

**International Journal of Innovative Research in Science,
Engineering and Technology**

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

Development and Evaluation of Fatigue Property and Microstructure Analysis of Al6061 Reinforced with TiB₂

Lakshmana H K¹, Mohan Kumar G², Manju R B³

Lecturer, Department of Technical Education, Government Polytechnic Holenarasipura, Bangalore, India¹

Lecturer, Department of Technical Education, Government Polytechnic Mirle, Bangalore, India²

Lecturer, Department of Technical Education, Government Polytechnic Holenarasipura, Bangalore, India³

ABSTRACT: In modern industries Metal Matrix Composites (MMCs) plays a vital role due to its excellent mechanical properties like high wear resistance, low thermal expansion, high strength to weight ratio etc. Owing to these superior mechanical properties, MMCs find applications in aircraft structures, space shuttles, military and shipbuilding. The MMCs are yet to revolutionize the industries with its application to all fields of engineering. Extensive research is required to develop technology to manufacture MMCs in large quantity as well as economically. In this present work In-Situ process is adopted to produce Aluminum alloy Al6061 reinforced with 1.5% of magnesium with different weight fractions of (0, 3, 6, 9 and 12 wt. %) TiB₂ particles by using inorganic K₂TiF₆ and KBF₄ salts. The microstructures studied using scanning electron microscopy revealed that In-Situ formed TiB₂ particles were uniformly distributed with clear interface and good bonding in the aluminum matrix. With the addition of TiB₂ fatigue life of aluminum can be enhanced and as the percentage of reinforcement increases, the number of cycles can be reduced.

KEYWORDS: MMC, Aluminum alloy, Composite, Microstructure analysis, Fatigue

I. INTRODUCTION

Composite materials are the sandwich of two or more materials which are different in form and chemical composition. The advent of advanced reinforced composite materials has been called the biggest technical revolution since the jet engine. This claim is very striking because the tremendous impact of jet engine on military aircraft performance is readily apparent. The impact on commercial aviation is even more striking due to the airlines switched from propeller driven planes to all jet fleets within a span of just few years. Numerous materials when they are in a fibrous form exhibit very good strength property but to achieve these properties the fibers should be bonded by a suitable matrix. The matrix isolates the fibers from one another in order to prevent abrasion and formation of new surface flaws and acts as a bridge to hold the fibers in place. The role of the reinforcement in a composite material is fundamentally one of important mechanical properties of the resin system. All of the different fibers used in composites have different properties and so affect the properties of the composite in different ways. In most of the applications, the fibers need to be set into some form of sheet, like fabric, for easy handling.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

The term fatigue refers to gradual degradation and eventual failure that occur under loads which vary with time, and which are lower than the static strength of the metallic specimen, component or structure concerned. Notches are present in many mechanical and structural components and fatigue cracks often nucleate and grow from notches. In certain cases, the state of stress at a notch may be multi axial due to the stress concentration effect of the notch, and/or due to loading in different directions, either simultaneously or in a sequential manner. In addition, multi axial loading can have a significant effect on the location and magnitude of these stress concentrations. Therefore, study of notched fatigue behavior under multi axial stress states presents an important area of much practical significance. The complete solution of a fatigue crack propagation problem includes determination of the crack path. At the present state of the art the factors controlling the path taken by a propagating fatigue crack are not completely understood. In general, fatigue crack paths are difficult to predict.

II. MANUFACTURING TECHNIQUES OF METAL MATRIX COMPOSITES

Raw materials like Aluminum alloy Al6061, magnesium with different weight fractions of (0, 3, 6, 9 and 12 wt. %) TiB_2 particles, K_2TiF_6 and KBF_4 salts are used to produce the composite.



Fig2.1: shows a) Aluminum alloy Al6061 b) K_2TiF_6 c) KBF_4 d) magnesium



Fig 2.2: Components stir casting process

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

Aluminum alloy Al6061 reinforced TiB_2 particulate composites were successfully synthesized by the In-Situ reaction of K_2TiF_6 and KBF_4 salts to molten aluminum. Machining of the composites as per ASTM standards was carried out to conduct mechanical and micro structure analyses. In-Situ synthesized particles and fibers are smaller than those in materials with separate fabrication of dispersed phase (ex-situ MMCs). Fine particles provide better strengthening effect.



Figure 2.3.1 Different weight fractions of TiB_2 reinforced MMC's



Figure 2.3.2 Machined ASTM Fatigue test specimens for different weight fractions of TiB_2

III. FATIGUE CHARACTERISTICS OF ALUMINUM-BASED METAL MATRIX COMPOSITES

Modern machine components and structures are designed to be failure free. However, failure does occur and is commonly linked to fatigue. For example, high cycle fatigue (HCF) is one of the main causes of failure in engineering and airplane structures. Different design tools have been developed to analyze this issue. The most commonly such used tool is a stress versus cycles plot, or S-N curve. These curves provide fatigue strength with respect to time to failure. Other common tools for predicting fatigue properties are the Goodman diagram and the modified Goodman diagram, which are the popular choices for a failure-free machine component design criterion.

3.1 Test Procedure

A simple fatigue test can be performed with hands by taking a thin wire and bend it back and forth many times, the wire will break after a number of cycles depending on the stress level. However, for good testing it is required more accurate control of the cyclic load and this can be done by a rotating bending machine as shown in figure 3.1.1.

- ❖ Open the Plexiglas enclosure by rotating it about the hinges at the middle of the machine.
- ❖ Remove each of the bearing housings by lifting them straight up and out of the machine and set them down on the bench.
- ❖ The roller supports fit tightly between the rails and thus will jam against the sides very easily.
- ❖ Take care not to twist them in anyway while removing.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

- ❖ Insert collet on both side of the specimen and note that collet is being drawn into the both ends of bearing housing.
- ❖ Connect motor to the bearing assembly.
- ❖ Reset the load, speed control knob and number of cycle's counters.
- ❖ Close the Plexiglas cover before starting the machine.
- ❖ Start the machine and allow the specimen to break. Once the specimen breaks the total no of cycles to failure should be noted to determine fatigue life.
- ❖ Repeat the procedure for different weight fractions of TiB₂reinforced composite material specimens.

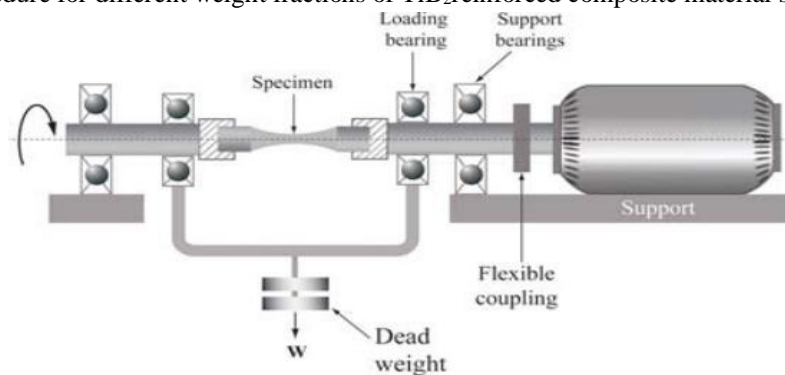


Figure 3.1.1 Rotating bending machine

IV. RESULTS AND DISCUSSION



(a)



(b)



(c)



(d)

Fig.4.1: a, b, c & d shows ASTM Standard test specimens after fatigue failure

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

4.1 Fatigue Result

After the tests number cycles for failure are noted and the results for different weight fractions of TiB₂ are as shown in table 4.1. Also noticed that with the addition of TiB₂ ductile failure modes were observed for 3, 6 and 12 % and 9 % reinforcement the failure mode will be brittle in nature due to agglomeration of TiB₂. Similar results were observed in many literatures and they restrict the reinforcement within 9% hence it is required to optimize the % of reinforcement.

Table: 4.1. Number of failure cycles for TiB₂reinforced composite system

Percentage of reinforcement	No. of failure cycles
0	5,28,368
3	1,76,339
6	1,55,941
9	52,418
12	31,023

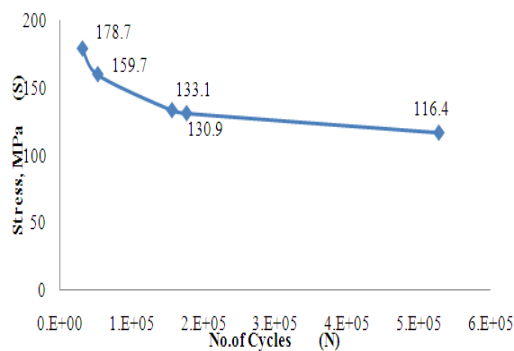


Figure: 4.2 S-N curve for different weight fractions of TiB₂

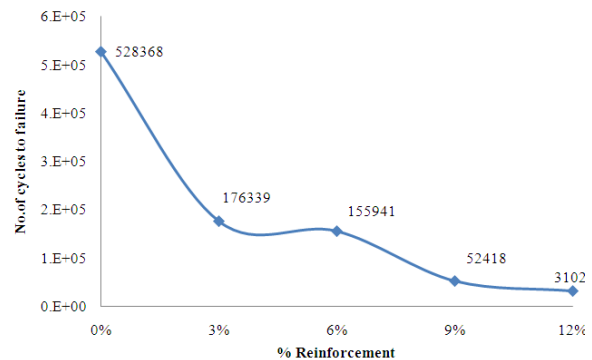


Figure.4.3 No. of cycles of failure for different % of reinforcement

S-N curve for the AMC with different weight fractions of particle reinforcement is shown in Figure 4.2. The results indicated that the fatigue life of the composite is lower than that of the unreinforced alloy for any given number of cycles.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

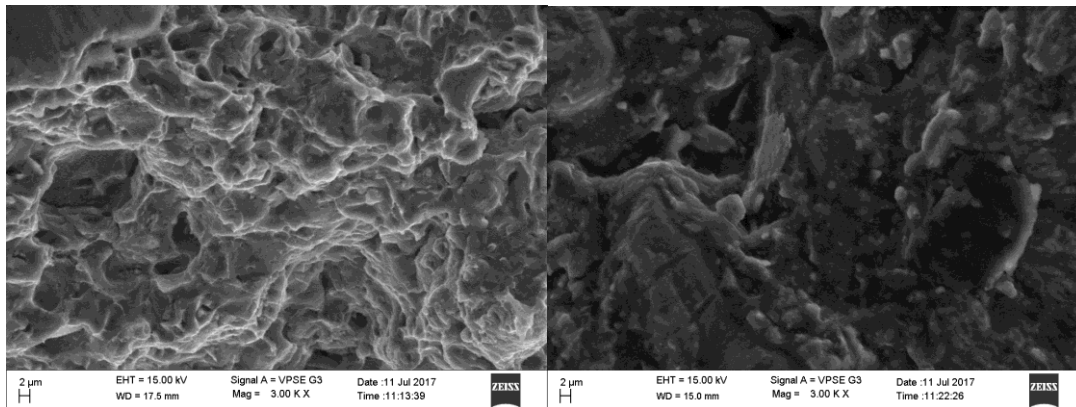
Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

Figure 4.3 shows the number of failure cycles for different percentage of reinforcement and it is observed that as the percentage of reinforcement increases, the number of cycles was reduced.

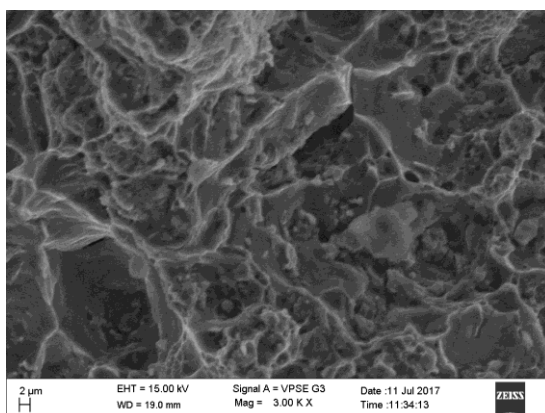
4.2 Microstructure Analysis

The SEM micrographs of the fatigue and fracture AMCs are presented in figure 4.2. The in situ formed TiB_2 particles are distributed homogeneously in the aluminum matrix with interface and good bonding of the TiB_2 particulates in the base Al alloy matrix. Such kind of particulate distribution is an essential requirement to achieve better fatigue property and solidification process dictates the uniform distribution of TiB_2 particles in the matrix.

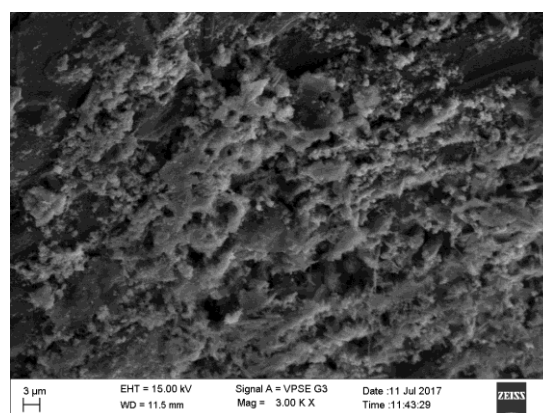


(a) Al6061 + 1.5% Mg

(b) Al6061 + 1.5% Mg + 3% TiB_2



(c) Al6061 + 1.5% Mg + 6% TiB_2



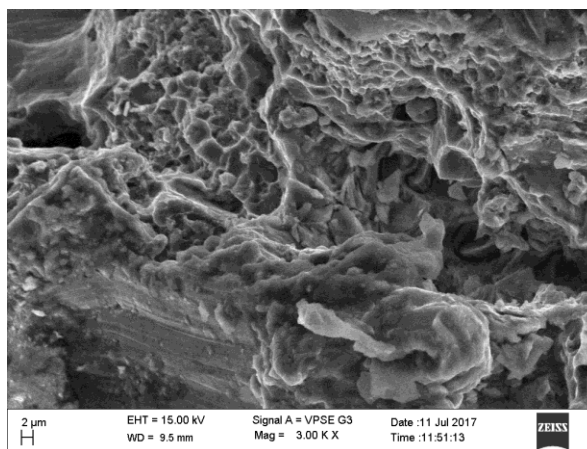
(d) Al6061 + 1.5% Mg + 9% TiB_2

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017



(e) Al6061 + 1.5% Mg + 12% TiB₂

Figure: 4.2 Microstructure Images of Fatigue Test Specimens

Fatigue cracks in the composite initiated at inclusions near the surface due to stress concentration caused by pileup of dislocations. Addition of TiB₂ particles to aluminum alloy delayed the crack initiation in the composite thereby resulting in better fatigue properties. Fracture in the composite initiates due to void initiation in the matrix near the interface. These voids eventually grow as micro cracks and crack propagation takes place as these micro crack links with other micro cracks preferentially in the matrix adjacent to the interface. Fracture mechanism in composite with 6wt% of TiB₂ particles was due to ductile rupture and decohesion of particle-matrix interface while in case of composite with 9wt% of TiB₂ particles fracture mechanism occurred due to matrix brittle rupture by particle fracture.

V. CONCLUSION

In this work, the Al-TiB₂-Mg metal matrix composite were developed using In-situ reactive processing method with the addition of 1.5% of Mg. ASTM standard test specimens were machined using CNC machines. Fatigue behavior of TiB₂ reinforced composite is analyzed and found that with the addition of TiB₂ fatigue life of aluminum can be enhanced and as the percentage of reinforcement increases, the number of cycles was reduced. It is noticed that ductile aluminum does not exhibits endurance limit this implies that sooner or later aluminum will fail under a cyclical load. Hence with the addition of TiB₂ fatigue life of aluminum can be enhanced.

REFERENCES

1. Shang, Jian Ku, Weikang Yu, and R. O. Ritchie. "Role of silicon carbide particles in fatigue crack growth in SiC-particulate-reinforced aluminum alloy composites." *Materials Science and Engineering: A* 102, no. 2 (1988): 181-192.
2. Mason, J. J., and R. O. Ritchie. "Fatigue crack growth resistance in SiC particulate and whisker reinforced P/M 2124 aluminum matrix composites." *Materials Science and Engineering: A* 231, no. 1 (1997): 170-182.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

3. Srivatsan, T. S., Meslet Al-Hajri, M. Petraroli, B. Hotton, and P. C. Lam. "Influence of silicon carbide particulate reinforcement on quasi static and cyclic fatigue fracture behavior of 6061 aluminum alloy composites." *Materials Science and Engineering: A* 325, no. 1 (2002): 202-214.
4. Uygur, Ilyas, and M. KEMAL KÜLEKÇİ. "Low Cycle Fatigue Properties of 2124/SiC Al-Alloy Composites." *Turkish Journal of Engineering and Environmental Sciences* 26, no. 3 (2002): 265-274.
5. Srivatsan, T. S., and Meslet Al-Hajri. "The fatigue and final fracture behavior of SiC particle reinforced 7034 aluminum matrix composites." *Composites Part B: Engineering* 33, no. 5 (2002): 391-404.
6. Zhenzhong, Chen, He Ping, and Chen Liqing. "The role of particles in fatigue crack propagation of aluminum matrix composites and casting aluminum alloys." *journal of materials science & technology* 23, no. 2 (2007): 213-216.
7. Rafiqzaman, M. D., Y. Arai, and E. Tsuchida. "Fracture mechanisms of Aluminum cast alloy locally reinforced by SiC particles and Al₂O₃ whiskers under monotonic and cyclic load." *Materials Science and Technology* 24, no. 3 (2008): 273-280.
8. Uematsu, Y., K. Tokaji, and M. Kawamura. "Fatigue behavior of SiC-particulate-reinforced Aluminum alloy composites with different particle sizes at elevated temperatures." *Composites Science and Technology* 68, no. 13 (2008): 2785-2791.
9. Achutha, M. V., B. K. Sridhara, and D. Abdul Budan. "Fatigue life estimation of hybrid Aluminum matrix composites." *International journal on design and manufacturing technologies* 2, no. 1 (2008): 14-21.
10. Mkaddem, A., and M. El Mansori. "On fatigue crack growth mechanisms of MMC: Reflection on analysis of 'multi surface initiations.'" *Materials & Design* 30, no. 9 (2009): 3518-3524.
11. Chawla, Nikhilesh, and V. V. Ganesh. "Fatigue crack growth of SiC particle reinforced metal matrix composites." *International Journal of Fatigue* 32, no. 5 (2010): 856-863.
12. Shin, C. S., and J. C. Huang. "Effect of temper, specimen orientation and test temperature on the tensile and fatigue properties of SiC particles reinforced PM 6061 Al alloy." *International Journal of Fatigue* 32, no. 10 (2010): 1573-1581.
13. Iqbal, AKM Asif, Yoshio Arai, and Wakako Araki. "Effect of hybrid reinforcement on crack initiation and early propagation mechanisms in cast metal matrix composites during low cycle fatigue." *Materials & Design* 45 (2013): 241-252.
14. Rotundo, F., A. Marconi, A. Morri, and A. Ceschini. "Dissimilar linear friction welding between a SiC particle reinforced aluminum composite and a monolithic aluminum alloy: Microstructural, tensile and fatigue properties." *Materials Science and Engineering: A* 559 (2013): 852-860.
15. Iqbal, AKM Asif, A. R. A. I. Yoshio, and Wakako Araki. "Fatigue crack growth mechanism in cast hybrid metal matrix composite reinforced with SiC particles and Al₂O₃ whiskers." *Transactions of Nonferrous Metals Society of China* 24 (2014): s1-s13.
16. Hruby, Peter, Sudhanshu S. Singh, Jason J. Williams, Xianghui Xiao, Francesco De Carlo, and NikhileshChawla. "Fatigue crack growth in SiC particle reinforced Al alloy matrix composites at high and low R-ratios by in situ X-ray synchrotron tomography." *International Journal of Fatigue* 68 (2014): 136-143.
17. Luk, M. J., F. A. Mirza, D. L. Chen, D. R. Ni, B. L. Xiao, and Z. Y. Ma. "Low cycle fatigue of SiCp reinforced AA2009 composites." *Materials & Design* 66 (2015): 274-283.
18. Iqbal, AKM Asif, and Yoshio Arai. "Analysis of fatigue crack propagation behavior in SiC particulate Al₂O₃ whisker reinforced hybrid MMC." In *IOP Conference Series: Materials Science and Engineering*, vol. 114, no. 1, p. 012115. IOP Publishing, 2016.