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

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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 workIn-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. %) TiB_2particles by using inorganic $K_2TiF_6$and KBF_4salts. The microstructures studied using scanning electron microscopy revealed that In-Situ formed TiB_2particles were uniformly distributed with clear interface and good bonding in the aluminum matrix. With the addition of TiB_2fatigue life of aluminum can be enhanced and as the percentage of reinforcement increases, the number of cycles can be reduced.
Keywords:MMC, Aluminumalloy, Composite, Microstructure analysis, Fatigue

1. 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 isfundamentally 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. 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

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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.

2. 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. %) TiB2 particles, K2TiF6 and KBF4 salts are used to produce the composite.

(a) (b)

(c) (d)

FIGURE 2.1shows a) Aluminum alloy Al6061 b) K2TiF6 c) KBF4 d) magnesium

FIGURE 2.2 Componentsstircastingprocess

Aluminum alloy Al6061 reinforced TiB2 particulate composites were successfully synthesized by the In-Situ reaction of K2TiF6 and KBF4 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.

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FIGURE 2.3.1 DifferentweightfractionsofTiB2reinforced MMC's

FIGURE 2.3.2 Machined ASTM Fatigue test specimens for different weight fractions of TiB2

3. 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.

3.1Test 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.
- 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.

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- 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

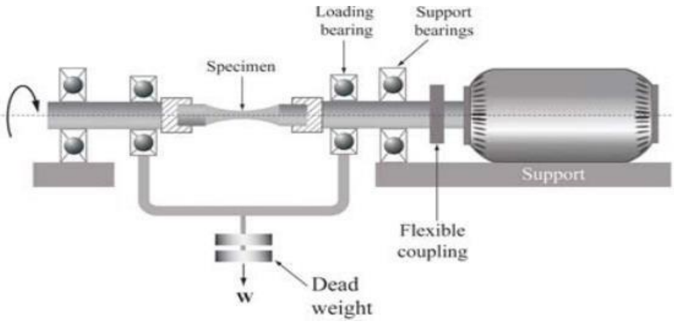

Figure 3.1.1 Rotating bending machine

4. RESULTS AND DISCUSSION

(a)

(b)

(c)

(d)

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

4.1Fatigue Result

After the tests number cycles for failure are noted and the results for different weight fractions of

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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

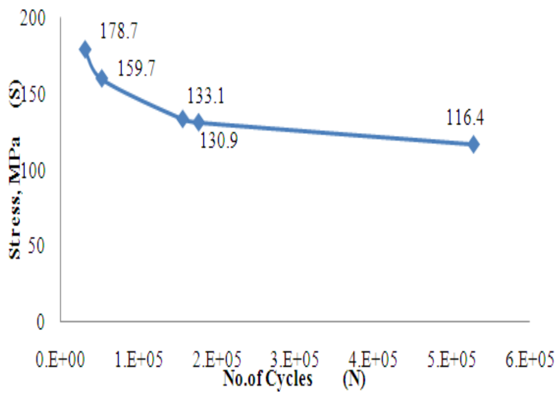

Figure: 4.2 S-N curve for different weightfractions of TiB2

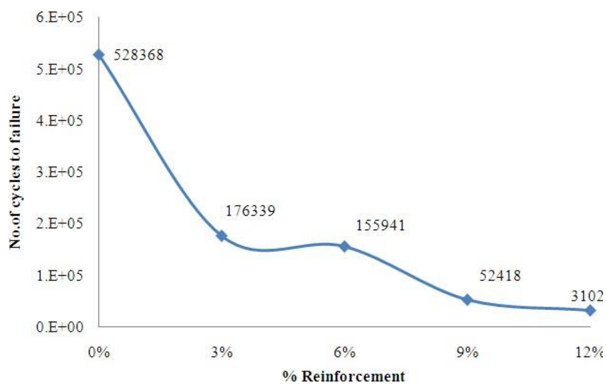

Figure: 4.3 No. cycles of failure for different % of reinforcement

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.

Figure 4.3 shows the number of failure cycles for different percentage of reinforcement and it is

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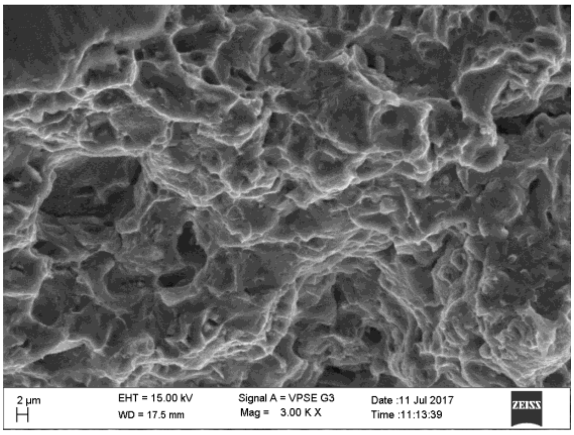
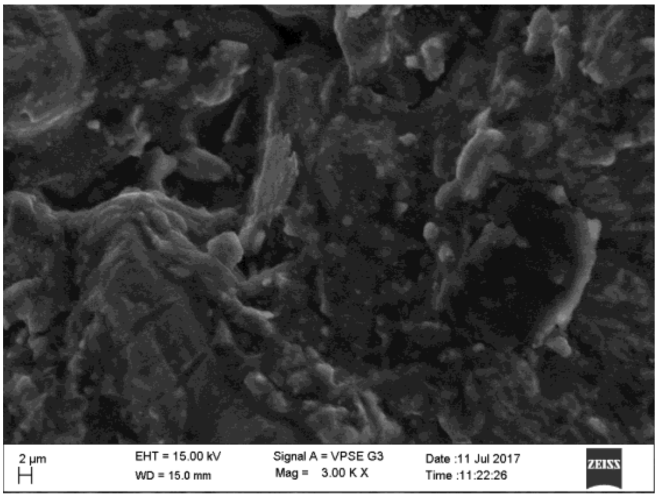
observed that as the percentage of reinforcement increases, the number of cycles was reduced.

4.2Microstructure Analysis

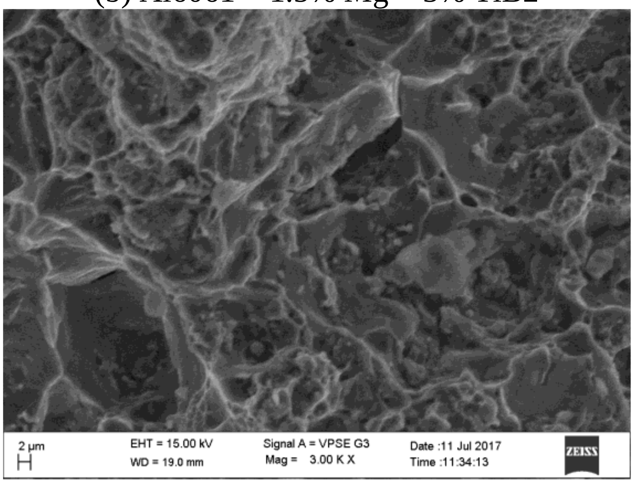
The SEM micrographs of the fatigue and fracture AMCs are presented in figure 4.2. The in situ formed TiB2 particles are distributed homogeneously in the aluminum matrix with interface and good bonding of the TiB2 particulates in the base Al alloy matrix. Such kind of particulate distribution is an essential requirement to achieve better fatigue property and solidification process dictates the uniform distribution of TiB2 particles in the matrix.



(a) Al6061 + 1.5% Mg



(b) Al6061 + 1.5% Mg + 3% TiB2



(c)Al6061 + 1.5% Mg +6 %TiB2

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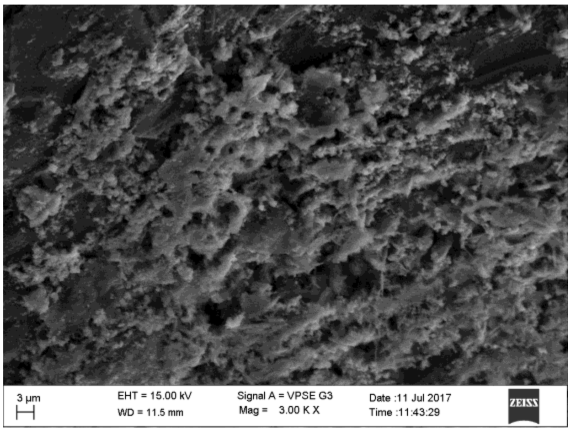
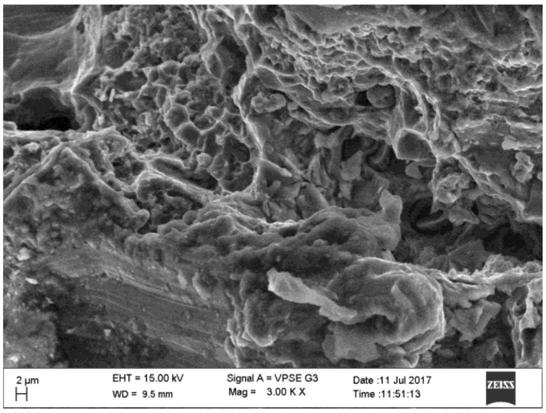


(d) Al6061 + 1.5% Mg + 9%TiB2



(e) Al6061 + 1.5% Mg + 12% TiB2

Figure: 4.4 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.

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.

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