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Synthesis and tribological evaluation of aluminum-titanium diboride ($Al-TiB_2$) metal matrix composite

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ABSTRACT – Aluminum matrix composites (AMCs) have evolved into a special field of materials science and engineering by becoming a premise for consistent research due to their excellent strength, low density, improved wear resistance, and enhanced thermal properties. The essence of AMCs lies in their ability to offer countless opportunities to tailor material properties as per the design requirements. In the current investigation, AMC has been synthesized by incorporating titanium diboride (TiB_2) particles into pure aluminum melt adopting liquid state processing route. AMCs containing 3, 6, 9, 12 and 15wt.% of TiB_2 were obtained by varying the reinforcement content. Metallographic and tribological studies were conducted on the as-cast AMCs. Microstructural observation shows a homogenous distribution of TiB_2 particles into the aluminum matrix. A pin-on-disc tribometer was used to evaluate the dry sliding behavior of the AMC under varying load and speed at a constant sliding distance. The obtained results show an improvement in the wear behavior of AMC in contrast to unreinforced aluminum. The addition of TiB_2 plays an important role in enhancing the tribological properties of AMCs. The details presented in the current work encourage researchers to shift concentration from conventional metals and alloys to AMCs which offer superior wear properties.

1. INTRODUCTION

Ronald Wilson Reagan, 40th president of United States, in 1986 while addressing the state of the union, revealed officially that the nation was seriously committed to its space program to develop indigenous aerospace vehicles and space station under National Aerospace Plane (N.A.S.P.) project [1]. This incident motivated research community to shift its paradigm towards developing materials with high specific stiffness and near-zero coefficient of thermal expansion, and eventually led to the evolution of metal matrix composites (MMCs) into a new domain of research in materials science. MMCs are "materials fabricated by combining a metallic matrix and a ceramic reinforcement to realize a set of properties that the constituents lack" [2]. MMCs consist of a metal or alloy (such as aluminum, copper, magnesium, titanium or their alloys) as base matrix, and a ceramic material (such as carbide or oxide or boride), in the form of fibre or particles, as reinforcement phase [3].

Aluminum matrix composites (AMCs) have gained substantial attention over the decades owing to their high strength-to-weight ratio, high stiffness, increased wear resistance over monolithic aluminum and its alloys. Amongst various available reinforcements for the production of AMCs, titanium diboride (TiB_2) stands out as more promising and outstanding candidate owing to its excellent features such as high stiffness-to-density ratio, and superior wear resistance [4].

The current study emphasizes an investigation of tribological performance of $Al-TiB_2$ MMC synthesized through liquid state processing route. Dry sliding wear tests were conducted by means of a pin-on-disc tribometer under ambient environment as per the ASTM standards. Metallographic studies were performed to understand the reinforcement distribution, wear patterns etc.

2. METHODOLOGY

2.1 Specimen preparation

Bottom pour liquid metal processing technique was adopted to develop $Al-TiB_2$ MMC for the present study (Figure 1).

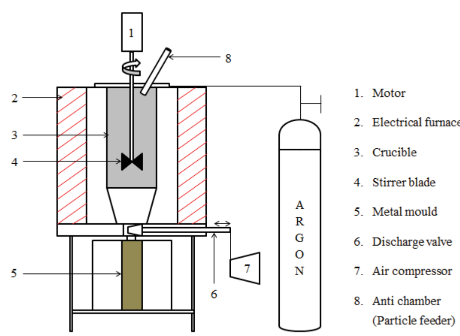

Figure 1 Bottom pour liquid metal processing furnace.

Pure aluminum billets cut into small pieces were placed inside the crucible of bottom pour liquid metal processing furnace. The furnace temperature was set to raise to 700°C from room temperature over a specified time. Mechanical stirring was then carried with a stirring speed of 450 rpm for about 10 minutes to create a vortex inside the melt. Weighed amount of preheated TiB_2 particles (procured from Dali Electronics, Mumbai, India, with a purity of 99.2%) of average size 2-4µm, were added into the vortex of aluminium melt through an anti-chamber and stirring was kept continuous for another 10 minutes to ensure homogeneous mixing. Finally, the molten mixture was easily bottom-poured into a cast iron die kept below the crucible in a closed chamber. The process is repeated by varying the weight percentage TiB_2 particles from 3 to 15 wt% in steps of 3.

2.2 Tribological studies

To evaluate the dry sliding behavior, Al-TiB_2 MMC pins of Ø8 mm and 25 mm length were prepared and tests were conducted on the same on a pin-on-disc tribometer having a cast iron disc of 165 mm diameter and 8 mm thickness as shown in Figure 2.

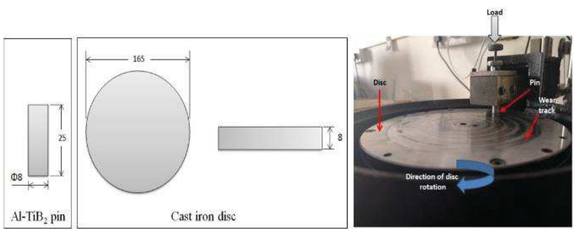

Figure 2 Pin on disc setup.

Experiments were conducted under dry condition, by varying applied load and sliding velocity while keeping the sliding distance constant. Loads of 10N, 30N, 50N and velocities of 100 m/min, 200 m/min, and 300 m/min were employed over a constant sliding distance.

3. RESULTS AND DISCUSSION

3.1 Microstructure

Microstructure of the Al-15wt.% TiB_2 reinforced aluminum matrix composite is shown in figure 3. Uniform distribution of TiB2 particles suggests the effectiveness of bottom pour liquid process technique.

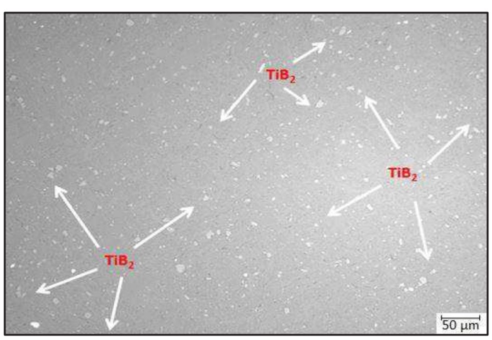

Figure 3 Microstructure of Al-15wt.%TiB_2 MMC.

3.2 Wear characteristics

The variation of wear rate with respect to weight percentages for varying load and speed is shown in Figure 4.

From figure 4(a), it can be seen that for all the applied normal loads, wear resistance increases with increasing content of TiB_2 particles. It can be stated that wear resistance is higher at lower applied load and is more or less similar at higher loads. Nevertheless, the composite shows higher wear resistance at 15wt% of the reinforcement. Figure 4(b) shows the wear resistance behavior the composite for varying sliding speeds. At higher speeds, the wear resistance is lower than at the lower speeds. At lower speed, the composite shows good wear resistance.

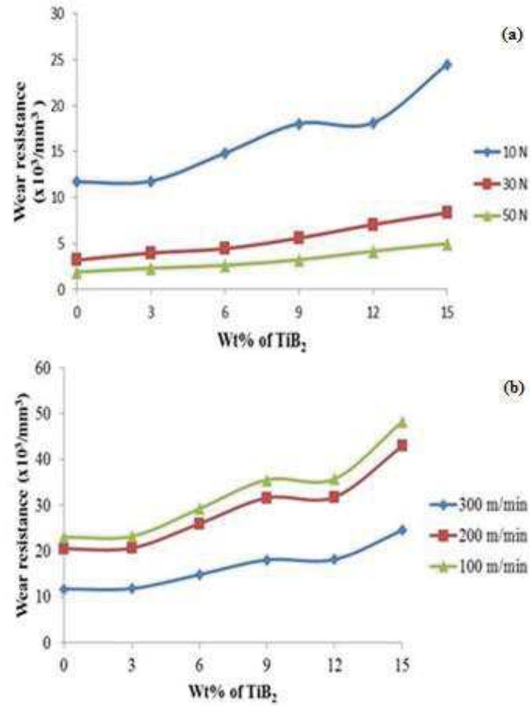

Figure 4 Wear resistance as a function of weight percentages for varying (a) load and (b) speed.

4. CONCLUSION

TiB_2 reinforced aluminum matrix composite has been successful prepared through bottom-pour liquid metal processing route. Tests were conducted on a pin-on-disc tribometer to evaluate the tribological performance of the composite with varying load sliding speeds. Microstructure analysis of the composite reveals that homogenous mixing of TiB_2 particles into aluminum. It was observed that wear resistance increases with increased weight percentage of TiB_2 particles in the composite. Further, the wear resistance was observed to be decreasing when both load and sliding speed increase.

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