Micro Structure and Tensile Property of Al-Alb2 Metal Matrix Composites

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***Abstract*— In this present study, micro structure and tensile property of Al-AlB2 composite were produced by liquid metallurgy route have been experimentally investigated. The composite materials containing 5Wt% of AlB2reinforcement phase have been compared with the unreinforced aluminium alloy. The composite were performed by the reaction between Al6061 and carefully measured calculated stochiometrical quantities of KBF4 halide salt were added by the exothermic reaction. Micro structural characterizations were investigated by using Scanning electron microscope and tensile tests were carried out in order to identify the mechanical properties of the composites. The results of the microstructural study revealed uniform distribution of reinforcement into the base alloy.**

***Keywords*— Al6061, AlB2, Ultimate tensile strength, stircasting.**

I. INTRODUCTION

Metal–matrix composites (MMCs) consist of at least two or more physically and chemically distinct phases suitably distributed to provide properties not achievable with either of the individual phases. In MMCs, generally a metal or alloy is used as matrix phase and the reinforcement may be metallic or ceramic. MMCs are mainly of three types viz., particle reinforced, short fiber or whisker reinforced and continuous fiber or sheet reinforced MMCs Generally, aluminium, magnesium, Aluminium, copper and their alloys are used as a matrix. The reinforcements are commonly used in the form of fibers, whiskers and particulate of different metal oxides, nitrides and carbides. Particle reinforced MMCs are preferred over fiber reinforced materials, mainly due to ease of processing, lower fabrication cost and isotropic properties. The properties and structure of MMCs can be controlled by the form, size and shape of the reinforcement, however, nature of bonding between the matrix and reinforcement also affects the overall properties.

With increasing demand for light weight and high performance materials in aerospace and automotive industries aluminium–matrix composites (AMCs) are gaining rather more importance and to fulfill these demands different manufacturing techniques with various ceramic reinforcements have been used. AMCs have already replaced or replacing conventional alloys in many applications due to excellent combination of other properties such as high wear resistance, low thermal expansion, and high strength– weight ratio, etc[2-5]. Unique combination of such properties makes AMCs potential candidate for many applications such as brake drums/rotors, cylinder liners, connecting rods, cylinder blocks, pistons, gears, drive shafts and suspension. Variety of ceramic reinforcement particulates generally used in AMCs are SiC, B_4C, Al_2O_3, TiC, graphite, TiO_2, SiO_2, Si_3N_4, BN, AIN, fly ash, AlB2, and ZrB_2.[8][13]

For the production of insitu master alloys there were different halide salts have been extensively used more than two decades. MMC have been drawn considerable attention through the world because of its excellent mechanical and tribiological properties. AMC with ultra fined ceramics material or particles have been extensively used in aerospace and automotive application. The reinforcement phases in the form of fibres ,particle, flake, or whiskers ha rapidly increased in now days in the advanced engineering materials .There were different particulate reinforcement were most often used in AMC that includes SiC, B4C,TiB2,Al2O3 and ZrB2.For via TiB2,Al2O3 and ZrB2.For various application like aerospace and transport industries particulate reinforcement AMC have high specific strength[2][6].

In the recent years the researcher have given more attention to insitu composites mainly because of its clean interface formed between the matrix with reinforcement , high bonding strength , good interfacial integrity , uniform distribution in the matrix with high mechanical properties and low fabrication costs. Because of its uniform distribution in the matrix , the insitu AMC are mainly used in structured application , when high strength to weight ratio is plays important role in the aeroplane industries and automotive chassis[1][3].

To improve the interfacial compatibility and reduce the reinforcement size various new processing techniques are being employed to produce the high performance in situ composites. Ultrafine ceramic particles (AlB2) are produced in situ by the exothermic reaction between aluminium and the ceramic compounds. The literature on the in situ AlB2 particle composites is very limited.

Among the various reinforcements, aluminium-diboride (AlB_2) has emerged as an outstanding reinforcement because of its excellent stiffness, hardness, wear resistance. The present paper is focused on AMCs reinforced with KBF4 halide salt and an emphasis has been given to micro structureand mechanical properties. Further, possible future research areas are also explored.

II. MATERIALS AND EXPERIMENTAL PROCEDURE:

In this study commercial available pure 99% blocks (PMC Corporation, Bangalore) aluminium 6061 alloy with theoretical density of 2700 Kg/m3 was used s matrix material alloy and 99.2 % of KBF4 halide salt(Madras Fluorine Factory, Chennai). The salt is in powder form and small quantity coverall 11 and cryolite(Na3AlF6) is used as a refining flux[7][8].

The chemical composition of matrix material is as shown in the table determined by using Atomic absorption spectrometry in CMTI, Bangalore Table:1 shows the chemical composition of the Al6061 alloy used in the present study[13].

TABLE 1

Elements	Si	Fe	Cu	Ni	Pb	Zn	Ti	Sn	Mg	Cr	Al
%	0.43	0.7	0.24	0.139	0.05	0.24	0.25	0.001	0.80	0.25	Balance

The experiments were carried out in an electrical furnace equipped with a graphite crucible and stirrer. Metal matrix composite have been produced by using vertex method. The cast ingot Al alloy was sectioned into small pieces for microstructural analysis, SEM and also for tensile properties[6-8].

III. EXPERIMENTAL DETAILS:

There have been base alloy Al6061 and 5 wt% of AlB2 experiments were conducted. The composite specimen were prepared by melting, carefully measured and adding calculated stochiometrical quantities of KBF4 pre heated at 300^0 C halide salt into the melt with small quantity of coverall 11, cryolite (Na3AlF6) and degassing tablet(C_2Cl_6) for refining flux.

The experiments were conducted at 850^0-900^0 C in an electrical furnace in an atmospheric environment using an mechanical stirrer at a speed of 150 rotation /minute for 5- 20 minutes. The slag is removed before pouring the composite .The melt was poured into the pre heated cast die[7][8].

Fig.1. shows cast die, Al6061 and Al6061 + 5wt% AlB2

According to the Wang et.al there was possible reaction that takes place with Al with KBF4. Reaction occurring during the process of interaction between Al6061 and KBF4 is[4]

12KBF4 + 13Al = AlB12 + 12KAlF4
=AlB12+12KF+12AlF3…….(Eq 1)

2KBF4(S) + 3Al(L) = AlB2(S) + 2KAlF4(L)
=AlB2+2KF+2AlF3………..(Eq 2)

IV. CHARACTERIZATION AND TESTING:

For microstructural characterization, metallographic samples were sectioned from cylindrical castings and machined according to the metallurgical procedure by using emery papers and diamond grinders[13].Microstructures were examined by using SEM equipped with EDS(Hitachi Su-1500 Model) to identify the morphology and formation of AlB2 compound in the base alloy by the halide salt.The experimental density of the composite was obtained by Archimedian of weighing small quantity of cut piece from the composite first in the air and then in water, while the theoretical density is calculated by using the mixtures rule according to the weight fraction of the base alloy and KBF4 halide salt.

Tensile tests were carried out to check the mechanical behaviour of the composite and unreinforced base alloy.The composite and matrix alloy cylindrical rods were machined to tensile specimens with a gauge diameter of 9mm and gauge length of 45 mm . The surfaces of the samples were polished 600 grit size papers.The tensile tests was conducted ona computerized UTM(INSTROM) at AML, Bangaluru as per ASME E8 standard .The tensile tests were conducted on two specimens for 5wt%AlB2 reinforcement and the reinforced aluminium alloy and average values were reported[13].

V. RESULTS AND DISCUSSIONS:

A. *Micro structural studies:*

Figure 3 presents SEM image of unreinforced base alloy. It is clearly seen that the of grains formation in as cast alloy and grain distribution is more compared to that of the composite.

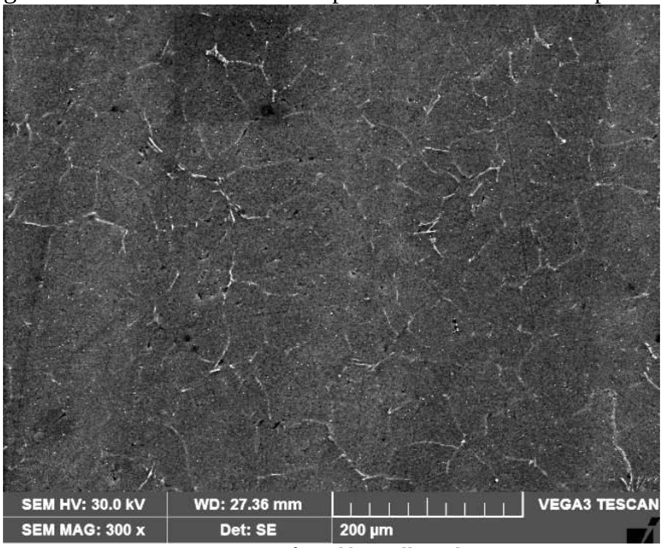

Fig. 2. Unreinforced base alloy Al6061

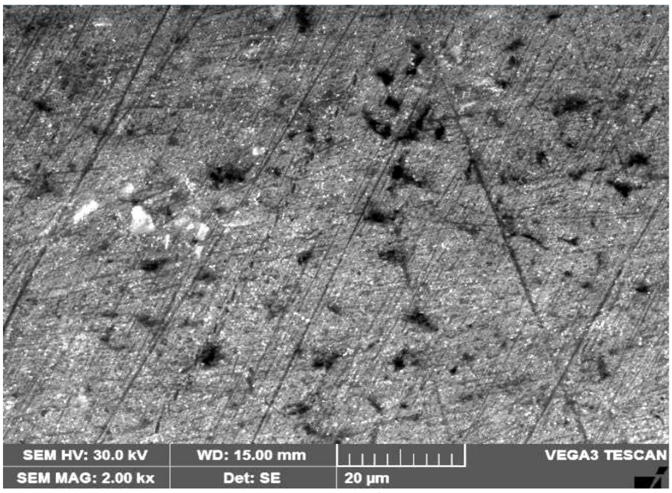

Fig. 3. 5 Wt% of AlB2

Figure 4 shows the microstructure of the solidified material regionclose to the metal slag.It shows clearly the formation precipitates is observed. It is somewhat string like morphology precipitate are associated which indicated the formation during the metal salt reaction. It clearly shows the formation of AlB2 , this indicates the there is a uniform distribution of halide salt throughout the base alloy and also agglomeration at few places were observed in the composite reinforced with 5Wt% of reinforcement[7][8].

Microstructural analysis highlights a good interfacial integrity between the AlB2 particles and matrix. There is local increased in the temperature due to the exothermic reaction which leads to decrease the wetting angle of AlB2 particles and liquid aluminium , thus improving wetting.

In the figure 3and 4 reveals that there is a formation of AlB2 with respect to the unreinforced aluminium alloy .AlB2 formation was clearly seen with the higher magnification .It can distinguish by black AlB2 and AlB12 particles[8].

To determine the stability of borides precipitates in the obtained composite material required thermodynamic calculation.The free energy changes of reaction for the one mole of KBF4 are

Delta $G^0 1$ = -204 kJ / mol + 9 T J /mol

Delta $G^0 2$ = -248 kJ / mol + 16.45 T J /mol

For the calculation of Delta G^0 the reaction product is substituted by KF and AlF3 because of standard free energy change for the formation of KAlF4 is not known[8-11].

Delta G1 = -204 kJ / mol and Delta G2 = -248 kJ / mol

Therefore AlB2 is more stable phase than AlB12.The calculated values are also in agreement with the prediction of Al-B binary phase diagram[7].

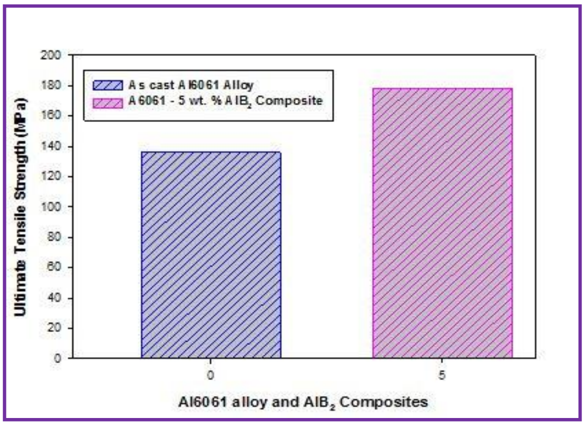

Fig. 4.Al-B binary phase diagram.

At Boron concentration less that 44, 5wt% at a temperature above 975^0C is expected to form AlB12 and then decompose it into liquid Al and AlB12 by peritectic reaction that occurs on cooling[7-11].

5Al(L)+AlB12(S)=6AlB2(Solid)……………………….(Eq 3)

The standard free energy change for the reaction is

Delta $G^0 3$ = -639 kJ / mol +89.4 T J /mol

At 900^0C Delta $G^0 3$ = -435 KJ / mol

B. *Tensile Properties:*

The results of the tensile tests carried out on the composite prepared by the melt stirring involving are presented in the figure. It shows the extent improvement obtained in ultimate tensile strength and yield strength at 5 wt% of AlB2 compared to the unreinforced base alloy Al6061.The increase in the ultimate tensile strength may be due to the formation of AlB2 throughout the matrix.

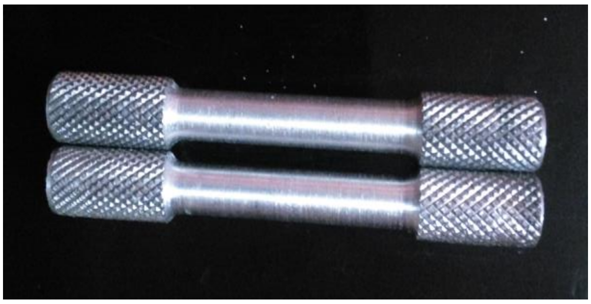

Fig. 5. Tensile specimen

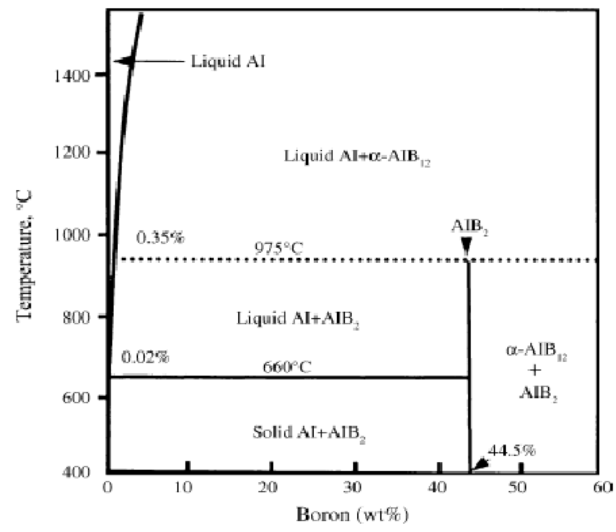

Fig:6: Graph 1 Al6061 with 5 wt% of AlB2 for UTS

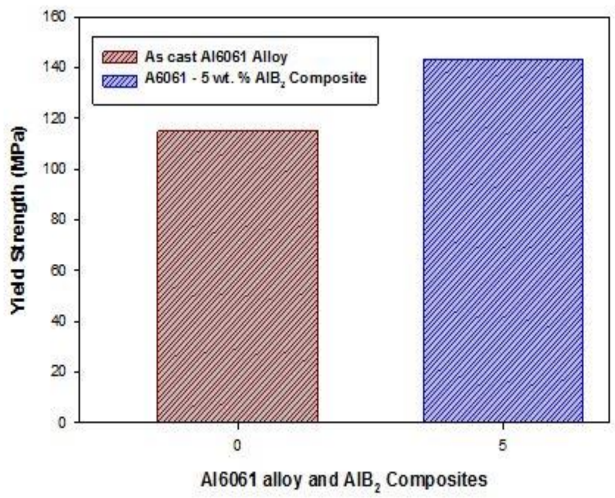

Fig:7:Graph 2 : Al6061 with 5 wt% of AlB2 for YS

VI. CONCLUSIONS:

The present work on Al-AlB2 metal matrix composite is produced by exothermic reaction between Al6061 with KBF4 has led to the following conclusions

1. The 5 Wt% of AlB2 composite was successfully fabricated by stir casting method.
2. The SEM microstructural analysis highlights an excellent bond between the matrix and reinforcement in the studied composite.
3. It has been concluded that the 5 Wt% of AlB2 composite has resulted homogenous distribution of AlB2 particles through the base alloy with no clustering or agglomeration as evident form the SEM micrographs.
4. The tensile property of the composite is increased with the increasing the 5 Wt% of AlB2 particles. An extent improvement of ultimate tensile strength and yield strength is increased are in compared to unreinforced base alloy.

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