Journal of Material Science and Mechanical Engineering (JMSME)
Print ISSN: 2393-9095; Online ISSN: 2393-9109; Volume 2, Number 1; January-March, 2015 pp. 8-12
© Krishi Sanskriti Publications
http://www.krishisanskriti.org/jmsme.html

Some Mechanical Properties of Aluminum Alumina Silicon Carbide Matrix Particulate Reinforced Hybrid Composite

N. Laxmi[1], K.S. Raghu Ram[2] and Ch. Sivarama Krishna[3]

[1]M. Tech Student Vignan's Institute of Information Technology, Visakhapatnam, A.P
[2]Vignan's Institute of Information Technology, Visakhapatnam, A.P.
E-mail: [1]lakshmi.nellipudi@gmail.com, [2]k_sraghuram@yahoo.co.in, [3]srkchadaram@gmail.com*

Abstract—*The present work gives improved properties of light weight Aluminum matrix composite materials. The present work gives evolution of innovative material used for various aviation applications of aero industry. More Strength/weight ratio is the main property of the material manufactured in the present work. Metal matrix composites provide significantly enhanced properties like higher strength, stiffness and weight savings in comparison to conventional materials. Particle reinforced Metal Matrix Composites are widely used due to their cost-effectiveness, isotropic properties and their ability to be processed using similar technology used for monolithic materials.*

This review captures the salient and special features of experimental characterization of the advanced materials and the mechanical behavior of Metal Matrix Composites made from the industrial waste. The main focus of this work is on wrought particulate reinforced light alloy matrix systems, with a particular emphasis on tensile and impact behavior of the material made from industrial waste.

1. INTRODUCTION

Industrial waste disposal is a major problem being facing by lot many industries. The present paper is aimed to give value addition to the industrial waste. Aluminum purification industries are segregating lots of heaps of mud after the purification of Aluminum ore. It is being a social and health problem. The present work is the production of Aluminum Matrix particulate composite material that suits best light weight applications of aeronautical, automobile and aviation industries. The aluminum Matrix Composite materials are widely used in a number of defense applications. Aluminum Metal matrix composites (MMCs), like most composite materials, provide significantly enhanced properties over conventional monolithic materials, such as higher strength, stiffness, and weight savings.[1-4]. While continuous fiber reinforcement provides the most effective strengthening (in a given direction), particle reinforced materials are more attractive due to their cost-effectiveness, isotropic properties, and their ability to be processed using similar technology used for monolithic materials. A large amount of work has been conducted in an effort to characterize the mechanical behavior of particle reinforced metal matrix composites. In this review, we attempt to capture the salient features of experimental as well as analytical and computational characterization of the mechanical behavior of MMCs. We restrict ourselves to wrought particulate reinforced light alloy matrix systems, with a particular emphasis on tensile, creep, and fatigue behavior.

2. STRENGTHENING MECHANISMS IN METAL MATRIX COMPOSITES

The strengthening mechanisms observed in MMCs may be divided into two categories, direct and indirect strengthening. Direct strengthening in particulate reinforced metals is an extension of the classical composite strengthening mechanisms used to describe the behavior of continuous fiber reinforced composites.[1,5,6] Under an applied load, the load is transferred from the weaker matrix, across the matrix/reinforcement interface, to the typically higher stiffness reinforcement.

In this manner, strengthening takes place by the reinforcement carrying much of the applied load. Due to the lower aspect ratio of particulate materials, load transfer is not as efficient as in the case of continuous fiber reinforcement, but is still significant in providing strengthening.[7,8,9]

In metal matrix composites, where a high stiffness ceramic reinforcement is embedded in a metallic alloy, the thermal mismatch between the high expansion metallic matrix and the low expansion ceramic is typically quite high. Thus, upon cooling, dislocations form at the reinforcement/matrix interface due to the thermal mismatch. In this manner, thermally induced dislocation punching results in ªindirect strengtheningº of the matrix.[10 – 13].

There may be a distribution of precipitates in the particle/matrix interface region. Higher density of dislocations in the composite material by stir casting also causes acceleration in the time to peak-aging compared to the unreinforced alloy of a similar composition. An increase of reinforcement volume fraction or a decrease in particle size increases the amount of indirect strengthening. This causes a larger amount of interfaces exist for dislocation punching to take place.

Table 1: Showing the different types of composite materials manufacturing methods with various parameters

Method	Range	Shape of the Casting	Volume fraction	Reinforcement damage	Cost of production
Stir Casting	Wide range of shapes	Larger size upto 500 Kg.	Upto 0.3	No Damage	Least Expensive
Squeeze Casting	Limited (reform is needed)	Shape upto 2Cm height	Upto 0.5	Severe Damage	Moderate Expensive
Powder Metallurgy	Wide Range	Restricted Shape		Reinforcement fracture	Expensive
Spray Casting	Limited shape	large shape	0.3 – 0.7		Expensive

The indirect strengthening is very difficult to quantify than the contribution from direct strengthening. Krajewski et al.[15] used a thermomechanical treatment, consisting of solution treating, rolling, followed by aging (T8 treatment) to provide a homogeneous distribution of dislocations (and subsequently precipitates) in both the matrix of the composite and the unreinforced alloy. In this manner, the difference in strengthening between unreinforced and composite could be attributed primarily to load transfer to the reinforcement.

Chawla et al.[9] compared experimental data on T8-matrix composites with a simple modified shear lag analysis proposed by Nardone and Prewo,[7] and obtained extremely good correlation. It was also shown that in peak-aged materials only (without rolling), the strengthening in the composite could be partitioned into direct and indirect strengthening components.

3. TENSILE BEHAVIOR

In metal matrix composites, the reinforcing phase typically is much stiffer and ceremic in nature than the matrix material. Thus a significant volume fraction of the stress is initially borne by the reinforcement. This is given by adopting rule of mixtures to the composite material

Microplasticity takes place in MMCs, at a fairly low stress, which corresponds to a slight deviation from linearity in the stress-strain curve. This point is termed the proportional limit stress. Microplasticity in the composites has been attributed to stress concentrations in the matrix at the poles of the reinforcement and/or at sharp corners of the reinforcing particles.[16±18] The initial microyielding stress decreases with increasing volume fraction, as the number of stress concentrating points increases.[18] The incorporation of particles in the matrix so results in an increase in apparent work hardening in the material. The term ‘apparent’ is used here because the higher observed work hardening rate is a simple function of lower matrix volume (by incorporation of the particles) and not necessarily due to a change in work hardening mechanisms. Thus, the higher work hardening rate observed in the composites is due to geometric constraints imposed by the presence of the reinforcement. When the matrix is significantly work hardened, the matrix is placed under great constraint with an inability for strain relaxation to take place. This causes the onset of void nucleation and propagation, which take place at a lower far field applied strain than that observed in the unreinforced material.

The tensile strength of the Aluminum Alumina Silicon Carbide matrix composite with varying volume fraction and particle size of approximately 30 microns are studies. With an increase in volume fraction, higher elastic modulus, macroscopic yield and tensile strengths were observed, coupled with lower ductility.

With increasing volume fraction of the particulate, more load is transferred to the reinforcement which also results in a higher ultimate tensile strength. The work hardening rate increases with increasing volume fraction of reinforcement and decreasing matrix volume. The lower ductility can be obtained to the earlier onset of void nucleation with increasing amount of reinforcement. It should be noted that the cracked particles in the composite material, which may result from processing of composites with fairly coarse particulate reinforcement, do not contribute to load transfer or strengthening and would decrease strength. The high stress concentration at the tips of the cracked particles would also contribute to a lower ductility in the composite, compared to the unreinforced alloy. The rule of mixtures adopted for manufacturing composite material is given by

$$\sigma_c = v_m \sigma_m + v_p \sigma_p$$

where σ_c,σ_m and σ_p are the densities of composite material, matrix and particulate material respectively and

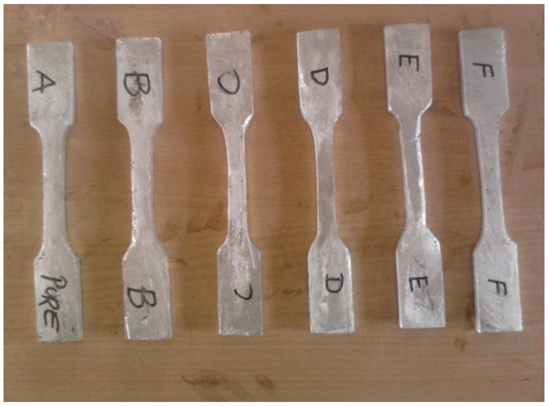
V_m and V_p are the volume fractions of the matrix and particulate materials.

Table 2: showing the properties of the reinforcement particulates that can be mixed with Aluminum

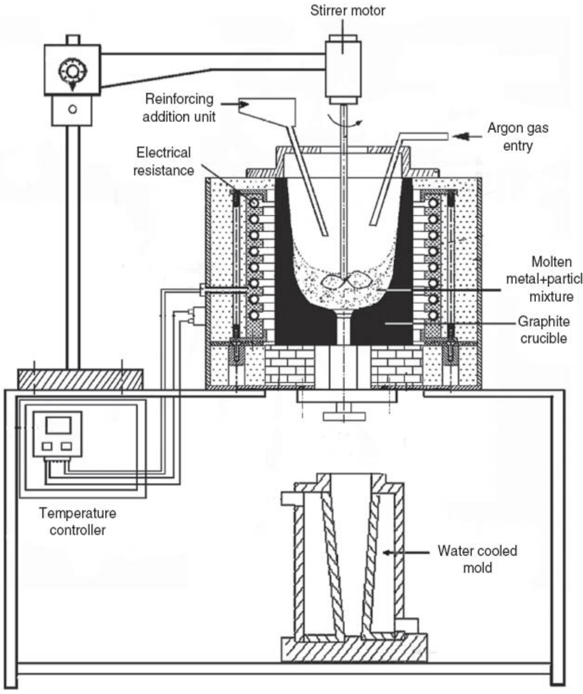
S. No.	Material	Tensile Modulus (GPa)	Tensile Strength (GPa)	Compressive Strength (GPa)	Density (g/cm3)
1.	Alumina	350 – 380	1.7	6.9	3.9
2.	Boron	415	3.5	5.9	2.5 – 2.6
3.	SiC	200	2.8	3.1	2.8

The effect of particle size on tensile behavior, documented by several investigators,[19 - 21] indicates an increase in ductility with a decrease in particle size. This may be attributed to an increase in the Al_2O_3 SiC particle strength with a decrease in particle size, because the probability of a strength-limiting flaw existing in the volume of the material decreases.

Figure showing the specimens



Specimens with varying % Volume A)Pure Aluminum B) 10% C)15% D)20% E) 30% F)35% volume fraction of the Al2O3 SiC particulate material



Schematic diagram showing the experimental setup for the preparation of the specimens for the present composite material preparation.

At relatively large particle sizes of this particulate material, a significant amount of particle cracking takes place during extrusion prior to testing. Cracked particles in the composite material do not carry any load effectively and can be treated as as voids, so the strength is lower than that of the unreinforced material. It has also been proposed, however, that because of the higher plastic constraint imposed by the lower interparticle spacing, that the nucleated voids are unable to coalesce as easily.[20] A higher work hardening rate has also been observed with decreasing particle size.[21,22] This is attributed to the formation of dislocation tangles around the particles, due to plastic incompatibility between the reinforcement and matrix, and the formation of a dislocation cell structure with a cell size inversely proportional to the interparticle spacing.[23]

The tensile fracture surface of a particulate reinforced composite shows quite a contrast between the dimpled nature of fracture in the matrix coupled with brittle fracture of the SiC particles[24]. Notice that the particle/matrix interface remains intact, indicating that the shear strength at the interface was higher than the particle fracture.

The mathematical Equations representing the Upper and Lower values of the Composite material.

$$E_c(u) = E_m V_m + E_p V_p$$

$$E_c(l) = \frac{E_m E_p}{V_m E_p + V_p E_m}$$

In the above two equations $E_c(u)$ and $E_c(l)$ are the upper and lower Young's moduli of Elasticity of the composite material

E_m, E_p are the Young's modulus of the matrix and particulate material calculated from the tables V_m, V_p are the Volume fraction of the matrix and particulate material With decreasing particle size of the particulate material, for a given reinforcement volume fraction, the reinforcement inter particle spacing decreases, resulting in more barriers for the reversible slip motion that takes place during tensile testing of the specimens.

Processing-related defects in the form of inter metallic inclusions or particle clusters are part of the matrix microstructure, and play a role in tensile strength, particularly in powder metallurgy processed materials.[19] These defects develop stress concentrations and increase the local stress intensity in the material and promote easy crack nucleation. It is observed that crack initiation during tensile test takes place at these defects, which are typically located at the surface of the specimen. This is because inclusions at the surface are more highly stressed than the inclusions completely within the matrix (where more load is shared by the reinforcement), so a higher stress concentration and higher probability for crack initiation is present at the surface. For a given inclusion size, the stress concentration in a composite where the inclusion is surrounded by high stiffness reinforcement particles, is lower than in the unreinforced alloy. Since more of the load is being shared by the high stiffness SiC particles in the composite, an inclusion in the composite will be subjected to lower stress than a similar inclusion in the unreinforced alloy.

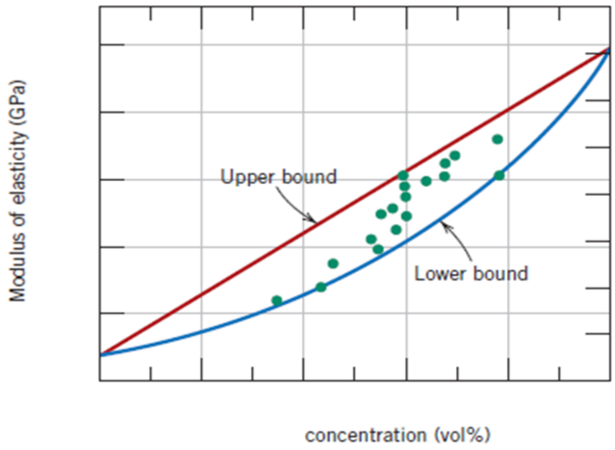
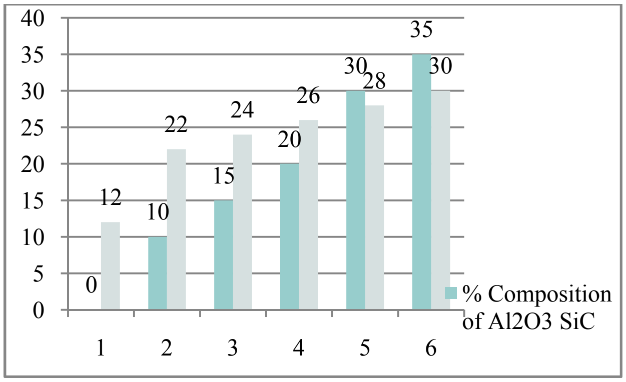


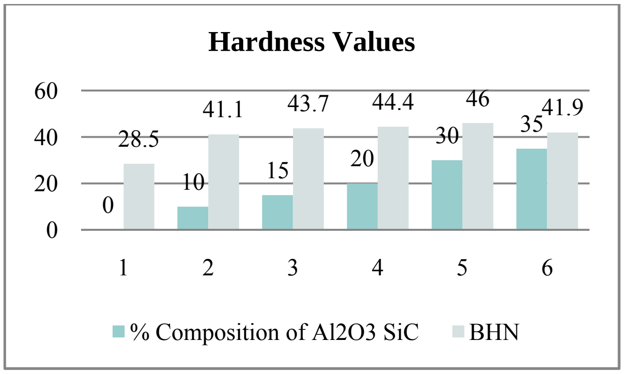
Figure showing the variation of Upper bound and Lower bound values of Modulus of Elasticity with respect to Volume fraction

This means that the proportional limit for the composite is actually lower than that of monolithic matrix material, although the composite shows much higher macroscopic yield strength.

The applications of the above said composite material is also high in the fields of aerospace technologies where strength/weight ratio is the main criteria. Also the Aluminum Matrix Composite materials widely used in the Automobile industries.



Graph showing the impact strength with various % Composition of the specimens



Graph showing the hardness values of the different composite materials

4. CONCLUSIONS

This investigation led to the following conclusions:

- Discontinuous Al_2O_3 SiC / Al composites offer a 50 to 60 percent increase over the modulus of unreinforced aluminum and offer a good modulus.
- The Al_2O_3 SiC/Al Composites had modulus/density ratios of up to almost twice those of pure titanium and aluminum structural alloys.
- The modulus of Al_2O_3 SiC/Al composite tends to be isotropic and was controlled by the amount of Al_2O_3 SiC reinforcement.
- The yield and tensile strengths of Al_2O_3 SiC/Al composites demonstrated upto a 60% increase over those of the unreinforced matrix alloys.
- High value of strength/Weight ratio is obtained with the Aluminum Matrix Composite Material.

REFERENCES

[1] K. K. Chawla, Composite Materials - Science and Engineering, 2nd Ed., Springer-Verlag, New York, 1997, 102.
[2] Y. Jaya Santhoshi Kumari, K.S.Raghu Ram, Ch.Siva Rama Krishna, "Aluminum Fly Ash Metal Matrix Composites – A value added material made from thermal power plant's waste disposal, Paper submitted at International Conference ASET-2015, JNU, New Delhi.
[3] T. W. Clyne, P. J. Withers, An Introduction to Metal Matrix Composites, Cambridge University Press, Cambridge, 1993, 1.
[4] M. J. Koczak, S. C. Khatri, J. E. Allison, M. G. Bader, in Fundamentals of Metal Matrix Composites, (Eds. S. Suresh, A. Mortensen, A. Needleman), Butterworth-Heinemann, Stoneham, MA, 1993, 297.
[5] H. L. Cox, Brit. J. App. Phys., 1952, 3, 122.
[6] A. Kelly, Strong Solids, Clarendon Press, Oxford, 1973, 157.
[7] V. C. Nardone, K. M. Prewo, Scripta Metall., 1989, 23, 291.
[8] L. C. Davis, J. E. Allison, Metall. Trans. A, 1993, 24A, 2487.
[9] N. Chawla, U. Habel, Y.-L. Shen, C. Andres, J. W. Jones, J. E. Allison, Metall. Mater. Trans., 2000, 31A, 531 - 540.
[10] K. K. Chawla, M. Metzger, J. Mater. Sci., 1972, 7, 34.
[11] K. K. Chawla, Phil. Mag., 1973, 28, 401.
[12] M. Vogelsang, R. J. Arsenault, R. M. Fisher, Metall. Trans. A, 1986, 17A, 379.

[13] R. J. Arsenault, N. Shi, Mater. Sci. Eng., 1986, 81, 175.

[14] S. Suresh, K. K. Chawla, in Fundamentals of Metal Matrix Composites, (Eds. S. Suresh, A. Mortensen, A. Needleman), Butterworth-Heinemann, Stoneham, MA, 1993, 119.

[15] P. E. Krajewski, J. E. Allison, J. W. Jones, Metall. Mater. Trans., 1993, 24, 2731.

[16] J. N. Goodier, J. Appl. Mech., 1933, 55±7, 39.

[17] S. F. Corbin, D. S. Wilkinson, Acta Metall. Mater., 1994, 42, 1319.

[18] N. Chawla, C. Andres, J. W. Jones, J. E. Allison, Scripta Mater., 1998, 38, 1596.

[19] N. Chawla, C. Andres, J. W. Jones, J. E. Allison, Metall. Mater. Trans., 1998, 29A, 2843.

[20] P. M. Mummery, B. Derby, D. J. Buttle, C. B. Scruby, in Proc. of Euromat 91, (Eds. T. W. Clyne, P. J. Withers), vol. 2, Cambridge, UK, 1991, 441 - 447.

[21] M. Manoharan, J. J. Lewandowski, Mater. Sci. Eng., 1992, A150, 179 - 186.

[22] J. J. Lewandowski, D. S. Liu, C. Liu, Scripta Metall., 1991, 25, 21.

[23] S. Kamat, J. P. Hirth, R. Mehrabian, Acta Metall., 1989, 37, 2395.

[24] N. Chawla, J. J. Williams, G. Piotrowski, R. Saha, in Proc. of Internat. Congress on Fracture ICF-10, (Eds.: K. Ravichandran, R. O. Ritchie), 2001, in press.

[25] F. A. Mohamed, K.-T. Park, E. J. Lavernia, Mater. Sci. Eng., 1992, A150, 21 - 35.

[26] T. G. Nieh, Metall. Trans., 1984, 15A, 139±146.

[27] D. Webster, Metall. Mater. Trans., 1982, 13A, 1511 - 1519.

[28] K.S.Raghu Ram, Dr. N.V.S.Raju, Dr. C.V.Gopinath, N.Rao, “Aluminum-Alumina matrix in-situ particulate composites – A smart material” at 4th international Conference on Advances in Mechanical Engineering (ICAME) conducted by NIT Surat.

[29] K.S.Raghu Ram, Dr.N.V.S.Raju, “Manufacturing results of Aluminum Matrix composite materials Reinforced by in-situ Al2O3 SiC particulates”,Bionano Frontier ISSN 0974-0678.

[30] K.S.Raghuram, Dr. N.V.S.Raju, “Strength properties of Aluminum matrix particulate composite materials” a technical paper submitted by at the international conference at Swarnandra Engineering college, Palkol.

[31] A.K.Kaw, Mechanics of Composite Materials, CRC Press LLC, 1997, p.145.

[32] D.J.LIoyd, “Particle reinforced aluminum and magnesium matrix composites,” International Materials Reviews, Vol. 39, No. 1, 1994, p.1-23.

[33] R.M.Jones, Mechanics of Composite materials, Taylor &Francis Inc., 1999, p.137.

[34] T.S.Srivatsan and R.Annigeri, “The quasi-static and cyclic fatigue fracture behavior of 20 14 aluminum alloy metal-matrix composites,” Metallurgical and Materials Transactions A, Vol. 31A, No. 3, 2000, p. 959.

[35] N.Chawla, U.Habel, Y.L.Shen, C.Andres, J.W.Jones, J.E.Allison, “The effect of matrix microstructure on the tensile and fatigue behavior of Sic particle-reinforced 2080 Al matrix composites,” Metallurgical and Materials Transaction A, Vol. 31 A, 2000, p.531,