ALUMINIUM -B4C METAL MATRIX COMPOSITES- A REVIEW

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Abstract

out of the varities of metal matrices used in composites viz., Aluminium, Iron, Magnesium, Titanium, Copper etc, Aluminium as a matrix is widely used for various applications due to its light weight, reliable mechanical properties, high thermal and electrical conductivity, ductility, malleability, low coefficient of thermal expansion, better corrosion resistance and may moredesirable properties. Addition of various particulate reinforcements like SiC, Al_2O_3, Boron, B_4C, TiC etc into Aluminium improves there stiffness, specific strength, fatigue, conductivity, creep and fatigue properties, and also improves resistance to wear and corrosion. Of all the particlulates B_4C is emerging as a promising reinforcements due to its high hardness, good chemical resistance, good nuclear properties and low density. This paper focusses on the effects of B4C reinforcement on Aluminium matrix composites.

Keywords: Aluminium Matrix Composites (AMCs); Reinforcement, B_4C

Introduction

Metal matrix composites (MMCs) constitute an important class of design and weight-efficient structural materials that are encouraging every sphere of engineering applications[1]. In recent years, metal matrix composites are gaining tremendous popularity over the conventional metals/alloys in various sectors such as automobile, aerospace and sports owing to the fact that properties can be tailored as per ones requirement- A uniqueness of composites[2]. Metal matrix composites possess higher strength, better wear resistance, higher temperature oxidation resistance, good damping characteristics when compared with its matrix alloy.

MMCs are metals reinforced with other metal, ceramic or organic compounds. They are made by dispersing the reinforcements in the metal matrix. Reinforcements are usually used to improve specific properties of the base metal like strength, stiffness, conductivity, etc. Aluminium and its alloys have attracted most attention as base metal in metal matrix composites. Aluminium MMCs are widely used in aircraft, aerospace, automobiles and various other fields. The reinforcement should be stable in the given working temperature and non-reactive in nature. The most commonly used reinforcements are Silicon Carbide (SiC) and Aluminium Oxide (Al_2O_3)[3]. Aluminium Metal matrix composites (MMCs) are a range of advanced materials providing properties which are superior when compafred to their conventional counterparts. These materials range from metals like copper, cast iron, brass etc, which have been available for several hundred years, to the more recently developed, advanced materials viz., composites, ceramics, and high-performance steels. Due to the wide choice of materials, today's engineers are posed with a big challenge for the right selection of a material. Among all materials, composite materials have the potential to replace widely used steel and aluminium, with superior performance. Replacing steel components with composite components can save 60 to 80% in component weight, and 20 to 50% weight by replacing aluminium parts. Composite materials have become common engineering materials and are designed and manufactured for various applications including automotive components, sporting goods, aerospace parts, consumer goods, and in the marine and oil industries [4].

The particle distribution plays a very vital role in the properties of the Al MMC and is improved by intensive shearing. Boron Carbide is one of hardest known elements with high elastic modulus and fracture toughness (4). The addition of Boron Carbide (B_4C) in Al matrix increases the hardness, but does not improve the wear resistance significantly (5). Further, B4C possesses the specific ability of neutron absorption. Al-B_4C metal matrix composites (MMCs) can enhance the properties of aluminium alloy matrix, such as higher strength and stiffness, better wear resistance, and smaller thermal expansion. Combination of these properties is not available in a conventional material Therefore, Al-B_4C MMCs have been increasingly used as structural neutron absorber, aircraft landing gear, armour plate materials, and as a substrate material for computer hard disks. In addition, the possible applications include air-frame components, automotive engines, brake disc components, bicycle frames and many more to be explored.

Aluminium as a metal matrix

The aluminium matrices are in general Al-Si, Al-Cu, 2xxx or 6xxx alloys. As proposed by the American Aluminium Association the AMCs should be designated by their constituents: accepted designation of the matrix/abbreviation of the reinforcement's designation/ arrangement and volume fraction in % with symbol of type (shape) of reinforcement. For Example, an aluminium alloy AA6061 reinforced by particulates of alumina, 22 % volume Fraction, is designated as; AA6061/Al_2O_3 /22p. 6061Al is quite a popular choice as a matrix material to prepare MMCs owing to its better formability characteristics. Among different kinds of the recently developed composites, particle reinforced metal matrix composites and in particular aluminium base materials have already emerged as candidates for industrial applications.

Table.1.1: Al 6061 alloy composition

Compsition		Al	Mg	Si	Fe	Cu	Cr	Zn	Ti	Mn
%age Weight	Min	95.85	0.8	0.40	0.0	0.1	0.04	0.0	0.0	0.0
	Max	98.56	1.2	0.8	0.7	0.40	0.35	0.25	0.25	0.15

Boron Carbide as Reinforcement

Boron carbide is one of the hardest ceramic compound known. It is a cristaline compound of Boron and Carbon. It is a very hard synethetically manufactured materials mostly used in abrasive and wear resitant materials like bullet proof vests, armour tank etc. Hence, B4C reinforced aluminium matrix composite has gained more attraction with low cost casting route. Table 1.2 shows various properties of B_4Ccompound.

Table 1.2: B_4C composition

Property	Value
Density (g/cm^3)	2.52
Melting Point (°C)	2445
Hardness (kg/mm^2)	2900 - 3580
Fracture Toughness (MPa)	2.9 - 3.7
Young's Modulus (GPa)	450 - 470
Electrical Conductivity (at25°C)(S)	140
Thermal Conductivity (at25°C)(W/m.K)	30 - 42

Literature

K. Raj Kumar et.al., [5] have investigated on the effect of the B_4C reinforcement on Aluminium matrix. The composites were fabricated with the reinforcement varied from 5 to 15wt% fabricated by the stir casting method. It is reported on the mechanical and machining characteristic of aluminium- Boron Carbide composites. It is stated that the hardness of the composite increases with increase in reinforcement. Whereas, the impact strength of the material is decreased with increase in weight percentage of reinforcement which was quoted to increase in brittleness with increase in B_4C wt% in the matrix. Further, the influence of the cutting speed, feed rate and depth on cutting force during machining of MMC is reported. It is reported that with increase in cutting speed will reduce the chip tool contact length therefore cutting force is reduced. However, the cutting force increased with increase in feed rate which was attributed to that fact that, at constant speed and depth of cut, an increase in feed rate causes excessive friction between the tool and work piece, which increases the cutting force. Also, at for a given constant speed and feed rate values, an increase in the depth of cut causes more cutting force**. Gopal Krishna U B** [6]. has reported on the enhancement of mechanical properties like tensile strength and hardness of AMCs by reinforcing 6061Al matrix with B $_4$C reinforcement via stir casting route. It is stated that, there was homogeneous dispersion of B_4C particles in the matrix. Further, it is reported that the tensile strength and hardness of the composite increased with increase in the wt% of reinforcement **Saikeerthi.S.P et.al.,** [7] have investigated on the properties of aluminium 6061 alloy reinforced with boron carbide and silicon carbide particles for different particle size (Viz 37μm , 44μm,63μm, 105μm and 250 μm) fabricated by stir casting process. It is reported that, the B_4C particles were dispersed uniformly in the aluminium matrix. Further, it is stated that, the micro hardness of AMCs increased with increase in both particle size and wt% of reinforcement. However, the micro vicker's hardness of AMCs was found to be maximum (129 VHN) for the particle size of 250μm. Also, it is reported that the mechanical properties of matrix alloy Al6061 have improved on B_4C incorporation.**S. Rama Rao et al.,**

[8] have reported on the fabrication aluminium alloy - boron carbide composites by liquid metallurgy techniques with different weight fraction of the reinforcement vis., 2.5,5 and &.7.5wt%. It is stated that there was uniform distribution of the boron carbide particles in the matrix phase and hardness of the composites increased, whereas density decreased

with Increase in the amount of the boron carbide in the matrix phase. Also the increased amount of boron carbide particles in composites caused the ultimate compression strength to increase. **Niranjan et al.,** [9] have reported that dispersion of hard ceramic particles in a soft ductile matrix results in improvement in strength. This has been attributed to large residual stress developed during solidification and to the generation of density of dislocation due to mismatch of thermal expansion between hard ceramic particles and soft aluminium matrix. **Doel and Bowen** [10]. have reported the tensile properties of particulate reinforced metal matrix composites. The effect of ageing on the tensile properties of Al7075-SiC composites has been investigated. Composites exhibited higher 0.2% proof stress and tensile strength values when compared with unreinforced materials in peak aged conditions. However, all the composites exhibited lower ductility when compared with the unreinforced materials.

Zhen fang et al., [11] have reported the friction behaviour of 6061 Al alloy composite reinforced with SiC and Al_2O_3 at relatively high loads and speeds on conventional scratch machine using a pyramid type indenter. It is identified that ploughing, adhesion and particle fracture all contribute to friction and wear. The friction coefficient increases with particle volume fraction but is independent of the range of normal loads and sliding speeds tested. A new friction theory has been established based on the theories of adhesion and ploughing and the effect of particle fracture. The validity of the model is confirmed by experiments and microscopic observations on the scratch topography of the metal matrix composites. **Lin et al.,** [12] have studied the tribological performance of 6061-Al alloy/ graphite materials in oil lubrication

with EP additives. It is reported that the concentration of EP additives has a significant effect on coefficient of friction of studied composite. Under boundary lubrication conditions the EP additives was unable to generate chemically reactive films. **Chan et al.,** [13] have carried out the friction analysis of carbon nano fibre-reinforced polymeric coatings on AA 6061 aluminium and alumina composite against rotating steel disc. It is observed that there is a formation of a lubrication layer of carbon and its transfer onto steel counter face has resulted in lowering of coefficient of friction. Higher levels of fibres contents resulted in faster formation of these layers. **Candan et al**[14]**.,** reported that the addition of SiC particles to Al-4 wt% Mg improved the corrosion resistance of the composites over that of the base alloy in 3.5 wt% NaCl solution. They postulated that the Mg 2 Si phase generated from a two-step reaction between liquid Al and SiC hindered the passage of electrons thus improving the corrosion resistance of the composites. On the other hand, **Kiourtsidis et al**[15]**.,** noted that although Sic was not directly responsible for the enhanced pitting corrosion of aluminium AA2024 Composites in 3.5 wt.% NaCl solution, intermetallic phases surrounding the particles initiated pitting attack of the material. They have attributed the pits adjacent to the interdendritic zone to galvanic couples between the cathodic Al_2Cu and anodic α-phases. Further, in the dendrite cores, depletion of Cu created local anodes which coupled galvanically with the α-phase. **Aylor et al**[16]**..,** reported that the presence of Sic in AA6061 matrix did not increase the susceptibility of the composites to pitting attack in marine environment. Pits however occurred at the SiC/Al interface. **Prado et al., and Griffiths et al**[17]**..,** also reported that the Sic particles and Al matrix did not form any galvanic couple. Graphite particles, unlike Sic, formed galvanic couple with aluminium matrix. In a galvanic couple between aluminium and graphite, aluminium, which has a more active potential, preferentially corrodes.

Conclusions

With the scope of the present study, The following conclusions can be drawn:

1) AMMCs reinforced with B4C and others have found supperior properties than unreinforced metals and their alloys.
2) Mechanical as well as wear/abrasion resistance improved by adding of reinforcements in aluminium/aluminium alloy matrix materials.
3) VHN and BHN, yield and ultimate tensile strength and abrasion/ wear resistance enhanced by reinforcement of B_4C
4) Thermal stability increases by increasing reinforcement
5) With the increase of the B_4C particle size, the micro hardness of composites is improved, and the corresponding ultimate tensile strength of composites is declined.
6) Further, it can be concluded that reinforcing B4C in Aluminium matrix has yeilede better and improved mechanical, tribological and corrosion properties.

Reference

1) I.A. Ibrahim, F.A. Mohamed, E.J. Lavernia, “Particulate reinforced metal matrix composites - A Review”, Journal of Materials Science 26 (1991) 1137.
2) M.K. Surappa, “Aluminum Matrix composites: Challenges and opportunities” Sadhana 28 1-2 / February, (2003).
3) S. Candan and E. Bilgic, “Corrosion Behaviour of Al-60 Vol.% SiCp Composites in NaCl Solution”. Materials Letters 58 (2004) 2787- 2790.

4) Zhao Nai-Qin, Nash P Yang, Xian-Jin, "The effect of mechanical alloying in SiC distribution and properties of 6061 Aluminum composites". Journal of Material Processing Technology 170 (2005) 586-592

5) K. Rajkumar, J. Maria Antony Charles, K. Vinoth Kumar, J. John Charles Praveen, A. Padmanathan, "Mechanical & Machining Characteristics of Al/B4C Metal Matrix Composites", Proceedings of the "National Conference on Emerging Trends In Mechanical Engineering 2k13", 306-312.

6) Gopal Krishna U B, Sreenivas Rao K V and Vasudeva B, "Effect Of Percentage Reinforcement Of B4C On The Tensile Property Of Aluminium Matrix Composites", Int. J. Mech. Eng. & Rob. Res. 2012, Vol. 1, No. 3, October 2012, 290-295.

7) Saikeerthi.S.P, Vijayaramnath.B, Elanchezhian.C, "Experimental Evaluation of the Mechanical Properties Of Aluminium 6061-B4C- SiC Composite", International Journal of Engineering Research, Volume No.3 Issue No: Special 1, pp: 70-73.

8) S. Rama Rao, G. Padmanabhan, "Fabrication and mechanical properties of aluminium-boron carbide composites", International Journal of Materials and Biomaterials Applications 2012; 2(3): 15-18.

9) H.B. Niranjan et al., "Tensile and corrosive properties of Al Hematite composite" in Proc. of the First Australasian conference on Composite Materials (ACCM-1), Osaka, Japan, 7-9 October (1998), 546.

10) T.J.A. Doel and P. Bowen, "Tensile properties of particulate- reinforced metal matrix composites", SI1359-835X (96)000- 40-1, 655-665.

11) Zhang fang, Liangehi Zhang and Yiu Wing Mai, "Modelling friction and wear of scratching ceramic particle-reinforced metal composites". Wear 176 N 2 (1994) 231-237.

12) Jen Fin Lin, Ming Guu Shih and Yih Wei Chen, "The Tribological performance of 6061 Aluminium alloy/Graphite composite materials in oil lubrications with EP additives". Wear 198 N 1-2 (1996) 58- 70.

13) M.Y. Chen, Z. Bai, S.C. Tan and M.R. Unroe, "Friction and wear scar analysis of carbon nanofiber-reinforced polymeric composite coatings on Alumina/Aluminum composite". Wear 252(7-8) (2002) 624-634.

14) S. Candan and E. Bilgic, "Corrosion Behaviour of Al-60 Vol.% SiCp Composites in NaCl Solution". Materials Letters 58 (2004) 2787- 2790.

15) G. Kiourtsidis and S. M. Skolianos, "Corrosion Behaviour of Squeeze- cast Silicon Carbide-2024 Composites in Aerated 3.5 wt.% Sodium Chloride". Materials Science and Engineering A 248 (1998) 165-172.

16) D. M Aylor and P. J. Moran, "Effect of Reinforcement on the Pitting Behaviour of Aluminum-B) e Electrochemical Society 321(6) (1985) 1277-1281.

17) A. Pardo, M. C. Merino, F. Viejo, S. Feliu, M. Carboneras, and R. Arrabal, "Corrosion Behaviour of Cast Aluminum Matrix Composites (A3xx.x/SiCp) in Chloride Media". Journal of the Electrochemical Society 152(6) (2005) 198-204.