



# COMBINED EFFECTS OF STIR CASTING AND IN-SITU TECHNIQUES IN THE PRODUCTION OF AL 6061-TiB<sub>2</sub> METAL MATRIX COMPOSITE WITH DIFFERENT REACTION HOLDING TIMES AND ITS CHARACTERIZATION

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## ABSTRACT

*At 850°C, with the aid of KBF<sub>4</sub> and K<sub>2</sub>TiF<sub>6</sub> salts the exothermic effect utilizes to formulate in-situ TiB<sub>2</sub> particle-reinforced Al 6061 metal matrix composites. To inspect the level of effect and the expansion actions of TiB<sub>2</sub> united effect of stir casting and in-situ techniques experiential from a preference of composites by varying the period of exothermic reaction from 15 to 60 minutes period. This investigation reveals quite evident consequences on mechanical properties for instance tensile strength, yield strength and hardness based on reaction holding time. The comparative investigation on mechanical properties and microstructure of the composites with Al 6061 alloy (as cast) also presented.*

**Keywords:** In-situ TiB<sub>2</sub>, Al 6061 metal matrix composites, K<sub>2</sub>TiF<sub>6</sub> and KBF<sub>4</sub>, stir casting.

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## 1. INTRODUCTION

Researchers are constantly endeavoring to enhance different properties of engineering materials. This led to new classification of materials called composite materials; they are made out of a mixture of particularly dissimilar two or more micro or macro constituents that vary as organization and it is insoluble in each other.[1]

### **Composites:**

A "composite" is a minimum of two different materials are join mutually to create an unequaled and remarkable material. This greatly wide definition residue stable for every composites, moreover, further as of late the appearance "composite" represents reinforced plastics.[2]

### **Benefits of Composites**

Because of their superior properties similar to high strength, light weight, non-corrosive, non-conductive, long life, design flexibility these are utilized as a part of different applications like automobile components, sports goods, and so on.

### **Classification of composites: three fundamental classes:**

Particle-reinforced, Fiber-reinforced, Short fibers and Structural these kinds of composites cover a scope of various material combinations. The most ordinary sort is polymer matrix composites, but, metal matrix composites, and ceramic matrix composites are additionally normal, as are characteristic composites, for example, wood.[3]

### **Metal matrix composites**

Metal Matrix Composites are progressively utilized as a part of aerospace and car industries attributable to their upgraded properties, for example, hardness, elastic modulus, elevated temperatures and tensile strength at ambient, wear resistance mutual with major weight investments above unreinforced alloys. The generally utilized metallic matrices incorporate Cu, Ti, Al, Mg and their alloys. These alloys are favored matrix materials for the creation of MMCs.[4] Metal matrix composite has a superior grouping of properties that can be accomplished by either part material itself. The goal of adding reinforcement is to exchange the weight from the matrix to the reinforcement so that the strength and elastic modulus of the composite are expanded in extent to the strength, modulus and volume fraction of the reinforcement material.[5]

### **Aluminium Matrix Composites (AMCs)**

Aluminium Matrix Composites (AMCs) are the skilled material in the modern world. They are generally utilized in aerospace, automobile, marine industries, and so forth because of their fantastic mechanical properties. The Aluminium matrix is make stronger while it is reinforced by tough ceramic particles similar to TiB<sub>2</sub>, SiC, Al<sub>2</sub>O<sub>3</sub>, B<sub>4</sub>C, thus on carrying regarding upgraded wear resistance and enhanced strength to weight ratio.[6]

### **Advantages and Disadvantages of AMCs**

The significance pros of AMCs associated with non-reinforced materials are detailed as: elevated temperature properties, superior strength, concentrated density, regulated thermal expansion coefficient, adapted electrical performance, Thermal/heat management, Enhanced and Improved stiffness, wear resistance and Improved abrasion, Improved damping capabilities, Control of mass. The significance cons of metal matrix composites generally deceit in the moderately elevated cost of fabrication and of the reinforcement materials.[7]

## Stir casting

Stir casting is one of the most straightforward and least demanding techniques to deliver castings. Stir casting process suit for mass production when contrasted with other manufacturing techniques. The real issue in this strategy is to acquire adequate wetting of reinforcement particle by the liquid metal and to get a homogeneous dispersion of particles.[8]

## Process parameters of stir casting process

It is imperative factor in stir casting methodology, which is necessary for vortex development. The flow pattern of the liquid metal chose by couple of parameters namely blade angle and number of blades. For uniform distribution of reinforcement in liquid metal, great line bonding the entire these are necessary and to stay away from clustering. [9]

## In situ technique

In situ fabrication includes exothermal reactions between elements and compounds with molten aluminum to produce ceramic particles. In situ technique shows a few advantages over ex situ strategies, for example, fine particle size, clean interface, good wet ability between the reinforcement particles with the aluminum matrix and homogeneous distribution. In this manner, in situ technique drew the consideration of specialists in the past decade.[10-12]

A few analysts revealed about the creation and portrayal of aluminium alloy metal matrix composites reinforced with TiB<sub>2</sub>. Data identified with the manufacture of aluminium based composites reinforced with TiB<sub>2</sub> with various reaction holding times is, though exceptionally constrained. The point of this examination is to research the impact of various reaction holding times in the production of in-situ Al 6061-TiB<sub>2</sub> metal matrix composites and the investigation of their mechanical properties.

## 2. LITERATURE REVIEW

Narinder kaushik and Sandeep Singhaal [13] 2017, had proposed the drift of study work from monolithic aluminum alloy to composite materials similar to Metal Matrix Composites (MMC's) is expected to the world-wide proviso for economical, high working execution and unrivaled quality materials. That paper gives a summary of mechanical, microstructural and wear performances of aluminum focused metal matrix composites delivered by stir casting process reinforced with single and various kinds of reinforcements. The impact of different reinforcement particles on aluminum matrix composites on mechanical properties similar to uts, ys, stiffness, hardness, fatigue, % E, wear and on coming about microstructure is talked about.

Himanshu Kala *et al.* [14] 2014, had recommended worldwide requirement for elevated act, economic cost and high-quality materials has made a move in inquire about as of monolithic to composite materials. If there should be an occurrence of MMC's, aluminum matrix composite suitable their elevated strength to weight ratio, elevated wear resistance and low cost are generally produced and utilized as a part of basic applications alongside aerospace and automobile industry. That paper exhibits an audit on the mechanical and tribological properties of stir cast aluminum matrix composites having single and an assortment of reinforcement. Natural reinforcement similar to fly ash, coconut ash additionally enhanced the tensile and yield strength. Self-lubricating assets of graphite enhanced the machinability of aluminum. Various creators had likewise revealed regarding changed stir casting route.

Gowri Shankar M.C *et al.* [15] 2013, had planned the single and consolidated impact of reinforcements on Aluminium Metal Matrix Composites. These AMMCs with single and dissimilar reinforcements (Hybrid MMCs) utilized in underwater, aerospace, space, transportation applications and automobile. It is mostly owing to enhanced mechanical and tribological properties similar to sturdy, stiff, impact resistant and abrasion and is not effectively consume. In the current situation, that manuscript conducts analysts and experts nears legitimate choice of equipments by allowing for change in material properties for pertinent use and significance of liquid metal handling method among developing of Metal Matrix Composites.

T.V. Christy *et al.* [16] 2010, had recommended that Al 6061 alloy is broadly utilized for profitable utilize in the transportation, improvement and equivalent engineering industries. It has incredible mechanical properties although enormous spending protection since of which the alloy discovers broad use in marine vessels manufacturing. Al-TiB<sub>2</sub> composite is a MMC that can make utilizing the in-situ salt-metal reaction. Among TiB<sub>2</sub> as the particulate count, the properties of Al 6061 alloy can be enormously move forward. An examination of the mechanical properties and the microstructure of Al 6061 alloy amid Al-TiB<sub>2</sub> metal matrix composite including 12% by weight TiB<sub>2</sub>p manufactured throughout the in-situ procedure were exhibit.

### Production of Al 6061

This material widely utilize in various engineering application such as construction, transport and so on, its chemical composition detailed in below table-1. This composition makes this material appropriate for marine structural uses, cost effective, lighter weight and high presentation materials for employ in a spectrum of structural and non-structural uses have outcome in the necessitate for fabrication of MMCs of different kinds.

**Table 1** Chemical composition of Al 6061 alloy

Element	Mg	Si	Mn	Cu	Fe	Ti	V	Al
Weight %	1.02	0.64	0.54	0.33	0.18	0.03	0.01	Bal

The following statements establish the inference of chemical salts essential to attain anticipated volume fraction of TiB<sub>2</sub> in Al MMC. Estimate each chemical atomic weight in salt, ratio of chemical composition of salt and meticulous composition, percentage of chemical required to turn out requisite quantity of TiB<sub>2</sub>.

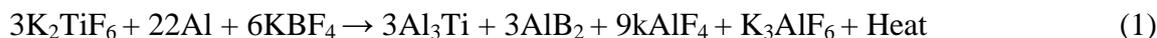
### 3. EXPERIMENTAL INVESTIGATION

**Materials:** The matrix phase utilized as a part of this work was an aluminium alloy Al – 6061. By the in-situ method, the halide salts potassium hexa fluorotitanate (K<sub>2</sub>H<sub>6</sub>Ti) & potassium tetra fluoroborate (KBF<sub>4</sub>) utilized for creating the reinforcement phase, TiB<sub>2</sub>.

**Processing:** The halide salts potassium hexa fluorotitanate (K<sub>2</sub>H<sub>6</sub>Ti) and potassium tetra fluoroborate (KBF<sub>4</sub>) were presented in the molten aluminium alloy on 850° C in the atomic ratio in agreement among Ti/2B utilizing the mixing strategy. A mild steel stirrer covered by zirconia utilized to maintain a strategic distance from conceivable stain of the melt. The development of TiB<sub>2</sub> occurred position as an outcome of chemical reaction among halide salts and the molten aluminium alloy in a couple of levels.

In the primary process, incorporation of halide salts reacted with molten aluminium bonding leads the formation of AlB<sub>2</sub> and Al<sub>3</sub>Ti. Subsequently, AlB<sub>2</sub> and Al<sub>3</sub>Ti bond mutually with cryolite slag and TiB<sub>2</sub>. These compositions develop due to same dispersal of strengthening phase TiB<sub>2</sub> in the Al-6061 alloy matrix phase. The chemical reaction between

halide salt and molten aluminium alloy leads the formation of cryolite slag skimmed off altogether prior to pouring the melt into the die. The accompanying were the chemical reactions in the configuration of TiB<sub>2</sub>, filled as reinforcement in the Al – 6061matrix for the combination of Al-6061-TiB<sub>2</sub> composition.



Utilizing an electrical protection heater Al 6061 alloy dissolved in a high-temperature of 850°C out of a graphite crucible of 1-kg competence. The alloy held in reserve at this temperature for around 5-min for homogenization temperature. Whereas, being stimulated at 600 rpm utilizing a mild steel stirrer covered with zirconia. Stirring continue whereas the couple of halide salts in proper quantity established to the melt. Various RHT in steps of 15 min to 45 min the temperature was kept up at 850° C to examine the connection linking the level of chemical reaction and the development performance of the reinforcement phase. Toward the finish of every RHT, the cryolite slag skimmed off completely and the composite cast in to rods of 16 mm diameter across utilizing a mild steel hollow cylindrical die covered by means of zirconia. The metallographic assessment, estimation of tensile properties and hardness complete for the portrayal composite.

A microscopic assessment of the composition arranged with various RHT and the base alloy led by optical microscope in the wake of getting ready appropriately position, polished and imprinted examples to regulate to assess the microstructure. The tensile analysis specimens for determine tensile properties be set up according to ASTM E8-03 standard and the tensile tests be done at ambient temperature beneath consistent strain rate utilizing a Hounsfield Tensometer. Table 2 demonstrates the consequences of the tensile analysis for different examples with an assortment of RHT. The tensile possessions of the composite of Aluminium alloy reinforced with TiB<sub>2</sub> were contrasted and a consequences of Aluminium 6061 alloy.

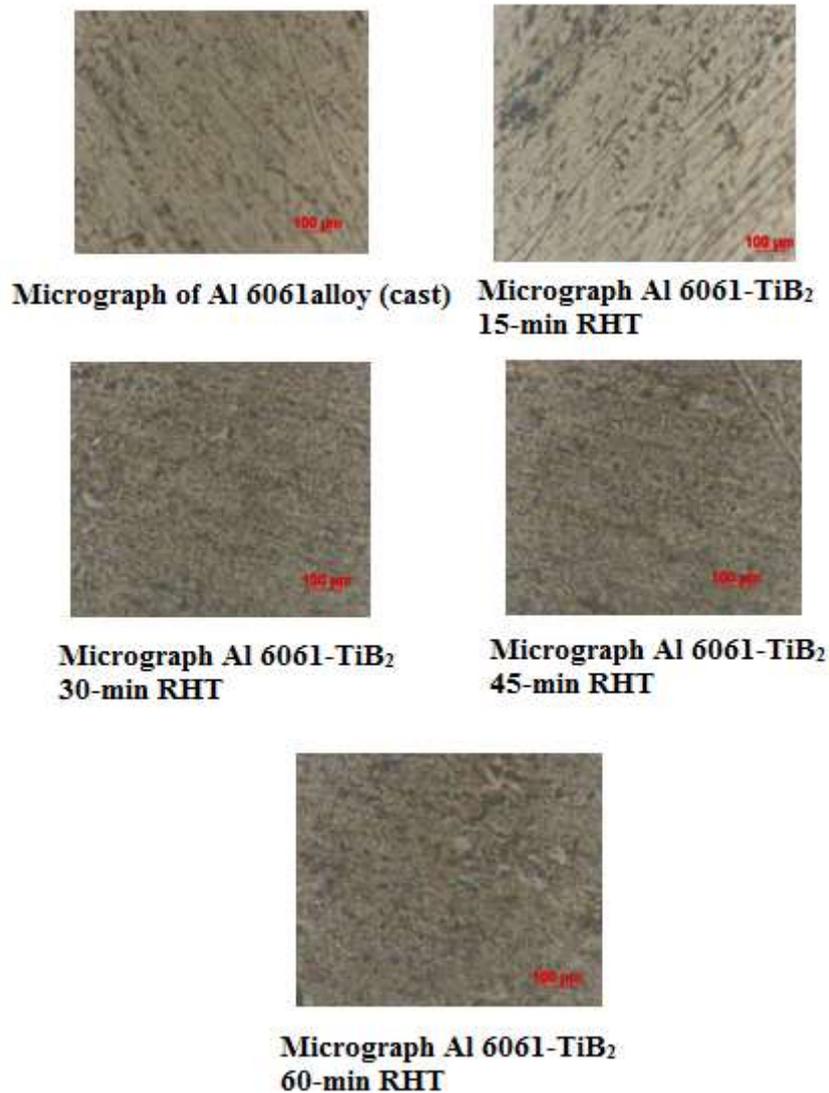
Investigative specimens for compute hardness set up since together with support alloy and the composition. Utilizing a Brinell hardness analyzer, hardness estimations done on the composites and the stand metal arrange to survey the impact of different RHT in which the salt-metal response occurred.

## 4. RESULTS AND INVESTIGATION

This investigation comprised of performance evaluation from 6061-TiB<sub>2</sub> MMC with different reaction holding time. The following detailed the various performance evaluations such as Micrograph of Al 6061alloy as cast along with various reactions holding time, tensile strength analysis for different reaction holding time, elongation analysis for different reaction holding time and eventually hardness analysis for different reaction holding time. The aforementioned sum up eventually with the effective outcome of incorporating halide salts, K<sub>2</sub>TiF<sub>6</sub> and KBF<sub>4</sub> to fabricate effective synthesize Al 6061-TiB<sub>2</sub> metal matrix composites.

### 4.1. Al 6061-TiB<sub>2</sub> Microstructure from different reaction holding time

The following figures-1, illustrate optical micrographs of the alloy Al 6061 (as cast) and the composites of Al 6061- TiB<sub>2</sub> out coming from different RHT (15min to 60 min). It is quite evident from the figure that reinforcement distributes uniformly in matrix phases and has no gap between them owing superior bonding. The volume of cryolite slag that was form through the reaction between aluminum alloy and halide salts at the heat of the melt enhances with RHT.



**Figure 1** Micrograph of Al 6061 alloy and composition as cast (1000X) and with different RHT

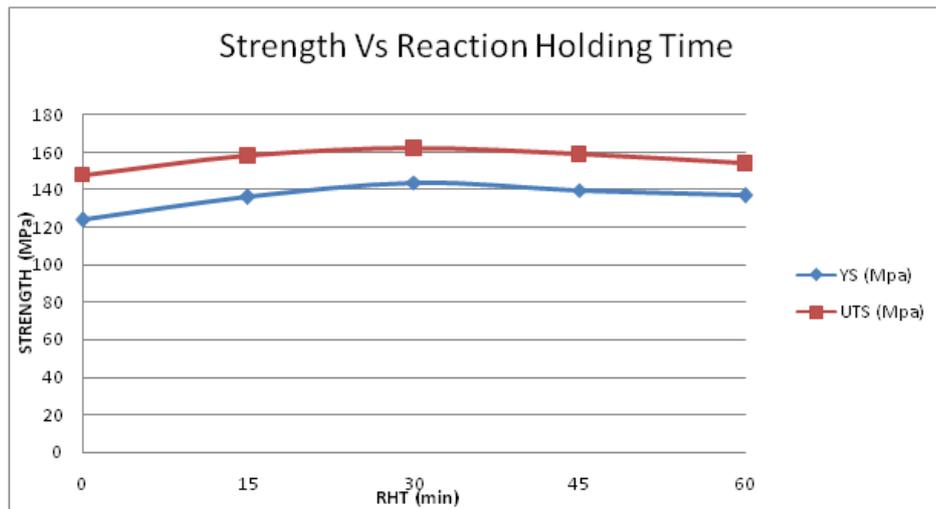
**Table 2** Tensile properties of composites with dissimilar RHT

Material	RHT (min)	YS (MPa)	UTS (MPa)	Elongation %
Al 6061 (as cast)	0	124	148	22.37
Al 6061 - TiB <sub>2</sub>	15	136	158	18.59
Al 6061 - TiB <sub>2</sub>	30	144	162	16.67
Al 6061 - TiB <sub>2</sub>	45	140	158	16.81
Al 6061 - TiB <sub>2</sub>	60	137	154	16.96

#### 4.2. Tensile strength analysis

From the table-1 and figure-2 it is quite evident that Al 6061- TiB<sub>2</sub> having greater tensile strength over Al 6061 with lower ductility. This outcome possible via uniformly distributed reinforcement and TiB<sub>2</sub> composition in the matrix. The following data reveal that the strength increase for first half RHT (30 min) and decrease further, this fix the optimal RHT as 30 min for greater tensile strength. Therefore, the optimum RHT of halide salts in Al 6061 alloy is 30 min.

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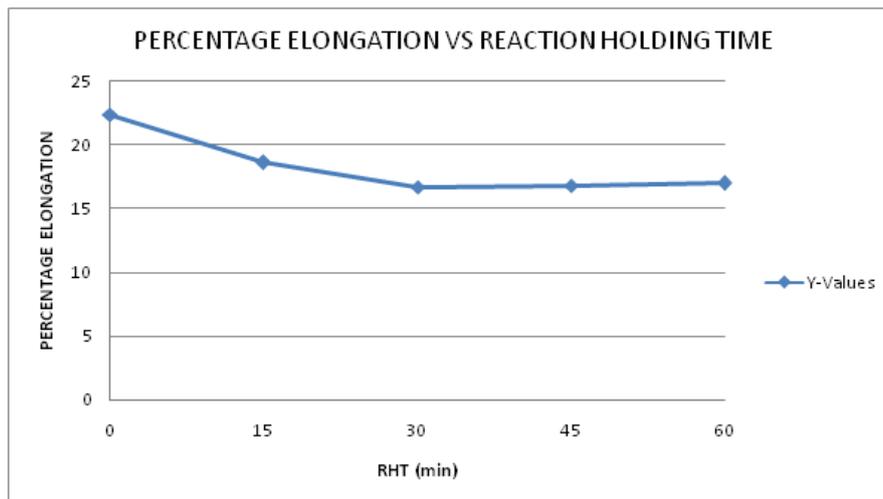


**Figure 2** Graph of Strength Vs RHT of halide salts in Al 6061

From the above figure-2, it is quite evident that greater Yield Strength (YS) and the Ultimate Tensile Strength (UTS) obtain in Al 6061 - TiB<sub>2</sub> composition from 30 min RHT. Obtained YS and UTS in 30 min RHT of halide salts in Al 6061 having greater strength over contest RHT in Al 6061 - TiB<sub>2</sub> composition and Al 6061 alloy casting.

### 4.3. Elongation analysis

The following figure-3 illustrates the percentage of elongation from different RHT for Al 6061 - TiB<sub>2</sub> composition. It is quite evident that RHT 30 min having lower elongation of 16.67% over contests RHT because of reinforcement particles incorporation. The Al 6061 alloys without composition having greater of 22.37% elongation that treated to be the greater over all, this shows the impact of Al 6061 - TiB<sub>2</sub> composition.



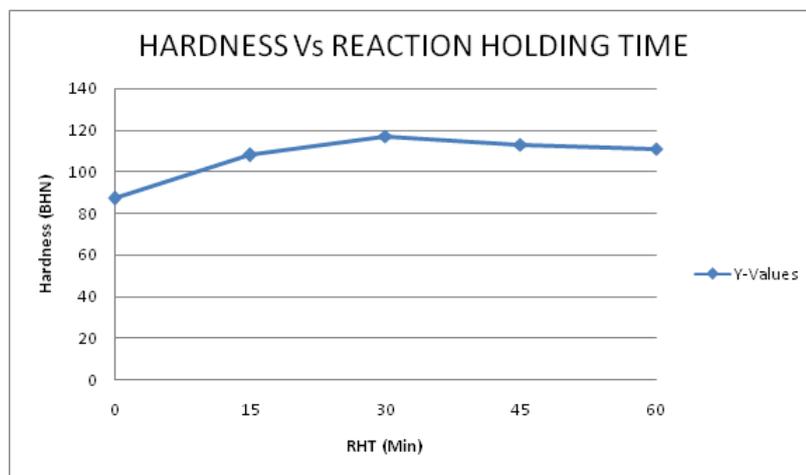
**Figure 3** Graph of Percentage Elongation Vs RHT of halide salts in Al 6061

#### 4.4. Hardness analysis

From the following figure-4, it is evident that the greater hardness achieve from RHT 30 min Al 6061 - TiB<sub>2</sub> composition having 117 over different contest RHT from composition and from base itself. The outcomes of the Brinell hardness investigation get hold of together composites and the base alloy with dissimilar RHT at dissimilar locations above the shell are tabulate as exposed in table-3. Fig. 4 shows the graph of hardness Vs reaction holding time for the composites and alloy with dissimilar RHT.

**Table 3** Hardness of base alloy and the composites

Material	Al 6061 (as cast)	Al 6061 - TiB <sub>2</sub>	Al 6061- TiB <sub>2</sub>	Al 6061- TiB <sub>2</sub>	Al 6061 – TiB <sub>2</sub>
RHT (min)	0	15	30	45	60
Hardness (BHN)	87	108	117	113	111



**Figure 4** Graph of Hardness Vs RHT of halide salts in Al 6061

#### 5. CONCLUSION

From the investigative results it is concluded that by including halide salts, KBF<sub>4</sub> and K<sub>2</sub>TiF<sub>6</sub> in the Al 6061 alloy at 850° C Al 6061-TiB<sub>2</sub> metal matrix composites have successfully synthesized. TiB<sub>2</sub> reinforcement phase prepared to be distributing equally in Al 6061 matrix phase by the in-situ process. Increased in RHT increases the quantity of cryolite slag produced through the reaction among the liquid alloy and halide salts, tensile strength, hardness and decreases the elongation of the composite at 30 minutes this would be superior over contest approaches.

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