Microstructure and Wear Behavior of In Situ TiB_2/2024 Composite Fabricated by Spray Deposition Technique

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Abstract. In situ 4.9wt.%TiB_2/2024 composite has been successfully prepared by displacement reaction and spray deposition technique, and its microstructure and wear behavior were investigated. Experimental results have shown that in situ TiB_2 particles uniformly distributed in the matrix, and the grain size of the composite was smaller than that of the alone 2024 alloy. Compared to the 2024 alloy, the composite showed accelerated aging process after solutionizing at 768K. The wear resistance of the composite improved considerably and a maximum wear resistance were obtained after over aging.

Introduction

Particle-reinforced metal matrix composites have become increasingly used in automotive, aerospace and mineral processing industries due to improved properties such as strength, stiffness, tribological behavior, and thermal stability [1-4]. Investigations over the past three decades have shown that spray deposition can be readily utilized to prepare particle-reinforced metal matrix composites. Reinforcement particles were usually injected into the spray cone consisting of molten droplets. Those reinforcement particles can be viewed as ex situ reinforcements. In this case, the size of the reinforcement particles is limited by the starting powder size, which is rarely below 1μm. Moreover, others main problems have to be overcome, such as inhomogeneous distribution of reinforcement particles, poor wettability and formation of unwanted reaction products at the interface between the matrix and reinforcement particles, etc.

The present authors have developed a displacement reaction and spray deposition technique to fabricated in situ particle-reinforced metal matrix composites [5]. In this technique, the matrix material is first melted, and then the reinforcement particles are in situ formed in the molten alloy by chemical reactions. Compared to the conventional injection technique (ex situ processes), the in situ process provide advantages such as finer reinforcement particle size, clear interface uniform distribution of reinforcement particles and thermodynamically stable reinforcement particles. In this study, the TiB_2/2024 composite was prepared by the displacement reaction and spray deposition technique. Microstructure and wear behavior of the composite were investigated.

Experimental Procedure

In this work, 2024 alloy (nominally 4.36% Cu, 1.54% Mg, and 0.35% Mn, in wt.%) was used as matrix material. Firstly, 2024 alloy ingot was melted and superheated to 1123 K in an induction furnace, after which a mixture of dried K_2TiF_6 and KBF_4 powder was added to the molt in the atomic ratio in accordance with Ti/2B using the stirring method. The processes were carried out in air. Secondly, the composite slurry was atomized and deposited. The spray deposition process parameters are briefly summarized as follows. The melt was superheated to 1023 K and atomized using argon gas at 0.6 MPa pressure. The atomizer-substrate distance was 400 mm, and a delivery tube (Al_2O_3) with a diameter of 3.5 mm was used. The composites containing 4.9wt..% TiB_2 were fabricated and 2024 alloy without TiB_2 was fabricated with a similar processing path. After the same procedure of hot working (reduction ratio about 8:1), samples of the composite and the 2024 alloy were solutionized at 768 K for 2h followed by quenching in cold water, and then aged at 453K.

The composites were characterized by X-ray diffraction (XRD) using Cu Kα radiation and canning electron microscopy (SEM). The composites subjected to aging were tested for their hardness using Vickers Hardness Tester at 20 kg load. Dry sliding wear tests were conducted using a pin-on-disc wear testing machine. Tests were carried out at 40N normal loads. The sliding velocity was kept constant at $1ms^{-1}$. All tests were carried out for a sliding distance of 1800 meters.

Results and Discussion

Figs.1 (a) and (b) display the microstructures of as-deposited 2024 alloy and 4.9wt.%TiB_2/2024 composite. It can be seen that the grain size of the composite was smaller than that of the matrix alloy. It can be attributable to that the fine TiB_2 particles decreased effectively the growth rate of the grains in the solidification process. Moreover, one can see from the Fig.1(b) that the distribution of the in situ TiB_2 particles in the matrix was good, which indicated that the displacement reaction and spray deposition technique was good for improving the distribution of the reinforcement particles in the matrix.

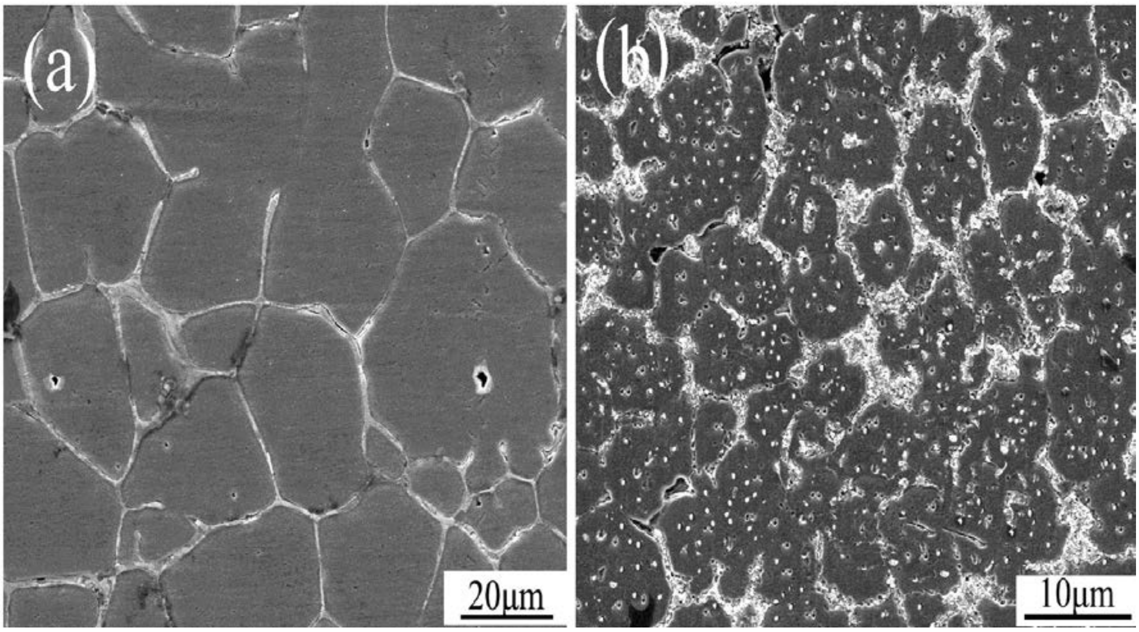

Fig.1. Microstructures of as-deposited 2024 alloy (a) and 4.9wt.%TiB_2/2024 composite (b).

Fig.2 shows the aging curves of the as-deposited 2024 alloy and 4.9wt.%TiB_2/2024 composite after solutionizing at 768K. One can see that, once aging started, hardness of the specimens increased rapidly. Compared to the 2024 alloy, the composite solutionized at 786K showed an accelerated aging behavior.

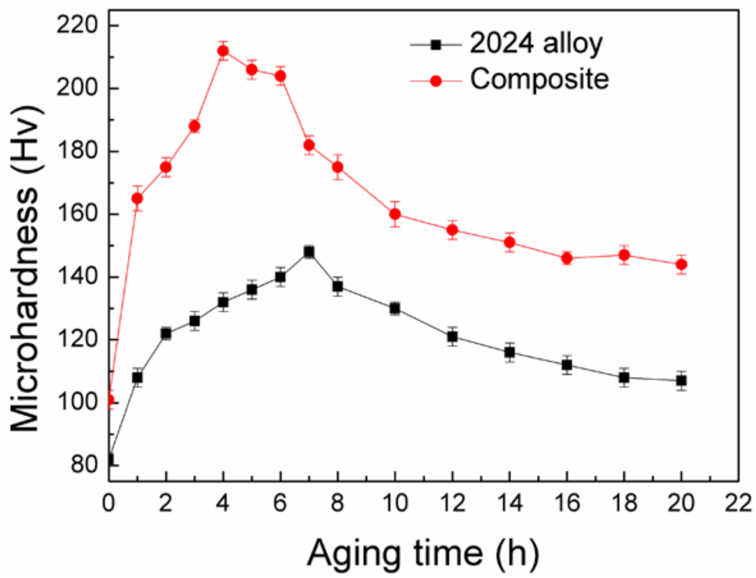

Fig.2. Aging curves of as-deposited 2024 alloy and 4.9wt.%TiB_2/2024 composite aged at 453K.

Fig.3 shows the wear rate of the as-deposited 2024 alloy and 4.9wt.% TiB_2/2024 composite. One can see that the wear rate of composite was lower than 2024 alloy under different aging conditions, which suggesting that the presence of in situ TiB_2 particles resulted in higher wear resistance. For the composite, a minimum wear rate was obtained after overaging. The direct relationship between wear resistance and hardness was not observed. Hardness after peak aging was much higher than that after overaging, but the amount of wear rate was not decreased. For the composite, in situ TiB_2 particles had higher hardness and wear resistance than the matrix. The good wear resistance of composite can be attributed to the presence of in situ TiB_2 particles, which can act as load-support and prevent effectively the softer matrix material becoming directly involved in the wear process. The matrix material showed higher hardness under peak aging conditions, but the wear rate was higher than that of the overaged specimens. Under peak aging conditions, crack easily nucleated and propagated in the matrix material due to the low ductility. Hence, the in situ TiB_2 particles would easily fall off the surfaces. Therefore, the wear rate of the composite was increased. However, the overaged specimen showed lower wear rate due to the higher ductility[6].

Conclusions

A displacement reaction and spray deposition technique had been successfully applied to prepare in situ TiB_2/2024 composites with homogeneously distributed reinforcements. Compared to the 2024 alloy, the in situ TiB_2/2024 composite showed accelerated aging behavior after being solutionized at 768K. Under different aging conditions, the composite showed higher wear resistance than that of the 2024 alloy. For the composite, a maximum wear resistance was obtained after overaging.

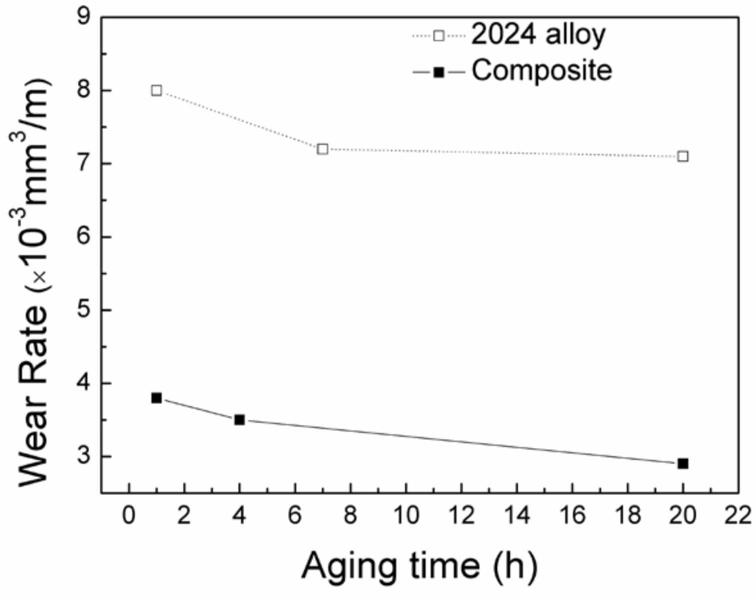

Fig.3. Wear rate of as-deposited 2024 alloy and 4.9wt.%TiB_2/2024 composite

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