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Characterizing an In Situ Tib_2 Particulates Reinforced Aluminium 707.1 Based Composite

[1]S. Hanish Anand, [2]Dr. N. Venkateshwaran,[3]J.P. Naveen Kumar and[1]P. Manigandan

[1]Assistant Professor, Mechanical, Kings Engineering College, Chennai, India
[2]Professor, Mechanical, Rajalakshmi Engineering College, Chennai, India
[3]Assistant Professor, Mechanical, JP College of Engineering, Thenkasi, India

Abstract: Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. With the increasing demand of light-weight materials in the emerging Industrial applications, fabrication of aluminium 707.1 based TiB2 particle reinforced composites is required. The influence of process parameters of aluminothermic reaction synthesis of in-situ Al-TiB2 metal matrix composites on their mechanical properties. The reaction between the salts potassium fluoborate (KBF4) and Potassium hexafluorotitanite (K2TiF6) in the aluminium melt leads to the formation of TiB2 particles were carefully controlled in order to regulate the volume fraction of TiB2 formation in the aluminium melt. The prepared Al-TiB2 composites were tested for their tensile properties and hardness.

Key words: In situ · K2TiF6 · KBF4 · Al-TiB2 · Metal matrix composites

INTRODUCTION

A metal matrix composite is a type of composite material with at least two constituent parts, one being a metal. The other material may be a different metal or another material, such as a ceramic or organic compound. The matrix is the monolithic material into which the reinforcement is embedded and is completely continuous [1]. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In structural applications, the matrix is usually a lighter metal such as aluminium, magnesium, or titanium and provides a compliant support for the reinforcement [2]. In high temperature applications, cobalt and cobalt-nickel alloy matrices are common.

The reinforcement material is embedded into the matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity [3]. The reinforcement can be either continuous, or discontinuous. Discontinuous MMCs can be isotropic and can be worked with standard metalworking techniques, such as extrusion, forging or rolling. In addition, they may be machined using conventional techniques, but commonly would need the use of polycrystalline diamond tooling [4].

Continuous reinforcement uses monofilament wires or fibres such as carbon fibre or silicon carbide. Because the fibres are embedded into the matrix in a certain direction, the result is an anisotropic structure in which the alignment of the material affects its strength [5].

One of the first MMCs used boron filament as reinforcement. Discontinuous reinforcement uses whiskers, short fibres, or particles. The most common reinforcing materials in this category is Titanium diboride

The major advantages of Aluminium Matrix Composites compared to unreinforced materials are as follows:

- Greater strength
- Improved stiffness
- Reduced density (weight)
- Improved high temperature properties
- Controlled thermal expansion coefficient
- Thermal/heat management
- Enhanced and tailored electrical performance
- Improved abrasion and wear resistance
- Control of mass (especially in reciprocating applications)
- Improved damping capabilities.

Corresponding Author: S. Hanish Anand, Assistant Professor, Mechanical, Kings Engineering College, Chennai, India
Email: hanishanand.s@gmail.com.

MATERIALS AND METHODS

Aluminium Alloy 707.1: Aluminium alloy 707.1 with Titanium diboride as the primary alloying element. It is strong, with strength comparable to many steels and has good fatigue strength and average machinability, but has less resistance to corrosion than many other al alloys. Its relatively high cost limits its use to applications where cheaper alloys are not suitable.

Fig.. 2.1: Aluminium Alloy

7000 series alloys such as 707.1 are often used in transport applications, including marine, automotive and aviation, due to their high strength-to-density ratio. Their strength and light weight is also desirable in other fields [6]. Rock climbing equipment, bicycle components and hang glider airframes are commonly made from 707.1 aluminium alloy. One interesting use for 707.1 is in the manufacture of M16 rifles for the American military. In particular high quality M16 rifle lower and upper receivers as well as extension tubes are typically made from 707.1. Due to its high strength, low density, thermal properties and its ability to be highly polished, 707.1 is widely used in mold tool manufacture.

Chemical Composition: The chemical composition for aluminium alloy 701.1 is given in Table 2.1.

Table 2.1: Chemical composition of Aluminium alloy 707.1

Element	Nominal
Composition	
Aluminum, Al	90.7 - 93.5 %
Chromium, Cr	0.20 - 0.40 %
Copper, Cu	<= 0.20 %
Iron, Fe	<= 0.60 %
Magnesium, Mg	1.9 - 2.4 %
Manganese, Mn	0.40 - 0.60 %
Silicon, Si	<= 0.20 %
Titanium, Ti	<= 0.25 %
Zinc, Zn	4.0 - 4.5 %

Titanium Di Boride: Titanium diboride (chemical formula TiB2) is an extremely hard compound composed of titanium and boron which has excellent resistance to mechanical erosion. TiB2 is also a reasonable electrical conductor, so it can be used as a cathode material in aluminium smelting and can be shaped by electrical discharge machining [7].

Potassium Hexafluorotitanate (K2TIF6): Potassium Hexafluorotitanate is a water insoluble Titanium source for use in oxygen-sensitive applications, such as metal production. In extremely low concentrations (ppm), fluoride compounds are used in health applications. Fluoride compounds also have significant uses in synthetic organic chemistry. They are commonly also used to alloy metal and for optical deposition. Certain fluoride compounds can be produced at nano scale and in ultra high purity forms. Potassium Fluotitanate is generally immediately available in most volumes. Ultra high purity and high purity compositions improve both optical quality and usefulness as scientific standards. Nano scale elemental powders and suspensions, as alternative high surface area forms, may be considered. Potassium Hexafluorotitanate(IV) is generally immediately available in most volumes. High purity, submicron and nano powder forms may be considered [8].

Potassium Tetrafluoroborate (KBF4): Potassium Tetrafluoroborate is a water insoluble Potassium source for use in oxygen-sensitive applications, such as metal production. In extremely low concentrations (ppm), fluoride compounds are used in health applications. Fluoride compounds also have significant uses in synthetic organic chemistry. They are commonly also used to alloy metal and for optical deposition. Certain fluoride compounds can be produced at nano scale and in ultra high purity forms. Potassium Tetrafluoroborate is generally immediately available in most volumes. Ultra high purity and high purity compositions improve both optical quality and usefulness as scientific standards. Nano scale elemental powders and suspensions, as alternative high surface area forms, may be considered. American Elements produces to many standard grades when applicable, including Mil Spec (military grade); ACS, Reagent and Technical Grade.

Fabrication of Mmc in Insitu Method

Stir Casting: This is a primary process of composite production whereby the reinforcement ingredient is incorporated into the molten metal by stirring.

A variant very applied of the Stir Casting is called "Compocasting" (or "Rheocasting), in which the metal is semi-solid. In particular the reinforcing ingredients are incorporated into vigorously agitated partially solid metal

slurries. The discontinuous ceramic phase is mechanically entrapped between the pro- eutectic phase present in the alloy, which is held between its liquid and solidus temperatures. This semi solid process allows near net shape fabrication since deformation resistance is considerably reduced due to the semi- fused state of the composite slurry.

The technologies just displayed are the most common and widespread, but there are many variations, mostly applied depending on the specific case and based on the particular application which will face the piece in producing. Techniques is adopted such as processes involving infiltration by centrifuge, ultrasound and magnetic electromagnetic even having all the essential purpose of obtaining a composite reinforced by the distribution of more homogeneous as possible.

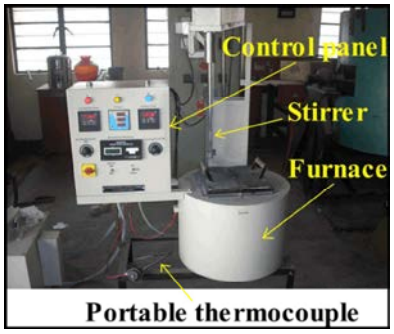

Fig. 3.1: Schematic view of Stir Setup

Methodology: Aluminum reinforced with in-situ TiB2 was produced through salt melt reaction or flux assisted synthesis. Calculated amounts of KBF4 and K2TiF6 powders are introduced into the aluminum melt and then subjected to stirring to facilitate the reaction in order to generate the required volume fraction, i.e., 3, 6, 9 vol. % of TiB2 particles. The melt temperature is 830°C and the reaction time is 60 min and volume fraction of TiB2 (3, 6 and 9%). The volume fraction of TiB2 that is formed is controlled by adding weighted amount of KBF4 and K2TiF6 according to stoichiometry. Calculated amount of potassium fluoborate (KBF4) was added first and stirred.

Since Potassium hexafluorotitanite (K2TiF6) reacts faster with aluminum it was added later into the melt. The interaction of two halide salts with the aluminium melt yields TiB2 particles through the following reactions. First KBF4 and K2TiF6 in the Al melt decompose according to.

KBF4(l) KF(l) + BF3(g) (1)
K2TiF6(l) 2KF(l) +TiF4(g) (2)

The formed TiF4 and BF3 gases diffuse into the liquid Al and the following aluminothermic reaction results.

BF3(g)+[Al] [B]Al +AlF3(l) (3)
TiF4(g)+[Al] [Ti]Al+AlF3(l) (4)

The Ti and B act as solutes in the Al melt and when the concentration of Ti and B reach saturation in the Al melt, they form intermediate compounds according to the following reactions.

[Ti]Al + 3[Al] Al3Ti (5)
2[B]Al + [Al] AlB2 (6)
[Ti]Al + 2[B]Al TiB2 (7)

Since aluminum produces a significant amount of dross and oxide during melting, degassing was employed by bubbling argon through the melt to absorb hydrogen and other impurities. After allowing sufficient time for the aluminothermic reaction to take place, the melt was allowed to solidify in a die, which was preheated to 400°C. Another set of experiments was tried by using scrap Al as the matrix material. However, for the present discussion, the mechanical properties are reported for the composites prepared using primary aluminum.

RESULT

Hardness: Hardness is the characteristic of a solid material expressing its resistance to permanent deformation. The hardness test was conducted according to ASTM E92-82(2003). The hardness tests were conducted on cast specimens. 5 mm Ball indenter was used and 500 kg was the applied force. Three tests were conducted and average value is taken as the hardness of the specimen.

Fig. 4.1: Schematic view of Brinell hardness

Table 4.1: The Hardness value of Aluminium With TiB2 Composite

Material	Brinell hardness in HBW
AL. 7071 / 3 % TiB2	48.33
AL. 7071 / 6 % TiB3	45.63
AL. 7071 / 9 % TiB4	56.30

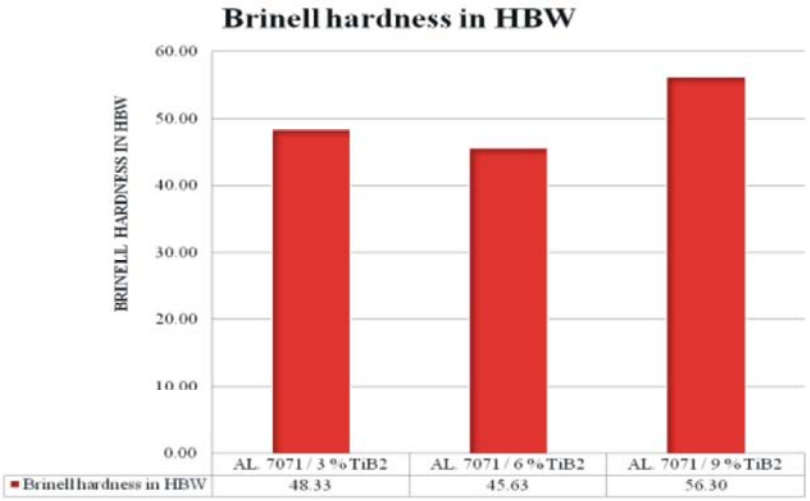

Fig. 4.1: Graph variations for Hardness

Tensile Test: Tensile samples were prepared as per ASTM standard (ASTM E08) as shown in Figure from the casted plates. Tensile tests were carried out to determine the ultimate tensile strength and % elongation under static loading of the composite. Three tensile test samples for each material (base alloy and each of the MMCs containing 3%, 6% and 9% TiB2) prepared as per ASTME08 standard were tested. During the test, the tensile load as well as the elongation of a previously marked gauge length in the specimen was measured with the help of load dial of the Universal Tensile Testing Machine and Extensometer respectively.

Table 4.2: The Tensile Strength value of Aluminium With TiB2 Composite

Material	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	Elongation in 4D GL
AL. 7071 / 3 % TiB2	107	149	18.5
AL. 7071 / 6 % TiB2	101	132	12.5
AL. 7071 / 9 % TiB2	0	96	0

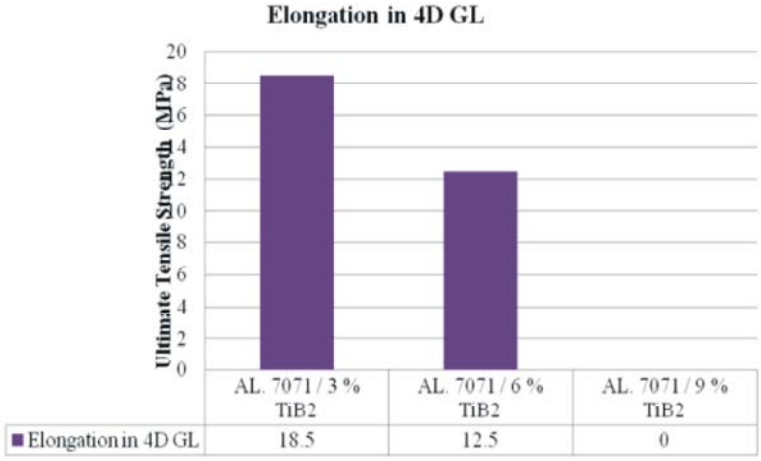

Fig. 4.2: Graph variations for Elongation

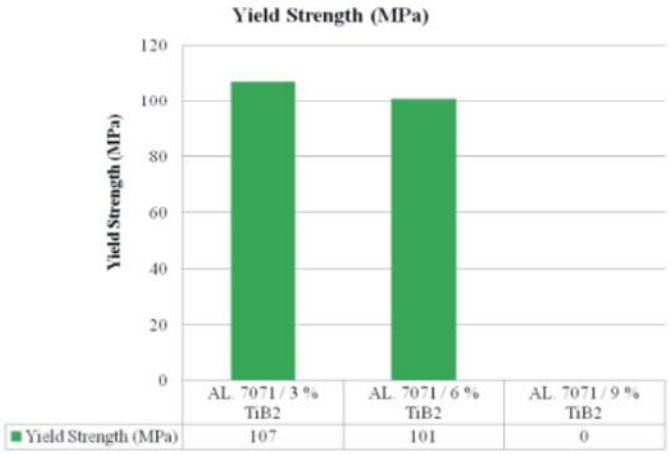

Fig. 4.3: Graph variations for Yield Strength

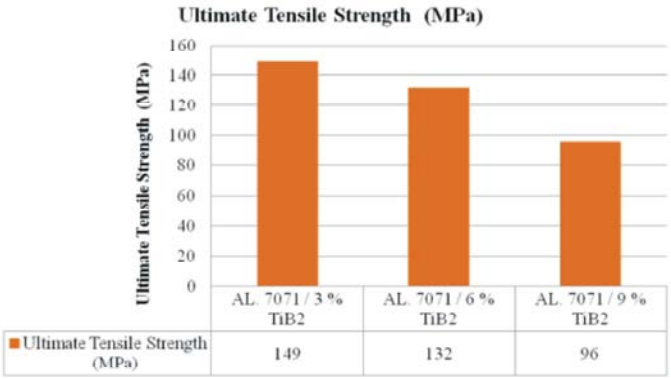

Fig. 4.4: Graph variations for Ultimate Tensile Strength

CONCLUSIONS

The metal matrix composite of aluminium alloy 707.1 is reinforced with titanium diboride was fabricated by using stir casting set up along with electrical resistant heating furnace. The material were prepared with different Volumetric Percentage of TiB2 using stir casting furnace. By increasing the Volumetric Percentage Hardness and the tensile strength of the composites will increased.

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