A Review On Properties Of Al-B4C Composite Of Different Routes

Yashavanth KumarT[1], G. Anil Kumar[2], J.Satheesh[3]and T. Madhusudhan[4]

[1]*P.G. Scholar, Dept. of Mechanical, SJB Institute of Technology, Bengaluru, Karnataka, India.*

[2]*Associate Professor, Dept. of Mechanical, SJB Institute of Technology, Bengaluru, Karnataka, India.*

[3]*Professor, Dept. of Mechanical, SJB Institute of Technology, Bengaluru, Karnataka, India.*

[4]*Professor,Dept.of Mechanical, SJB Institute of Technology, Bengaluru, Karnataka, India.*

Abstract -*The new generation of metal matrix composites are Aluminium hybrid composites that have the potentials of satisfying the recent demands of advanced engineering applications, particularly in the automobile industries, due to low weight, density, coefficient of thermal expansion, and high strength, wear resistance. Among the materials of tribological importance, AMC's have received extensive attention for practical as well as fundamental reasons. This paper attempts to review the mechanical and tribological properties of Al-B4C composite fabricated by powder metallurgy and stir casting techniques .The major techniques for fabricating these composites are briefly discussed.*

Key Words: Aluminium alloys, MMC, Boron carbide ,powder metallurgy, stir casting process

1.INTRODUCTION

General engineering materials have limitations in achieving optimum levels of strength , toughness, density, wear resistance and stiffness. The composite materials give engineers the opportunity to tailor the properties of material according to their needs. Metal matrix composites have attracted by the researchers from a decade ago due to its unique properties like good strength to weight ratio, stiffness, hardness and ductility and wear resistance [1,2]. Among all the type of MMC's aluminum is widely used because of its low density, good strength to weight ratio, easy fabricability, good corrosion resistance and also it has good engineering properties. Aluminum MMC's found in many applications in the contractions, aerospace, automobile, marine ,defense, consumer industries (sports goods) and the replacements of the nickel cast iron in conventional diesel engine piston crown by aluminium matrix composite has resulted in a lighter, more abrasive and cheaper product .In applications such as automotive drive shafts, cylinder liners, connecting rods and because of low thermal expansion and conductivity Al based composites are used as heat sinks in chip carrier multilayer boards, high speed integrated circuit packages for computers and in base plates for electronic equipment's [4,24]. Amongst the various MMCs available, aluminum matrix composites (AMCs), particularly those based on the Al 7xxx-series alloys, offer benefits such as low density and high specific strength. It is well established that introducing a hard particle in an Al-matrix can lead to significant improvements in wear and erosion resistance, stiffness, hardness and strength [22]. AMC's can be reinforced with silicon carbide(sic), Boron carbide(B4C), aluminum oxide(Al2O3), titanium carbide(tic), titanium dual Boron (Tib2),magnesium oxide(Mgo),titanium oxide(Tio2)[1].Recent studies indicated that a significant improvement in the tribological properties (including sliding and abrasive wear, friction and seizure resistance) of aluminium alloys can be attained by the addition of ceramic reinforcements. Wear behavior in MMCs can be divided into two categories depending upon the nature of reinforcements. These are metal/alloys containing soft reinforcements like graphite or hard particles like SiC, Al2O3 and TiO2. The presence of hard particles into the matrix also influences its wear behavior. The use of hard ceramic particles such as Al2O3 and SiC, as reinforcements in the metal matrix, has shown to reduce the wear loss more effectively compared to the base alloys . In general, it has been observed that the wear rate is decreased both by increasing the volume fraction of hard phase and the particles size. Furthermore, the use of hard phase helps in pushing the seizure on the higher load at constant sliding velocity [26]. Due to the higher cost of boron carbide powder compared to the more common abrasive powders (e.g. SiC and Al2O3), limited research has been conducted on B4C reinforced MMCs [1].In terms of reinforcement particles, B4C offers several advantages, such as an extremely high hardness (9.5+ in Mohs' scale , low density (2.51 g/cm3, and high wear resistance.

Available published information suggests that B4C can enhance the mechanical properties of Al 7xxx-series alloys. In General, a hard material is employed as reinforcement because of potential improvement in mechanical properties such as hardness and tensile strength which are the desirable properties in Tribological application. In related studies, Baradeswaran [1] prepared casted Al-7075/B4C composites with notable values of flexible strength, compressive strength and tensile strength of 497 MPa, 300 MPa and 350 MPa, respectively. And also Al-B4Ccomposites are can be performed at higher temperature than aluminum and also possess good electrical conductivity [6]. The type of reinforcement, size and morphology decides the fabrication process/methods for AMC and they are powder metallurgy technique, stir casting, squeeze casting, spray deposition, liquid infiltration methods [7]. The properties of MMC derived by matrix and ceramic properties, bonding between ceramic and matrix, size and distribution of ceramic particles in the matrix[8]. Boron carbide offers applications involving wear resistance, impact resistance and because of its nature of covalent bonding and its distinct advantages . The sintering temperature range required for boron carbide is 2000°C-2300°C it remains challenge for practical applications[9]. Some extent sintering temperature of boron carbide can be reduced by using the some additives such as boron ,carbon, TiB2,Be2c,W2B5,crB2, and aluminum based composites[9].Boron carbide applications include breaks with high wear resistance, disc drive actuators, light and disk substrates and armor plates with high ballistic efficiency [9].B4C particles are harder and less denser than the any other commercial reinforcements such as Sic, Al2O3, titanium [10].Superior wear resistance is one of the important properties in MMC's have approximately 10 times wear resistance than that of unreinforced materials in some load ranges. Various studies were performed to understand the effect of various factors such as the fraction of the reinforcing particles, particle size, the load and the sliding speed on the wear resistance of MMC's [14].

2.FABRICATION OF METAL MATRIX COMPOSITE

2.1 Powder Metallurgy Technique

The powder metallurgy procedure is the utmost widely used strategy for the production of discontinuousreinforced Metal matrix composites. Reinforcements are usually in the form of whiskers and particulates in the form of powder. Normally the matrix and reinforcement materials are blended in form of powder by subjecting them to various mechanical operations such as atomization and ball milling process. The powders are mixed according to the desired volume fractions and the powder is fed in to the mould of preferred shape. Pressure is applied to compact the mixed powder (i.e., Cold pressing) then the compacted specimen is subjected to sintering which involve heating of the compacted specimen in a controlled atmosphere well below the melting point of material, which ensures significant amount solid state diffusion of reinforcement in to the matrix material. Thus compacted metal matrix composite specimen is then subjected to further machining operations to get desired shape [15,29].The fabrication of components by powder metallurgy technique involves the following steps in sequence:(1) Production of metallic powders, (2) Mixing and Blending of powders, (3) Compaction of powders, (4) Sintering, (5) Secondary machining operations, (6) Finishing and inspection.

2.2 Stir Casting Process

In a stir casting process, usually the particulate reinforcement is distributed into aluminum melt by mechanical stirring. Mechanical stirring is the key element of this process. Composites with up to 30% volume fractions can be suitably manufactured using this method. A problem associated with the stir casting process is the segregation of reinforcing particles due to settling of particles during solidification. The distribution of the particles in the final solid depends on strength of mixing, rate of solidification, wetting condition of the particles with the melt and relative density. Geometry of the mechanical stirrer, position of the stirrer in the melt, melt temperature and the properties of the particles added determines the distribution of the particles in the molten matrix [3].

In a recent development in stir casting is a two-step mixing process. The matrix material is heated to above its liquidus temperature so that the metal is totally melted. The melt is then cooled down to a temperature between the liquidus and solidus points and kept in a semi-solid state. At this stage , the preheated particles are added and mixed. The slurry is again heated to a fully liquid state and mixed thoroughly. The effectiveness of this two-step processing method is mainly attributed to its ability to break the gas layer around the particles surface [29].

3. MECHANICAL PROPERTIES

The mechanical properties of composite materials depends on several factors such as size, shape, quality and type of reinforcement particles[3].

Baradeswaran et al. (2013) studied the influence of B4C on the tribological and mechanical properties of Al7075- B4C composites. The authors has revealed that the hardness of composite increased when compared with base alloy because of addition of B4C particular's and wear rate of composite decreased when compared with base alloy[1].Gopal Krishna U.B et al. (2013) investigated the Effect of boron carbide reinforcement on aluminium matrix composites. The authors produced Al- B4C by stir casting route with different particle size (Viz 37μ,44μ,63μ,105μ,250μ) of reinforcement and observed that the micro vickers hardnes of AMC's was to be maximum for the particle size of 250μ and for 12 wt% in case of varying wt% of the reinforcement of 105μ size. And the tensile strength of AMC's was found to be maximum for the particle size of 105μ and found maximum for 8 wt% in case of varying wt% of the reinforcement of 105μ size [5].

Ibrahim et al. (2013) investigated mechanical properties and fracture of Al-15vol%B4C based Metal matrix composites. The authors observed that the ductility of the composite material decreases with increased vol% B4C and the fracture of B4C reinforcements occurs by a cleavage mechanism[6].Kalaiselvan et al. (2011) fabricated Al6061- B4C composite by stir casting route. They observed that the micro and macro hardness of composite linearly increased from 51.3HV to 80.8HV and 34.48BHN to 58.6 BHN with addition of B4C particles (wt%) and also tensile strength increased from 185Mpa to 215Mpa[7].Cambronero et al. (2003) investigated the mechanical characterization of AA7015 aluminum alloy reinforced with ceramics and concluded that hardness increased by ceramic addition due to this the plastic deformation of composite is decreased and better wear behavior achieved[8].Jinkwan jung and shinhoo kang et al. (2004) Advances in manufacturing Boron-carbide Aluminum composites. The authors revealed that with addition of titanium metal to Aluminum born carbide composite reduces 100-200°C sintering temperature of composite and Heat treatment of boron carbide skeleton in the temperature range of 1000-1400°C before infiltration has a optimum effect on the infiltration of liquid aluminum on boron carbide. Bimodaldistribution of powder mixture increases the green density of the skeleton and mechanical properties (toughness, hardness) [9]

A.Mazahery et al. (2010) studied on hardness and tensile strength of Al356- B4C composites(stir casting) and Authors revealed that porosity level of composite increased slightly with increasing particulate content and the hardness of the MMCs increases with the volume fraction of particulates in the alloy matrix because of the increasing ceramic phase of the matrix alloy. The higher hardness of the composites could be because B4C particles act as obstacles to the motion of dislocation[11,27].F. Toptan et al. (2010) studied the effect of Ti addition on the properties of Al- B4C interface and A micro structural study and author reported that an effective bonding could not be formed on the material/reinforcement interface in Al- B4C composite produced at temperature of 858°C. Because of poor wetting of B4C particles by liquid aluminum and the wetting problem was effectively solved by the formation of very thin Tic and TiB2 reaction layers with addition of K2TiF6 flux [12].Mohsen ostad shabani et al. (2011) investigated A356 composites reinforced with B4C particles by FEM and ANN and author revealed that the great enhancement of mechanical properties of A356 composite reinforced with B4C particulates in values of hardness,elastic constant and UTS relative to monolithic aluminum experimentally[13].K. Kalaiselvan et al. (2014) investigated production and characterization of AA6061-B4C stir casting composite. authors concluded that the addition of 4 to 12 wt% of B4C particles the micro and macro hardness of the composite were changed from 51.3HV to 80.8HV and 34.4BHN to 58.6BHN respectively[15].C. Mathazhagan et al. (2013) studied the influence of graphite reinforcement on mechanical properties of Al boron carbide composites and revealed that with increasing graphite particles the hardness of the composite is decreased[16].

R. Ramesh et al.(2013) studied the micro structure and metallurgical properties of aluminum 7075-T651 Alloy/ B4C 4% volume surface composite by friction stir processing and the authors revealed that average hardness of friction stir processed surface composite was 1.5 higher than that of the base metal aluminum matrix [18].S. Suresh et al. (2013) studied process development in stir casting and investigation on microstructures and wear behavior of TiB2 on Al6061 MMC and the authors conducted that strength, micro and macro hardness of Aluminum composites increased with inclusion of reinforcement(TiB2) in it [19].Topcu et al. (2009) produced pure Al/ B4C composite by powder metallurgy route and investigated its mechanical properties. They observed that the hardness of the composite were increased with Increasing weight percent of B4C and sintering temperature . But, the effect of sintering temperature over 625 ◦C is lost after 15 wt% of B4C. and impact resistance of the compositereduced with increase in B4C content in the matrix and sintering temperature. And, the effect of sintering temperature is lost after 15 wt% of B4C [21].

Chuandong wu et al. (2014) studied the effect of plasma activated sintering parameters on microstructure and mechanical properties of Al-7075/ B4C composite. They observed that the High mechanical properties including Vickers hardness 181.6 HV, bending strength1100.3 MPa, high compression yield strength 878.0 MPa and fracture strength 469.3 MPa of the consolidated Al-7075/B4C composite sintered at 530°C for 3 min were achieved and attributed to a fully dense microstructure and a strong interface between matrix and reinforcement [22].V auradi et al. (2014) produced 11wt%B4C particulate reinforced with 6061 Al matrix composites by conventional melt stirring method. They observed that the improved mechanical properties (hardness, yield stress, UTS) of composite when compared to the matrix alone whereas ductility decreases. And they obtained extent of improvments in Yield strength and Ultimate Tensile strength were 44.35% and 42.6% respectively [24].

Pradeep V Badiger et al. (2015) Investigated Mechanical Properties of B4C Particulate Reinforced Al6061 Metal Matrix Composites.Authors observed that the hardness due to the addition of B4C particulates is increased remarkably and An improvement of 17% and 38.4% in ultimate tensile strength was achieved over Al6061 alloy after addition of 7 and 9wt% of B4C particulates respectively. The Compressive strength was achieved over Al6061 alloy after addition of 7wt% and 9wt% of B4C particles is 330N/mm2 and 355 N/mm2 respectively [25].
S.C. Vettivel et al. (2014) studied the experimental investigation on mechanical behavior, modelling and optimization of wear parameters of B4C and graphite reinforced aluminiun hybrid composites. Authors revealed that the high hardness and good % of elongation obtained in the AA 7075 hybrid composite compared to the AA 6061 alloy and its hybrid composite [27].A Canakci et al. (2012) Investigated Abrasive wear behaviour of B4C particle reinforced Al2024 MMCs and authors observed that the density of composites is decreased with increasing particle volume fraction and decreasing particle size, but the porosity and hardness of the composites are increased with increasing particle content and decreasing particle size [26].

4. TRIBOLOGICAL PROPERTIES

Harun mindivan et al.(2009) studied the reciprocal sliding wear behavior of B4C particulate reinforced aluminumalloy composite and authors reported that wear resistance of composite increases by increasing the B4C content upto 10 weight % [10)]. F. toptan et al.(2012) investigated reciprocal dry sliding wear behavior by B4C reinforced aluminum alloy matrix composites and author conducted that COF and wear rates was increased as volume fraction and distance increased, COF and wear rates decreased as velocity increased and COF decreased and wear rates increased as load increased and also he concluded that the volume fraction is the most important factor for COF, while load is the most important factor for wear rates [20].Siddhartha prabhakar N et al. (2014) investigated tribological behavior of aluminium/ B4C composite under dry sliding motion . and they observed that in tribological results of LM14 aluminium alloy matrix reinforced with 5% of B4C particles fabricated through stir casting route wear rate and coefficient of friction has a direct relation with the load , whereas inverse with the sliding speed and distance. And load was the major factor (47.4%) in determining the wear rate followed by distance and sliding velocity whereas distance affects the coefficient of friction to a large extent (44.1%) followed by load and sliding velocity [23].

A Canakci et al. (2012) Investigated Abrasive wear behaviour of B4C particle reinforced Al2024 MMCs and authors observed that the abrasive wear properties of the 2024 Al alloy were considerably improved by the addition of B4C particles, and the abrasive wear resistance of the composites was found to be much higher than that of the unreinforced 2024 Al alloy. The harder B4C particles provide the major contribution for the abrasive wear resistance. The abrasive wear resistance of the composites is increased with increasing B4C particle content and size [17].S.C. Vettivel et al. (2014) studied the experimental investigation on mechanical behavior, modelling and optimization of wear parameters of B4C and graphite reinforced aluminiun hybrid composites. Authors observed that the wear resistance of the composite was increased with the addition of 10wt% B4C and 5% graphite particles. And the wear rate was significantly less for the composites compared to the base matrix. The MML formed on the warm surface of the composite is the key role played in controlling the wear properties of the composites [28].

5. CONCLUSIONS

From literature review related to the Aluminium alloy-B4C Composite material we have concluded that,

- Composite materials have better properties than monolithic metals and their alloys.
- Reinforcements added to matrix materials will help to improve mechanical and wear properties.
- Al- B4C composites can be successfully manufactured by use of powder metallurgy technique and stir casting process.
- Incorporation of B4C particles in aluminium matrix improves Hardness, compressive strength, tensile strength,yield strength and wear resistance.

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