

# Evaluation of Mechanical Behaviour of AA6061-TiB<sub>2</sub> Composites – A Review Paper

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**ABSTRACT:** The objective of this paper is to study the mechanical behaviour of AA6061-TiB<sub>2</sub> composite fabricated through various casting techniques. AA6061 is extensively used for commercial applications due to its excellent mechanical properties in addition to better corrosion resistance. Metal-matrix composites (MMCs) have emerged as an important class of materials for structural, wear, thermal, transportation and electrical applications, primarily as a result of their ability to exhibit superior strength-to-weight and strength-to-cost ratios when compared to equivalent monolithic commercial alloys. Among various reinforcement particles TiB<sub>2</sub> has emerged as an outstanding reinforcement due to the fact that TiB<sub>2</sub> has high hardness, superior wear resistance, and more importantly, does not react with aluminium to form any reaction product at the interfaces between the reinforcement and the matrix.

**KEYWORDS:** AA6061-TiB<sub>2</sub>, Casting process, Metal Matrix Composites, Mechanical Properties.

## I.INTRODUCTION

Aluminium Matrix Composites (AMCs) are the competent material in the industrial world. They are widely used in aerospace, automobile, marine industries, etc. due to their excellent mechanical properties. The Aluminium matrix is strengthened when it is reinforced with hard ceramic particles like TiB<sub>2</sub>, SiC, Al<sub>2</sub>O<sub>3</sub>, B<sub>4</sub>C, etc. resulting in enhanced wear resistance and improved strength to weight ratio. Al alloy Al 6061 is widely used in numerous engineering applications including transport and construction where superior mechanical properties such as tensile strength, hardness etc., are essentially required. In addition of foresaid ceramics, TiB<sub>2</sub> has emerged as an outstanding one due to its outstanding features like high melting point, high hardness, high elastic modulus and good thermal stability. It has resistance to plastic deformation temperature. Also it does not react with aluminium to form any reaction product at the interfaces between the reinforcement and the matrix [1].

The major advantages of Aluminium Matrix composites (AMCs) include greater strength, improved stiffness, reduced density, improved high temperature properties, controlled thermal expansion coefficient, thermal / heat management, enhanced and tailored electrical performance, improved abrasion and wear resistance and improved damping capabilities. One such MMC is Al – TiB<sub>2</sub>p containing TiB<sub>2</sub> as the dispersed second phase particle. When a molten metal or other liquid phase containing dispersed second phase particles solidifies, interactions take place between the advancing solidification front and the particles. Such interactions affect the front morphology and the particle solidification as well. The solidification front pushes or engulfs the particles. Due to this reason, the particles can be found at the grain boundaries, the interdendritic regions, or within the primary grains themselves [1,2].

In in situ TiB<sub>2</sub>P/Al composite, TiB<sub>2</sub> reinforcements were endogenously formed by various reactions between the different starting material systems. During the process of fabrication, thermodynamic control of the reactions and the reactive parameters such as particle size and reactive speed were not easy to control well. At the same time, the presence of Al<sub>3</sub>Ti intermetallic compound hindered the uniform distribution of reinforcement and deteriorated the

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properties of the composite. So far, most of the studies reported are related to the fabrication and formation mechanism of in situ TiB<sub>2</sub>/Al composite [3].

### II.LITERATURE SURVEY

Lawrance, CA & Suresh Prabhu, P (2015) [4] have experimented Al 6061 with TiB<sub>2</sub> metal matrix composite with different reaction holding times by in-situ method. It was concluded that addition of TiB<sub>2</sub> particles to the metal matrix increases the strength of matrix phase. Also a uniform distribution of reinforcement particles has been obtained in the matrix phase. With increase in reaction holding time, there was an increase in tensile strength and hardness of the composite up to 30 minutes of reaction holding time.

Ramkumar KR (2015) [5] have experimented mechanical and turning behaviour of Al 7075/x% wt.TiB<sub>2</sub>-1% Gr In-Situ composite fabricated through stir casting technique. The samples were taken under casted condition and the properties of the composite were tested by conducting characterization using X-ray diffraction (XRD), hardness test, flexural strength by using three-point bend test, scanning electron microscope (SEM), optical microstructure, grain size analysis and surface roughness. It was concluded that The XRD patterns of the prepared AMCs showed the formation of in situ TiB<sub>2</sub> particles without the presence of any other intermetallic compounds. The flexural or bending stress, deflection, flexural or bending strain of AA 7075/x% TiB<sub>2</sub>/1% Gr hybrid composite exhibited more value than AA 7075/3% TiB<sub>2</sub>/0% Gr composite due to the presence of hard ceramic particles TiB<sub>2</sub> and graphite particles in the matrix.

Suresh, S & Shenbaga Vinayaga Moorthi (2012) [1] studied the significance of Al-TiB<sub>2</sub> due to its combined superior properties and its applications. Also with the addition of TiB<sub>2</sub> particulate the properties of 6061 alloy can be greatly improved and increases the strength of aluminium. The wear resistance of this material is due to the lack of pull out of this material from the aluminium matrix. Also such material when machined with non-conventional machining process like EDM will show better machinability due to its high conductivity.

T.V. Christy et al (2010) [2] made a Comparative Study on the Microstructures and Mechanical Properties of Al 6061 Alloy and the MMC Al 6061/TiB<sub>2</sub>/12P. It was concluded that Strings as well as particulate agglomerates were present as distinct microstructural features of the composite. The manufactured Al-TiB<sub>2</sub> composite exhibited higher values of hardness, tensile strength and Young's modulus than the base alloy. The ductility of the composite was found to be slightly lower than that of the aluminium 6061 alloy.

Zhao Min et al (2004) [3] fabricated a dense and homogeneous TiB<sub>2</sub>P/Al composite through squeeze casting technology and its microstructure as well as mechanical properties was evaluated. For 35 vol.% TiB<sub>2</sub>P/Al composite, the bending strength was as high as 629MPa, the hardness was 170 HB, and the elastic modulus was 137 GPa. In addition, the fracture modes included ductile failure of Al matrix and brittle fracture of TiB<sub>2</sub> particles. With the increasing of TiB<sub>2</sub>, bending strength, hardness, and elastic modulus of 45 vol.% TiB<sub>2</sub>P/Al composite were 18, 61, and 26%, respectively, higher than that of 35 vol.% TiB<sub>2</sub>/Al composite.

Tee, KL, et al (2003) [6] have studied the effect of incorporation of carbon into the in-situ reaction. It was concluded that the Al<sub>3</sub>Ti intermetallic phase was found to decrease via the formation of TiC and the decomposition of Al<sub>3</sub>Ti since TiC is more stable in the presence of carbon. As the amount of carbon increases, the intensity of TiB<sub>2</sub> peaks is also observed to reduce, showing that the incorporation of carbon into the composite causes some of the Ti to react with the carbon to form TiC, and in the process renders a lesser amount of Ti to react with Al to form Al<sub>3</sub>Ti. A composite designed with composition of Al4.5%Cu\_ 15vol.%TiB<sub>2</sub> incorporated with 3 wt.% C was found to produce a tensile strength of 258 MPa, yield strength of 203 MPa and modulus of 97 GPa.

Feng, CF & Froyen, L (2000) [7] has studied the Microstructures of in situ Al/TiB<sub>2</sub> MMCs prepared by a casting route. It was concluded that dispersion of TiB<sub>2</sub> particles in Al is improved by adding Si to the matrix. A

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homogeneous distribution of TiB<sub>2</sub> is obtained when a eutectic Al-Si alloy is used. Furthermore, the use of Al-Si alloys with lower Si contents (5 wt% or 2 wt%) as the matrix materials does not lead to such a good distribution.

Lakshmi, S et al (1998) [8] have fabricated Al-TiB<sub>2</sub> metal-matrix composites using an exothermic reaction process at 850°C with K<sub>2</sub>TiF<sub>6</sub> and KBF<sub>4</sub> salts. It was found that the grain size also varies with the reaction holding time. There was an initial decrease in grain size up to 30 min, followed by a significant increase over the next 10 min. This phenomenon can be attributed to the coupled effects of the weight percentage of TiB<sub>2</sub> in the aluminium matrix, the size of TiB<sub>2</sub> and the α-Al grain nucleant in the matrix. Also it was obtained that there is a specific relationship between the rate of formation of TiB<sub>2</sub> and the volume of cryolite slag. In general, variation in the weight percentage of TiB<sub>2</sub> can be attributed to change in the volume of cryolite slag, which increases with reaction holding time.

Yuyong Chen & Chung DDL (1996) [9] experimented with Al-TiB metal matrix composite fabricated through In-Situ casting technique with particle size of 10-50 μm size at 900°C. It was concluded that formation of smaller amounts of TiB<sub>2</sub> and TiAl<sub>3</sub> occurred. The TiAl<sub>3</sub> was in the form of fine needles in the amount of 3 vol.%. The composite exhibited much higher hardness, microhardness, tensile strength and modulus, but slightly lower ductility than aluminium.

Jha, A & Dometakis, C (1997) [10] explained the dispersion mechanism of TiB<sub>2</sub> ceramic phase in molten aluminium and its alloys. For producing cast MMC, the dispersion of the ceramic phase via in-situ aluminothermic reduction of K<sub>2</sub>TiF<sub>6</sub> and KBF<sub>4</sub> flux mixture with molten aluminium and, via the addition of exogenously formed TiB<sub>2</sub> with the fluoride flux has been studied at 900°C. It was concluded that the ceramic particles, however, cluster together in order to reduce the interfacial energy. The presence of zirconium promotes the dispersion of TiB<sub>2</sub> by allowing Mg atoms to be desorbed from the boride surface.

**III. LITERATURE GAPS**

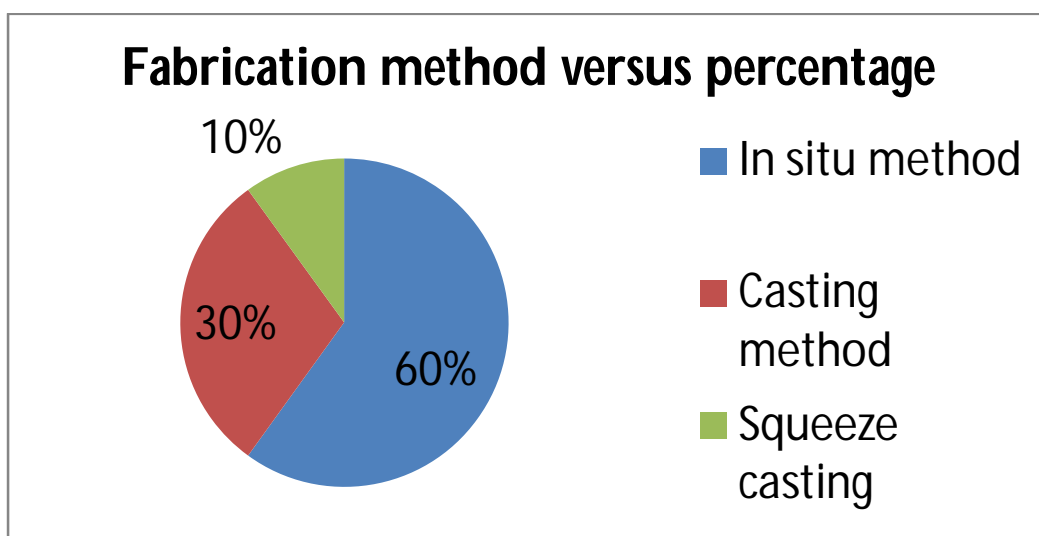


Figure 1: Fabrication method and its percentage

From an extensive literature survey it was noticed that most of the aluminium matrix composites fabricated through various casting routes other than squeeze casting would produce certain limitations. Also, from figure 1, it was

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noted that only a few research works has been carried out for fabricating aluminium titanium-diboride composites through squeeze casting technique. During the experimental work, the controlled and uncontrolled parameters may affect the reliability of results. Hence the inconsistencies are not revealed by using computational techniques like neural networks, response surface etc., Further it is suggested that the cast specimen is employed for any machining process in order to obtain desired mechanical properties. The major problems occurred during fabrication of AA6061-TiB<sub>2</sub> through in-situ reaction is as follows,

- Formation of intermetallic brittle compounds detriment the mechanical properties of metal matrix composites.
- The intermetallic compounds lead to occur a weak interfacial bonding between reinforcement and matrix.
- Difficulty in achieving uniform distribution of reinforcement particles in the composites.
- The cast specimens would have major defects like voids, porosity, blowholes.

### IV.CONCLUSION

- Hence, it is concluded that fabrication of AA6061-TiB<sub>2</sub> will act as a pavement for defect free casting product and in research areas.
- The addition of TiB<sub>2</sub> particles will improve mechanical as well as tribological properties.
- The squeeze casting route aids to obtain defect free products with homogeneous distribution of particles.
- The elimination of intermetallic brittle phase compounds can be achieved.

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