behaviour of Aluminium Fly Ash Composites*. Dept of Materials Engineering, Lublin University of Technology, Poland, 2008.
[4] O. Yilmaz, S. Butoz. *Compos Sci Technol*. 2001; 61: 2381–92p.
[5] N.L. Han, Z.G. Wang, L.J. Sun. *Scr Metall Mater*. 1995; 62: 1739–45p.
[6] Y.B. Liu, J.D. Hu, Z.Y. Cao, P.K. Rohatgi. Wear resistance of laser processed Al-Si-Gr composites, *Wear*. 1997; 206: 83–6p.
[7] C.B. Lin, R.J. Chang, W.P. Weng. A study on process and tribological behavior of Al alloy/Gr.(p) composite, *Wear*. 1998; 217: 167–74p.
[8] L. Krishnamurthy, B.K. Sridhara, D. Abdul Budan. Comparative study on the machinability aspects of aluminium silicon carbide and aluminium graphite composite, *Mater Manuf Process*. 2007; 22: 903–8p.
[9] M.L. Ted Guo, C.Y.A. Tsao. Tribological behavior of self-lubricating aluminium/Sic/Gr hybrid composites synthesized by the semi-solid powder densification method, *Compos Sci Technol*. 2000; 60: 65–74p.
[10] J. Hashim. The production of cast metal matrix composite by a modified stir casting method, *J Technol*. 2001; 35(A): 9–20p.
[11] G.R.C. Pradeep, A. Ramesh, G.B. Veeresh Kumar. *Int J Adv Eng Appl*. 2011.
[12] Department of Defense. *Handbook Composite Materials Handbook*. Vol. 4. metal matrix composites (mil-hdbk-17-4a volume 4 of 5 17 June 2002 superseding mil-hdbk-17-4 21 September 1999).
[13] J. Dinwoodie. Automotive Applications for MMCs based on Shot Stample Aluminum Fibers. 1987.
[14] M.D. Smale. *The Mechanical Properties of Squeeze Cast Diesel Pistons*. 1985, 29p.
[15] S. Basavarajappa, G. Chandramohan, J. Paulo Davim. Application of Taguchi techniques to study dry sliding behaviour of metal matrix composites, *Mater Design*. 2001; 28; 1393–8p.
[16] M.H. Korkut. Effect of particulate reinforcement on wear behaviour of aluminum matrix composite, *Mater Sci Technol*. 2004; 20: 73–81p.
[17] P. Naresh. Development and characterization of metal matrix composite using red mud an industrial waste for wear resistant applications, *Doctor of Philosophy*. 2006.
[18] A.M. Hassan, G.M. Tashtoush, J.A. Al-Khalil. Effect of graphite and/or silicon carbide particles addition on the hardness and surface roughness of Al-4 wt% Mg alloy, *J Compos Mater*. 2007; 41: 453p.
[19] T. Ozben, E. Kilickap, O. Cakir. Investigation of mechanical and machinability properties of SiC particle reinforced Al-MM, *J Mater Process Technol*. 2008; 198: 220–5p.
[20] R.N. Rao, S. Das, P.V. Krishna. Experimental Investigation on the influence of SiC particulate reinforcement in aluminium alloy composites, *J Eng Tribol*. 2008; 222: 1p.
[21] Y. Yang, B.E. Stucker, G.D. Janaki Ram. Mechanical properties and microstructures of SiC fiber-reinforced metal matrix composites made using ultrasonic consolidation, *J Compos Mater*. 2010; 44: 26p.

[22] S. Suresha, B.K. Sridhara. Wear characteristics of hybrid aluminium matrix composites reinforced with graphite and silicon carbide particulates, *Compos Sci Technol*. 2010; 70: 1652–9p.
[23] H. Kumar, J. Paulo Davim. Role of powder in the machining of Al-10% SiCp metal matrix composites by powder mixed electric discharge machining, *J Compos Mater*. 2010; 45: 133p.
[24] S. Gopalakrishan, N. Murgan. Production and wear characteristics of AA 6061 matrix titanium carbide particulate reinforced composite by enhanced stir casting method, *Composites, Part B*. 2011.
[25] D. Satishkumar, M. Kanthababu. Investigation of wire electrical discharge machining characteristics of Al6063/SiCp composites, *Adv Manuf Technol*. 2011; 56: 975–86p.
[26] S.K. Ghosh, P. Saha. Crack and wear behaviour of SiC particulate reinforced aluminium based metal matrix composite fabricated by direct metal laser sintering process, *MaterDes*. 2011; 32: 139–45p.
[27] S.A. Sajjadi, H.R. Ezatpour, M. Torabi Parizi. Comparison of microstructure and mechanical properties of A356 aluminum alloy/Al2O3 composites fabricated by stir and compo-casting processes, *Mater Des*. 2012; l-34: 106–11p.
[28] G. Celebi Efe, M. Ipek. An investigation of the effect of SiC particle size on Cu-SiC composites, *Compos: Part B.* 2012; 43: 1813–22p.
[29] Properties of Materials. (http://www.newagepublishers.com/samplechapter/001653.pdf).

