International Journal of Engineering Studies.
ISSN 0975-6469 Volume 9, Number 1 (2017), pp. 11-19

http://www.ripublication.com

Processing and Characterization of Particulate Reinforced Aluminum 6061 Hybrid Metal Matrix Composites

S. Mujeeb Quader[1*], Dr. B. S. N. Murthy[2] and Dr. P. Ravinder Reddy[3]

[1] Department of Production Engineering, DCET, Hyderabad
[2]Department of Mechanical Engineering GIT, GITAM University, Visakhapatnam.
[3]Department of Mechanical Engineering, CBIT, Hyderabad.
[*]Corresponding author

Abstract

This paper describes and discusses the processing and characterization of alumina red mud particulate reinforced aluminum 6061 alloy matrix composites. In this regard, alumina (Al_2O_3) and red mud particulate reinforced A6061alloy matrix composites were fabricated by sand molding process with different particulate weight fractions. Hardness and tensile tests were performed to determine the hardness, tensile strength, yield strength and modulus of elasticity. Scanning electron microscopy studies have been performed to study the morphological aspects and characterize the fracture surface of the composite samples after tensile testing. Hardness and tensile strength of the composites increased with the increase in weight fraction of particulates reinforcement. The processed composite materials mechanical behavior is well supported by the fractographs taken using the scanning electron microscope.

Keywords: MMCs; AA6061; Mechanical properties; Fractograph

1. INTRODUCTION

Engineers and designers are continually seeking materials which maximize desired properties and minimize unwanted detrimental traits. Composite materials, specifically particle-reinforced metal matrix composites (MMCs), have been developed to combine the positive attributes of both the ductile metallic matrix and the hard reinforcement ceramic particles. The metal matrix is intended to provide strength and toughness while the ceramic reinforcement particles enhance stiffness, provide wear resistance and further strengthening as well [1].Metal Matrix Composites (MMCs) offer high strength to weight ratio, high stiffness and better wear resistance resulting in an ever increasing use in the aerospace, automotive and bio-medical industries. Common reinforcement materials for these composites are silicon carbide, alumina and boron carbide particles, aluminum, titanium and magnesium are the most commonly used matrix materials [2-5]. However, very limited studies have been reported on the study of Alumina red mud reinforcement in A6061 and the data available on the mechanical properties and fracture analysis are scarce and hence make this study a significant one. In this investigation Al_2O_3, red mud reinforced AA6061 matrix composites were fabricated by compocasting and hot extruded into rods. In this research work the addition of different percentages of reinforcement in the A6061 alloy matrix is examined to study the mechanical behavior and fracture surface characteristic of the processed specimens. This study, also discusses hardness, tensile testing and Scanning Electron Microscopy to evaluate hardness, yield strength, tensile strength, Young's modulus, and to characterize the morphological features of the fracture surfaces in Al_2O_3 red mud particulate reinforced A6061 alloy composites after the tensile testing.

2. EXPERIMENTAL WORK

The materials used in this work are Aluminum 6061 alloy as the matrix and Al_2O_3 and red mud mixed in equal quantities as reinforcement with different percentages based on the variation in weight fraction. AA6061 is an aluminum alloy with magnesium, silicon and copper as the major alloying elements. The addition of magnesium and silicon to aluminum produces a compound of magnesium-silicide (Mg_2Si) which provides this material its ability to become solution heat treated for improved strength. [6-8]**.** Alumina (Al_2O_3) a chemical compound of aluminum and oxygen has good wear resistance and high hardness and provides excellent hardness, low thermal expansion and high compressive strength thereby making it more suitable for applications where hardness is desirable. Red mud (Bauxite residue) is the waste byproduct generated during the production of aluminum by Bayers process. The ever increasing demand for low cost reinforcement stimulated the interest towards the utilization of red mud. In this work an attempt was made to use red mud a waste byproduct available free of cost as reinforcement material along with Al_2O_3 and aluminum as matrix material. Sand casting process was used to prepare the ingots as per the standard moulding procedure. Al_2O_3 red mud reinforced MMCs were fabricated by compocasting and the ingots were hot extruded with an extrusion ratio of 20:1. Four different percentage weight fractions of reinforcement particle in the range from 2.5, 5.0, 7.5 and 10% are used.

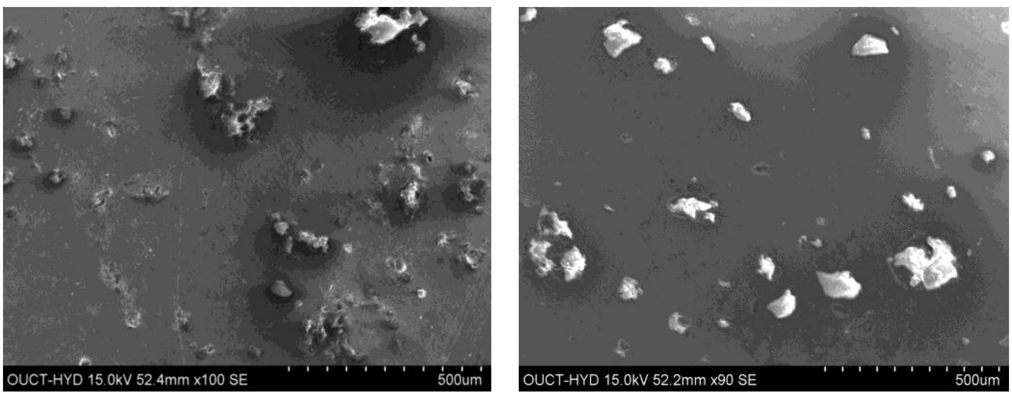
First proper quantity of matrix alloy was melted in a graphite crucible. The furnace temperature was first raised above the liquidus to melt the alloy completely and then temperature was reduced just below the liquidus to keep the slurry in a semi-solid state. At this stage the preheated reinforcement particles were added and mixed manually. After sufficient manual mixing was done, the composite slurry was reheated above the liquidus and then mechanical stirring was carried out for about 10 minutes at a stirring speed of 450 rpm [9]. In the final mixing process, the furnace temperature was controlled within 710^0 C. Composites containing 2.5, 5.0, 7.5 and 10.0 Wt% (Al_2O_3+Redmud) particles were cast into ingots. The cast ingots were hot extruded at 540^0C on a 50T hydraulic press with an extrusion ratio of 12:1. Specimens from the extruded rods were used for characterization and mechanical testing.

All tests were conducted in accordance with ASTM Standards. The hardness tests were conducted on the composite specimens in accordance with ASTM E-18 using a Rockwell hardness tester for different volume fraction of reinforcement and a graph is plotted between the hardness value and the particulate content. Tensile tests were performed at room temperature using a Universal Testing Machine in accordance with ASTM E8. The test samples are subjected to a tensile load on UTE 40 tensile testing machine and the mechanical properties determined. Tensile strength and young’s modulus values are calculated from tensile tests performed.

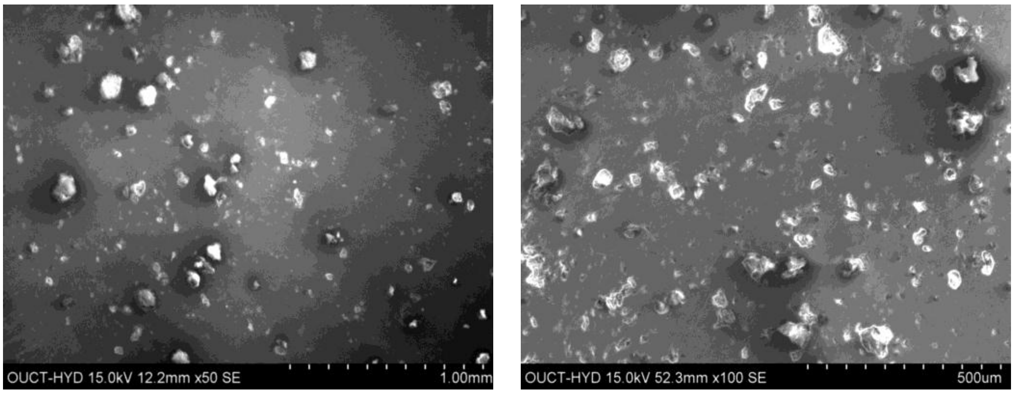
3. RESULTS AND DISCUSSION

3.1. Microstructure

The SEM micrograph in Fig. 1 shows the distribution of SiC particles in the composites in extruded conditions. Distribution of SiC particles is fairly uniform. Fig. 1(a) shows some clustering of the reinforcement.



(a) (b)



(c) (d)

Fig. 1. SEM micrograph of Al_2O_3 Red mud particle reinforced composite (a) 2.5% (b) 5.0% (c) 7.5% (d) 10.0% reinforcement.

3.2. Tensile test

The tensile test results conducted at room temperature on the cast and extruded Al 6061 alloy and their composites indicate an improvement in strength values with the increase in reinforcement content. Fig. 2 shows the relationship between the Ultimate Tensile Strength (UTS) values of Al_2O_3 red mud reinforced Al (6061) composites with respect to the varying weight fraction of reinforcement.

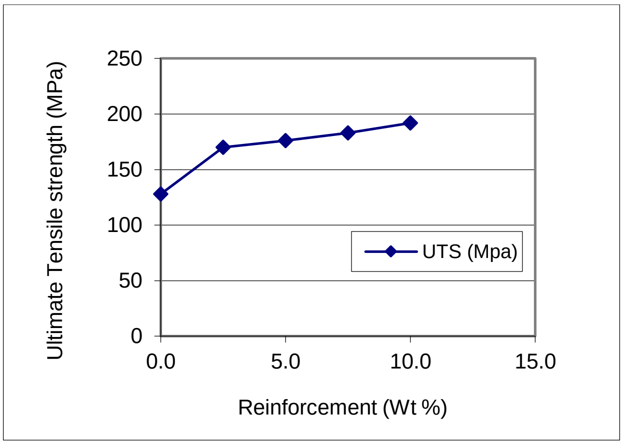


Fig. 2. Tensile strength versus volume fraction of Al_2O_3 and red mud

The modulus of elasticity values versus variation in volume fraction is shown in Fig. 3 The reinforcement particulate addition to Al 6061 alloy indicates that the young's modulus increase with increasing addition of reinforcement particulates. The fluctuation in modulus of elasticity maybe due to the non-uniform distribution of reinforcement particulates, and or also depends on the cooling rate of the castings.

This residual stress affects the material properties around the crack tips and the fracture toughness values would be altered. Consequently, these residual stresses would probably contribute for the brittle nature of composites [10-12].

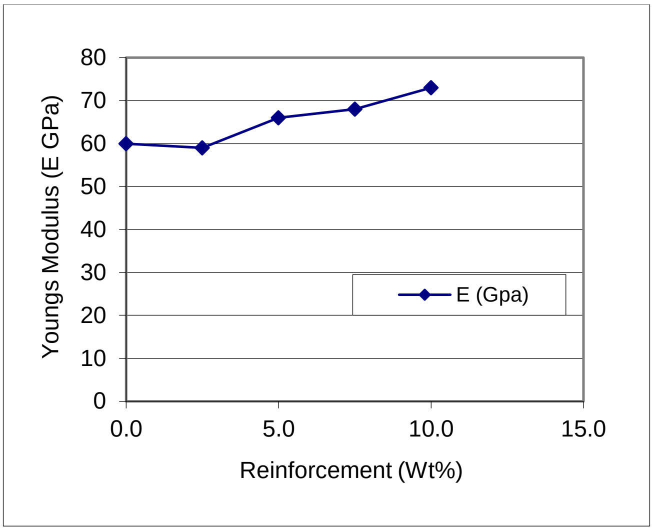


Fig. 3. Young modulus versus volume fraction of reinforcement

3.3. Hardness test

The Rockwell hardness measurements shown in Fig. 4 indicate an increase in the hardness values of the cast and extruded composite materials. This increase in hardness values corresponds to the presence of comparatively harder Al_2O_3 and red mud particles.

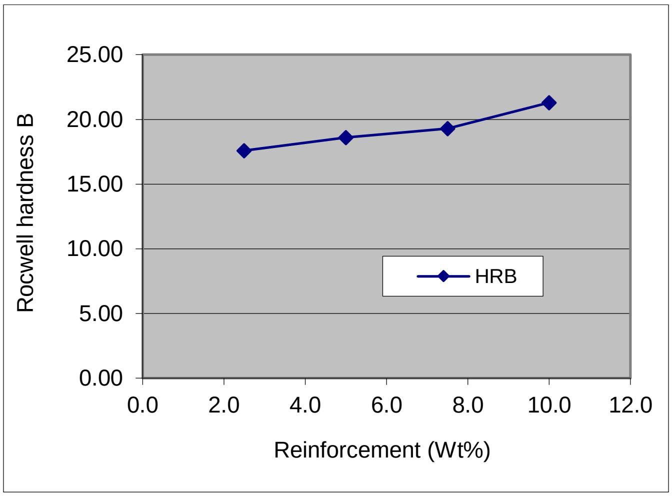


Fig. 4. Hardness versus Reinforcement volume fraction

3.4. Scanning Electron Microscopy (SEM)

Scanning Electron microscopy was employed to characterize the fracture surface of the composite. The fracture surface characterization results indicating the fracture mechanism of extruded AA 6061 composites under tensile loading are shown in Fig. 5-8. The fractured surface represents dimpled structure typical of tensile overload fracture in all the cases. The dimples are observed to be equiaxed and shallow which indicates low ductility of the material.

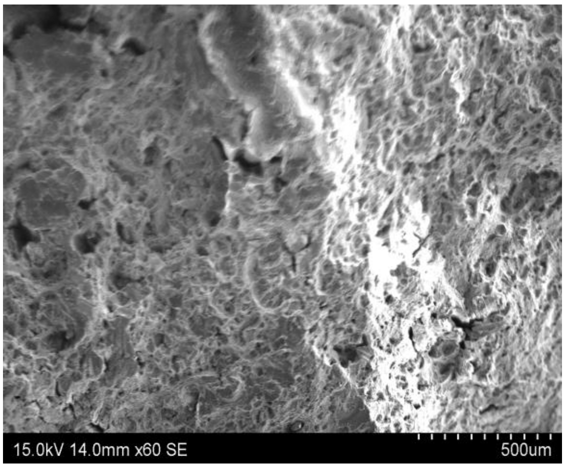


Fig. 5. Fractograph of 2.5% Al_2O_3 red mud particulates reinforced hybrid metal matrix composite after tensile testing.

The presence of dimples on fracture surface clearly indicates that necking had occurred prior to matrix fracture. With the increasing presence of reinforcement particulates, intergranular cracks and dimple like features (Fig. 8) were observed.

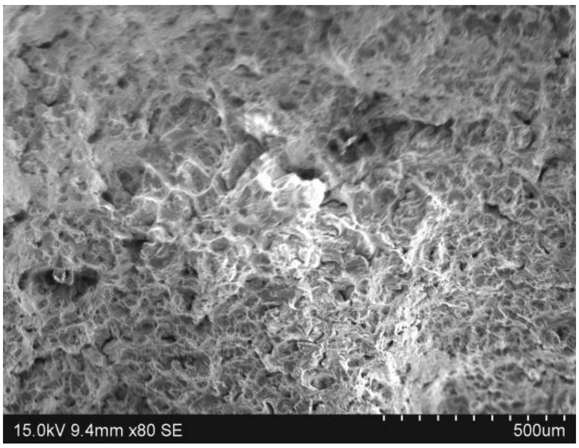


Fig. 6. Fractograph of 5.0% Al_2O_3 red mud particulates reinforced hybrid metal matrix composite after tensile testing.

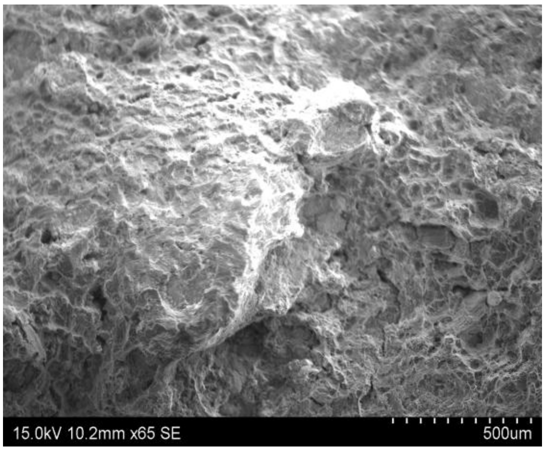


Fig. 7. Fractograph of 7.5% Al_2O_3 red mud particulates reinforced hybrid metal matrix composite after tensile testing.

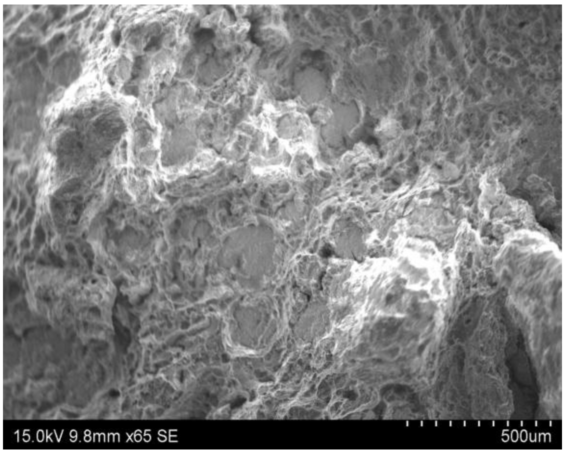


Fig. 8. Fractograph of 10% Al_2O_3 red mud particulates reinforced hybrid metal matrix composite after tensile testing.

It is observed that there are no gaps or micro-voids at the of particle/matrix interface in the fracture surface. Some micro shrinkage porosity is observed on the SEM fractographs, shown in Fig. 5-8 this seems to be the main mechanism of composites failure. The micro shrinkage may be due to the melt contraction within the reinforcement, since this is not compensated immediately before the melt solidifies.

4. CONCLUSIONS

In this experimental study, Al_2O_3 red mud reinforced AA6061 hybrid metal matrix composite containing different quantities of reinforcement were successfully fabricated by compocasting. Hardness, tensile strength and fracture surface morphological aspects of composites test specimens are described. Based on the experimental evidence from this research work the following conclusions are drawn:

1. The tensile strength and young's modulus values increased gradually as the reinforcement content in the composite increased from 2.5% to 10% by weight fraction.
2. The hardness value of the Al_2O_3 red mud reinforced AA6061 alloy matrix composites is increased with the increased addition of reinforcement particulate in the matrix and it is well supported by the increase in tensile strength.
3. The mechanical behavior of the processed composite had a strong dependence on the volume fraction of the reinforcement particulate on the alloy matrix.
4. All the composites showed some amount of ductility which is evident from the fractographs.

REFERENCES

[1] Callister, William D. Jr., *Materials Science and Engineering,* 2nd Edition, John Wiley & Sons, Inc., 1991.

[2] Zebarjad SM, Sajjadi SA. Dependency of physical and mechanical properties of mechanical alloyed Al–Al_2O_3 composite on milling time. Mater Des 2007; 28: 2113–20.

[3] Dandekar C.R, Shin Y.C. Effect of porosity on the interface behavior ofanAl_2O_3– aluminum composite: a molecular dynamics study Compos Sci Technol 2011; 71:350–6.

[4] Kalaiselvan K, Murugan N, Parameswaran S. Production and characterization of AA6061–B_4C stir cast composite.Mater Des 2011; 32:4004–9.

[5] Amirkhanlou S, Rezaei MR, Niroumand B, Toroghinejad MR. High-strength and highly-uniform composites produced by compocasting and cold rolling processes. Mater Des 2011; 32:2085–90

[6] Hamerton, R.G., Hirth, S.M., Gatenby, K.M., Court, S.A.., Ricks, R.A.: Al-Mg Alloys for Automotive Applications - Design Considerations and Matl's Selection, Proc. Intern'l Body Engg Conf. (IBEC97) (ed: S.G. Kelkar), 30/9 - 02/10 '97, Stuttgart, pp.1-6

[7] J.A. Jacobs, T.F. Kilduff, Engineering Materials Technology, Structures, Processing, Properties & Selection, Prentice hall, 1994.

[8] J.N. Fridlyander, Metal matrix composite, Chapman & Hall, 1995.

[9] .K. Rohatgi, R. Asthana and F. Yarandi, in *Solidification of Metal Matrix Composites,* (P.K. Rohatgi ed.), TMSASM Committee, TMS Publication, (1989) 51-76.

[10] S.J. Zhu, T. Iizuka, Fabrication and mechanical behavior of Al matrix composites reinforced with porous ceramic of in situ grown whisker framework, International Journal of Material Science and Engineering a 354 (2003) 306-314.

[11] T. Richardson, Composites design guides, New York industries press Incorporation, 1987.

[12] S.C. Sharma, K.H.W. Seah, B.M. Girish, R. Kamath, B.M. Satish, Mechanical properties and fractography of cast lead-alloy/quartz particulate composites, Materials & Design, International Journal of Material Science and Engineering 18/3 (1997) 149-153.