Microstructure and Wear Resistance of TiB2/7075 Composites Produced via Rheocasting

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Abstract: In this study, TiB2/7075 aluminum matrix composites were prepared via in situ synthesis. It was found that TiB2 particles are mainly quadrate. Large TiB2 particles (1–2 µm) agglomerate at grain boundaries, but most of the particles are on the submicron scale. Adding 4.5 wt.% TiB2 particles effectively optimizes α-Al grains in the 7075 aluminum alloy. By combining in situ reinforcing particles with the self-stirring effect of a serpentuator, rheocasting of the 7075 aluminum alloy was achieved in a simple and economical way. The average grain size of the specimen after rheocasting and heat treatment was smaller than 33 µm, and the shape factors were greater than 0.85. The wear resistance of the 4.5 wt.% TiB2/7075 aluminum matrix composite that was prepared via rheocasting and gravity casting was tested with loads of 30, 60, 90, and 120 N at a friction speed of 0.15 m/s for a duration of 30 min. Because of the optimized microstructure and increased hardness, the wear resistance of the 4.5 wt.% TiB2/7075 aluminum matrix composite was significantly better than that of the 7075 aluminum alloy, and the wear resistance of the rheocast TiB2/7075 aluminum matrix composite was better than that of the gravity cast one.

Keywords: TiB2/7075 composite; rheocasting; semi-solid; wear resistance

1. Introduction

Semi-solid forming technology has received extensive attention and has been used in practical applications in the aerospace and transportation industries [1,2]. The demand for lightweight materials in the automobile industry is rapidly growing due to the deepening world energy crisis and outstanding environmental pollution issues. Therefore, there have been a lot of studies on semi-solid forming of aluminum alloy. The current semi-solid forming technology for aluminum alloy is mostly focused on the cast aluminum alloys because the semi-solid slurry is easier to prepare [3–5]. Because the mechanical properties of cast aluminum alloys are relatively insufficient, wrought aluminum alloys with better performance have gradually become a research hotspot [6]. Wrought aluminum alloys, such as the 7075 aluminum alloy, are difficult to form via traditional casting methods. Instead, they are mainly prepared via plastic forming. The emergence of semi-solid forming technology make it possible to cast wrought aluminum alloys. At present, there have been many studies conducted on semi-solid forming of the 7075 aluminum alloy, and the mechanical properties of the 7075 alloy prepared via semi-solid forming technology are better than those of cast aluminum alloys, such as the...
A356 aluminum alloy [7–9]. The semi-solid forming of 7075 aluminum alloy can further expand the application of aluminum alloy in transportation field.

Rheocasting semi-solid forming technology that is more energy-saving, shorter in processing flows, and more straightforward in equipment needs than thixoforming, making it the focus of current research on semi-solid forming technology. The essence of rheocasting is the preparation of semi-solid slurries with globular grains. In the studies on the rheocast 7075 aluminum alloy, most of the average grains size in the slurry are more than 70 µm, and the shape factor are 0.7–0.8 [6]. Meanwhile, for the A356 aluminum alloy, semi-solid slurries with grain size less than 50 µm and shape factors greater than 0.85 (or even as high as 0.90) can be prepared [10,11]. Therefore, some researchers have added rare earth elements or grain refining agents to the 7075 aluminum alloy to further optimize its microstructure and mechanical properties [12,13]. Previous studies have shown that reinforcing particles, such as SiC [14,15], Al₂O₃ [16], or TiC [17] can be used either as heterogeneous nucleation cores or to hinder grain growth, and this effectively refines the aluminum alloy microstructure [18–20]. Meanwhile, adding hard reinforcing particles can further improve the wear resistance of the material [21–23]. In the most of researches, the ceramic particulates are externally fed to the molten metal in ex situ method. Compared to ex situ methods, in situ methods have numerous advantages, such as thermodynamic stable particles, superior interfacial bonding and low cost of processing [24]. Another way to get globular grains is to use simple equipment, such as pouring the alloy melt through a plate or tube [25,26]. The surface of plates and tubes is helpful for heterogeneous nucleation of the alloy melt.

In this study, TiB₂/7075 aluminum matrix composites were prepared via in situ synthesis to refine the microstructure and thereby obtain near-globular grains. In combination with the simple and economical serpentuator method, rheocasting of the 7075 aluminum alloy was achieved. Additionally, the wear resistance of 4.5 wt.% TiB₂/7075 aluminum matrix composites prepared via rheocasting and gravity casting was tested at room temperature, and the effects that reinforcing particles and forming processes have on wear resistance are discussed. It is expected that the high performance 7075 aluminum matrix composites prepared by this method can be used in the transportation field.

2. Materials and Methods

2.1. Material Preparation

The main composition of the 7075 aluminum alloy (General Research Institute for Nonferrous Metals, Beijing, China) that was used in the study is shown in Table 1, and the solid-liquid phase line of the alloy was determined using differential scanning calorimetry (DSC, STA 449 C Jupiter, NETZSCH, Selb, Germany).

| Zn  | Mg  | Cu  | Mn  | Si  | Cr  | Fe  | Al  |
|-----|-----|-----|-----|-----|-----|-----|-----|
| 5.52| 2.36| 1.51| 0.15| 0.18| 0.25| 0.26| -   |

An appropriate amount of K₂TiF₆ (wt.% > 97%) and KBF₄ (wt.% > 97%) were mixed at a molar ratio of 1:2 and dried at 300 °C for 2 h. The 7075 aluminum alloy was heated to 850 ± 5 °C in a resistance furnace. Then a salt mixture was gradually added under stirring with a graphite stirrer (180 r/min). To ensure that the reaction proceeded sufficiently, the temperature was held at 850 ± 5 °C for another 30 min after there was no more smoke or sparks. Then, the temperature was reduced to 720 °C, and the surface residue was removed. Meanwhile, C₂Cl₄ (with a mass that was 0.5% of that of the aluminum alloy) wrapped in aluminum foil was added to the aluminum alloy melt for refining and degassing. After that, the melt was poured into a graphite mold (diameter of 20 mm) to produce TiB₂/7075 aluminum matrix composites.
2.2. Rheocasting Process

A schematic diagram of the graphite serpentuator is shown in Figure 1; the diameter is 20 mm, and the vertical height is 390 mm. Simulation was used to determine whether the outlet temperature of metal slurry that flowed through serpentuator was in semi-solid interval. In addition, the melt flow process in the serpentuator can be observe by simulation. 3D modeling and numerical simulations were performed using ProE (Parametric Technology Corporation, Boston, MA, USA) and ProCAST (UNIVERSAL ENERGY SYSTEM, Dayton, OH, USA), respectively.

Figure 1. Schematic diagram of the serpentuator (unit: mm).

The 7075 aluminum alloy and TiB<sub>2</sub>/7075 aluminum matrix composites were heated to 720 °C until they were completely melted, and then cooled to the desired temperature. After preparing semi-solid slurries of the 7075 aluminum alloy and TiB<sub>2</sub>/7075 aluminum matrix composites, rheocasting and heat treatment were conducted. The specimens were solution-treated at 470 °C for 90 min, quenched in water, and then artificially aged at 120 °C for 24 h.

2.3. Microstructure Analysis

The microstructures and compositions of the composites were analyzed using an X-ray diffractometer (XRD, D/max-TTRIII, Rigaku Corporation, Tokyo, Japan) and scanning electron microscope (SEM, SUPRA55-FESEM, ZEISS, Jena, Germany), which was equipped with an energy-dispersive spectrometer (EDS).

The rheocast specimens were ground and polished with sandpapers and etched with a 0.5% HF solution. Their microstructures were observed using optical microscopy, and the grain size (D) and shape factor (F) were calculated using $D = 2 \sqrt{\frac{S}{C}}$ and $F = \frac{4\pi S}{C}$, where $S$ is the grain area, and $C$ is the grain circumference.

2.4. Hardness and Wear Tests

The Brinell hardness was measured using a hardness tester (HBS-3000E, Henwaii, Yantai, China) with a ball that had a 2.5 mm diameter at a load of 45 kg. Wear tests were conducted using a pin-on-disc machine (MMW-1, JINGCHENG, Jinan, China) at room temperature. The hardened chromium steel (Rc 64) was used as the counterface material. Frictional wear tests were performed with loads of 30, 60, 90, and 120 N at a friction velocity of 0.15 m/s for a friction duration of 30 min. The specimens were cleaned with acetone before and after the wear test. After drying, the specimens were weighed using an electronic balance that has a precision of 0.1 mg. SEM analysis was performed to analyze the morphologies of abrasion surfaces and wear debris.
3. Results and Discussion

3.1. Processing of Cast In Situ TiB$_2$/7075 Composite

DSC results show that the solidus of the 7075 aluminum alloy is 477 °C and that the liquidus is 639 °C. The difference between these two temperatures is 162 °C, and this suggests the possibility that semi-solid forming can be conducted. However, the solid fraction changes rapidly with temperature at the beginning of solidification, as seen in Figure 2. The solid fraction of the slurry that is suitable for rheocasting lies in the range of 0.3–0.5, which means that the temperature of the 7075 aluminum alloy slurry is in the range of 629–619 °C. Although the 7075 aluminum alloy has a wide semi-solid zone, its operable process temperature range is narrow, which makes rheocasting difficult.

![Figure 2. Solid fraction of the 7075 aluminum alloy versus temperature.](image)

Aluminum matrix composites that have different TiB$_2$ contents were prepared using the in situ reaction molten salt method. The reaction formula is shown in Formula 1. The by-products (AlF$_3$ and KF) can be removed via slagging.

$$3K_2TiF_6 + 6KBF_4 + 10Al = 3TiB_2 + 10AlF_3 + 12KF$$

(1)

XRD results are shown in Figure 3; these results indicate that TiB$_2$/7075 aluminum matrix composites were successfully prepared using the in situ reaction method. The peak that corresponds to TiB$_2$ increases with an increase of the content of TiB$_2$ particles, and no other impurity phases are generated in the reaction.

![Figure 3. X-ray diffractometer (XRD) pattern of the TiB$_2$/7075 aluminum matrix composites.](image)
The microstructures of the 7075 aluminum alloy and TiB$_2$/7075 aluminum matrix composites that were prepared via direct casting at 720 °C are shown in Figure 4. Abundant dendrites are observed in the 7075 aluminum alloy, whereas for the composites, the addition of TiB$_2$ by in situ synthesis effectively optimizes the α-Al microstructure, results in a decreased grain size, and transforms coarse dendritic grains to rosette grains. With 4.5 wt.% TiB$_2$ particles, the grains become near-spherical. However, microstructure is not further optimized with an increase in TiB$_2$ content. Instead, after the particle content exceeds 4.5 wt.%, the grain size gradually increases and shifts back to rosette grains. Nevertheless, the microstructure of 6 wt.% TiB$_2$/7075 is still superior to that of the 7075 aluminum alloy.

![Figure 4. Microstructure of specimens cast at 720 °C: (a) 7075, (b) 3 wt.% TiB$_2$/7075, (c) 4.5 wt.% TiB$_2$/7075, and (d) 6 wt.% TiB$_2$/7075.](image)

SEM characterization was performed on TiB$_2$/7075 aluminum matrix composites that had different particle contents, and the results are shown in Figures 5 and 6. TiB$_2$ particles are mainly distributed at the grain boundaries, and further observation reveals that the in situ generated TiB$_2$ particles are in quadratic shapes. The sizes of the large ones are about 1–2 μm, whereas most of the particles have submicron sizes. TiB$_2$ can be used as a crystallization nucleus for heterogeneous nucleation to effectively increase the number of primary nuclei [18,19,27,28]. As the grains grow, TiB$_2$ particles can block the solid-liquid interface migration and eventually become distributed at grain boundaries. These two effects work together and contribute to the refining of the 7075 aluminum alloy microstructure after the addition of TiB$_2$.

![Figure 5. Scanning electron (SEM) images of TiB$_2$/7075 aluminum matrix composites with different TiB$_2$ contents: (a) 3.0 wt.%, (b) 4.5 wt.% and (c) 6 wt.%](image)

![Figure 6. SEM images of TiB$_2$ particles: (a) 3.0 wt.% TiB$_2$/7075, (b) 4.5 wt.% TiB$_2$/7075.](image)
3.2. Rheocasting of TiB\textsubscript{2}/7075 Composite

Simulations of the rheocasting process were performed at different casting temperatures and using different serpentuator insulation temperatures. The melt temperature at the outlet was analyzed, and the results are shown in Table 2. When the casting temperature was 655 °C and the graphite tube temperature was 400 °C, the melt could not flow out entirely due to the high solid fraction and lower melt fluidity. When the casting temperature was 670–685 °C and the serpentuator tube temperature was 400 °C, the solid fraction of the melt after flowing through the serpentuator was 0.25–0.40, which is suitable for semi-solid rheocasting.

| Serpentuator Temperature (°C) | Casting Temperature (°C) |
|------------------------------|--------------------------|
|                              | 685 | 670 | 655 |
| 600                          | 639 | 628 | 619 |
| 400                          | 630 | 624 |   |

In the serpentuator, the temperature of the melt near the pipe wall drops because of the cooling effect of the pipe. Specifically, nucleation first occurs on the pipe wall, and these nuclei are moved by the subsequent melt and fall into the mold; this increases the density of nuclei in the semi-solid slurry. Meanwhile, the free crystallized nuclei in the supercooled liquid phase are a prerequisite for the formation of equiaxed grains [29]. Figure 7 shows the total velocity field and the velocity fields of the melt flowing in the X- and Y-directions. When the melt passes through the bend, the direction changes, and the flow velocity increases; thus, “self-stirring” occurs. This “self-stirring” results in microscopic thermal fluctuations in the melt, and this is beneficial for the nucleation of liquid metal in the supercooled region. It also increases the speed of solute transportation and increases the probability of atoms being captured by critical embryos, thereby increasing the nucleation rate. Moreover, “self-stirring” causes the solute distribution and temperature field in the melt to be more uniform, and both of these characteristics are conducive to the formation of spherical grains.

Figure 7. 7075 aluminum alloy melt flow process in a triple-bend serpentuator: (a) total velocity field, (b) velocity field in the X-direction, and (c) velocity field in the Y-direction.

Figure 8 shows the microstructure of the TiB\textsubscript{2}/7075 aluminum matrix composites that were prepared via casting at 670 °C and heating in a graphite tube at 400 °C followed by extrusion and heat treatment. As can be seen, all of the composites have near-spherical grains. The TiB\textsubscript{2}/7075 aluminum matrix composites all have desirable near-spherical grains after passing through the triple-bend
Metals 2020, 10, x FOR PEER REVIEW 7 of 14

Figure 8. Microstructures of specimens after rheocasting using a triple-bend serpentuator and heat treatment: (a) 3.0 wt.% TiB$_2$/7075, (b) 4.5 wt.% TiB$_2$/7075, (c) 6.0 wt.% TiB$_2$/7075.

3.3. Wear Resistance

Hardness and wear resistance tests were performed on the rheocast 7075 aluminum alloy and 4.5 wt.% TiB$_2$/7075 aluminum matrix composite, and 720 °C gravity cast 4.5 wt.% TiB$_2$/7075 aluminum matrix composite. The results are shown in Figure 9. Hardness can be increased with heat treatment, the addition of TiB$_2$ as hard ceramic particles, and the refining of grain structure. The rheocast 4.5 wt.% TiB$_2$/7075 aluminum matrix composites are harder than the rheocast 7075 aluminum alloy. Compared to the gravity cast specimens, the microstructures of the rheocast specimens are significantly finer, which makes their hardness higher than that of the gravity cast specimens. Meanwhile, the increased hardness and optimized microstructure are conducive to improving the friction and wear properties of the material. Figure 9b shows curves of wear rate versus load for each specimen. As seen in the figure, the wear rate increases with an increase in the frictional load. The rheocast 4.5 wt.% TiB$_2$/7075 aluminum matrix composite has the lowest wear rate, and the gravity cast specimen has the highest wear rate.

Figure 9. (a) Brinell hardness of specimens before and after heat treatment and (b) wear rate of specimens versus friction load.

The wear rate decreases with increases in hardness and frictional load [30–32]. Thus, the addition of TiB$_2$ helps to improve frictional wear performance. During wear, hard TiB$_2$ particles effectively carry the load and hinder the dislocation movement, which improves the frictional wear performance. Additionally, the refined grains also contribute to improving the frictional wear performance [31–33]. Hence, the wear rates of the rheocast 4.5 wt.% TiB$_2$/7075 specimens are lower than those of the 7075 aluminum alloy specimens. Although the gravity cast 4.5 wt.% TiB$_2$/7075 specimens have added ceramic particles, they have the highest wear rates because their microstructures are coarser than those of the rheocast ones. The wear resistance distinctly increases when rheocasting is applied to
the TiB2/7075 aluminum matrix composite. The wear resistance of semi-solid forming materials is improved, with a similar trend having also been found in other studies [23,34,35].

SEM images of wear tracks of the rheocast 7075 aluminum alloy under different friction loads is shown in Figure 10. These images indicate that the wear surface has noticeable furrows and wear tracks along the friction direction. Meanwhile, there are clumps of wear debris, which indicate typical characteristics of abrasive wear. Plastic deformation occurs, and judging from the edges of the furrows, adhesive wear also occurs. When the deformed metal is repeatedly extruded and piled up, pores or cracks result. When a crack extends to a certain length, the material peels off in sheets under the effect of stress, and the specimen surface shows step-like peeling pits, which is typical delamination wear [36]. Meanwhile, with an increase in the friction load, the number of furrows decreases and the degree of peeling increases. Thus, it can be concluded that the frictional wear mechanism for the rheocast 7075 aluminum alloy is mainly a combination of abrasive wear and delamination wear, and that the delamination wear increases with an increase in load.

![SEM images of wear tracks of the rheocast 7075 aluminum alloy under different friction loads](image)

Figure 10. SEM images of rheocast 7075 aluminum alloy tested under different friction loads: (a,b) 30 N, (c,d) 60 N, (e,f) 90 N, and (g,h) 120 N.

Wear debris is the result of interaction between the abrasive surface of the specimen and the friction pair during the frictional wear process. Therefore, the frictional wear mechanism is indicated by the size and morphology of wear debris. The wear debris of the rheocast 7075 aluminum alloy after frictional wear includes a large amount of black debris and some large flakes that have a metallic luster. The morphology of the wear debris under different loads is shown in Figure 11. The wear debris is mainly in the form of flakes and powder, and the sizes of the flakes are mainly in the range of 200–300 μm. The flake size increases with the load, and the maximum size reaches 1–2 mm. When the load was lower than 90 N, the wear debris was small, and the edges were uneven with numerous cracks. Plastic deformation occurs on the surface of the specimen during the friction process, and the deformed metal was repeatedly extruded and piled up until it was torn apart as wear debris under stress. Therefore, the wear debris exhibits corresponding characteristics. At loads of 90 and 120 N, the size of the wear debris increased significantly, and the surface of some wear debris became smooth. Notably, under a load of 120 N, the surface of wear debris shows a streamlined trace, indicating that the wear debris was directly cut off by the friction pair under a high load.
with sizes in the range of 200–300 \( \mu \)m were prepared under different loads. Additionally, the friction pair was partially worn during the experiment, and this led to the detection of Fe on the surface. SEM composition analysis of the wear debris for the 7075 matrix alloys. The crumbling becomes more severe with an increase in the friction load. For the rheocast 4.5 wt.% TiB_2/7075 specimens, the main wear mechanisms are three-body abrasive wear and fatigue wear [37,38]. EDS composition analysis of the wear tracks at a load of 60 N shows that the surface of the specimen was oxidized as a result of frictional heating. Additionally, the friction pair was partially worn during the experiment, and this led to the detection of Fe on the surface.

Figure 12 shows SEM images of wear debris of the rheocast 4.5 wt.% TiB_2/7075 specimens that were prepared under different loads. The wear debris was mainly in the form of flakes and powders with sizes in the range of 200–300 \( \mu \)m. The overall sizes of flakes are smaller than those of the flakes of the 7075 aluminum alloy that was processed under the same condition. In contrast, the irregular shape of wear debris and the presence of a large number of cracks on the surface indicate that a large number of cracks were produced on the subsurface of the material during the friction process and expanded to the surface under stress. The surface EDS analysis of the wear debris that formed at a load of 120 N suggests that during the frictional wear process, oxidation occurred as the surface heated, and the friction pair was also worn. Thus, a high content of Fe was detected, and this indicates that the surface should be the contact surface between the friction pair and the specimen.
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the surface breaks and peels off, indicating the characteristics of fatigue wear [36]. Because of the
surfaces. The TiB2 ceramic particles act as a hardening phase that can withstand and transmit loads
and shallower wear tracks. Cracks perpendicular to the direction of friction are observed on their
severely crumbled with deep peeling pits formin g in local areas, which is different from the
and block dislocation movement during the friction process. Thus, the resistance of the matrix to
plastic deformation is improved [37,38]. However, in this study, TiB2 particles agglomerated at grain
under stress. Th
friction, and the reinforcing phases hinder the def
composite material and the friction pair. Deformation occurs because of repetitive crushing during
frictional wear. This is typical wear debris of adhesive wear
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body abrasive abrasion. Thus, wear tracks are gene rated on the specimen surface. As seen in the
figure, the interior of the peeling pits of the 4.5 wt.% TiB 2/7075 aluminum matrix composite are
expanded to peel the surface off under stress. The surface EDS analysis of the wear debris that formed
number of cracks were produced on the subsurface of the material during the friction process and
with sizes in the range of 200–300
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m. The overall sizes of flakes are smaller than those of the flakes
under different loads. The wear debris was mainly in the form of flakes and powders
Figure 12. SEM and EDS results of the wear tracks on rheocast 4.5 wt.% TiB2/7075 specimens formed
under different friction loads: (a) 30 N, (c,d) 60 N, (e,f) 90 N, and (g,h) 120 N.

Figure 13. SEM and EDS results of the wear debris on rheocast 4.5 wt.% TiB2/7075 specimens formed
under different friction loads: (a,b) 30 N, (c,d) 60 N, (e,f) 90 N, and (g,h) 120 N.

| Element | wt.% | at.% |
|---------|------|------|
| O K     | 29.59| 48.24|
| Al K    | 37.85| 36.59|
| Ti K    | 2.04 | 1.11 |
| Fe K    | 27.76| 12.96|
| Zn L    | 2.76 | 1.10 |
| Totals  | 100.00|  

| Element | wt.% | at.% |
|---------|------|------|
| O K     | 6.57 | 16.32|
| Al K    | 22.19| 32.70|
| Ti K    | 2.29 | 1.90 |
| Fe K    | 68.94| 49.08|
| Totals  | 100.00|  
Figure 14 shows SEM images of the wear tracks that formed on the gravity cast 4.5 wt.% TiB2/7075 specimens under different loads. When the load was lower than 60 N, there were no apparent furrows on the surface. However, there are a lot of peeling traces that resulted from plastic deformation, and wavy traces of flowing metals are evident on the edges and inside of the peeling pits. This is because a relatively low load is not sufficient to break the bond between reinforcing particles and the matrix. Thus, a softer matrix experiences plastic deformation, and the deformed part is repeatedly crushed and cut under stress; this results in debris being peeled off, and this is typical of adhesive wear [36]. When the friction load increased to 90 N or more, shallow tracks were observed, peeling was more evident, and breakage at the bottom of peeling pits deteriorated more than was observed under low loads. Although TiB2 particles can withstand loads in a certain range, their strengthening effect is limited, especially when the strengthening phases are agglomerated in the specimen. When the load increased, the adhesion and shearing on the surface cause cracks to form in the subsurface. These spread to the surface and led to subsurface breakage and peeling off. Thus, the interior of the peeling pits crumbled severely. TiB2 particles were detached from the aluminum matrix and became abrasive particles between the friction pair and the specimen surface at the same time, and this led to three-body abrasive wear [37,38].

![SEM images of the wear tracks on 4.5 wt.% TiB2/7075 specimens cast at 720 °C under different frictional loads: (a,b) 30 N, (c,d) 60 N, (e,f) 90 N, and (g,h) 120 N.](image_url)

SEM images of the wear debris on the 4.5 wt.% TiB2/7075 aluminum matrix composite that was gravity cast at 720 °C are shown in Figure 15. The wear debris is mainly in the form of broken powders and irregular flakes. With an increase in the load, the size of the wear debris increased. When the load was greater than 90 N, some of the wear debris reached the size of 2–3 mm. High-resolution images show that the edges of the wear debris are incredibly uneven, and visible wavy traces of plastic flows are evident on the surface; these should correspond to the tearing surface under stress during frictional wear. This is typical wear debris of adhesive wear. Additionally, there are many cracks on some debris surfaces, and these should correspond to the contact surface between the composite material and the friction pair. Deformation occurs because of repetitive crushing during friction, and the reinforcing phases hinder the deformation flow of the matrix, which results in cracks under stress. The cracks gradually expand, grow, and peel off.
4. Conclusions

In this study, rheocasting of the TiB₂/7075 aluminum matrix composite was successfully carried out with the addition of appropriate amounts of TiB₂ particles into the 7075 aluminum alloy via an in situ synthesis method and with the use of a serpentuator. The frictional wear properties of gravity cast and rheocast composites were compared, and the main conclusions are as follows:

1. TiB₂ particles were successfully added into the 7075 aluminum alloy via in situ synthesis. TiB₂ particles were mainly distributed at grain boundaries, and some of the large particles have sizes in the range of 1–2 µm, whereas most of the particles have submicron sizes. The added TiB₂ particles effectively optimize the microstructure of the gravity cast 7075 aluminum alloy because of the transformation from coarse dendrites to rosette grains. Adding 4.5 wt.% TiB₂ results in the best optimization. TiB₂ can be used as a crystallization nuclei for heterogeneous nucleation to effectively increase the number of primary nuclei and block the solid-liquid interface migration when the grains grow. Rheocasting of the 7075 aluminum alloy was successfully achieved via the combined use of in situ TiB₂ particles and a serpentuator. Favorable near-spherical grains were obtained. The average grain sizes are 23 µm, and the shape factors are 0.96 of rheocast 4.5 wt.% TiB₂/7075.

2. At a friction velocity of 0.15 m/s, the wear mechanisms of the rheocast 7075 aluminum alloy are adhesive wear and delamination wear, and delamination wear begins to dominate as the load increases. The wear mechanism of the rheocast TiB₂/7075 aluminum matrix composite is three-body abrasion and fatigue wear. Fatigue wear becomes the primary mechanism under loads that are higher than 90 N.

3. Compared to the gravity cast specimens, the rheocast TiB₂/7075 composites have finer microstructures, increased hardness, and improved wear resistance. For gravity cast specimens, the TiB₂/7075 aluminum matrix composite exhibits a coupling of three-body abrasive wear and adhesive wear at low loads, and adhesive wear is the dominant mechanism. With an increase in the load, a combination of adhesive wear and fatigue wear results.

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