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Uniform distribution of TiC_p in $\text{TiC}_p/\text{Zn-Al}$ composites prepared by XDTM^①

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[Abstract] The prefabricated Al/TiC alloy with high TiC particle content was prepared by XDTM process. The uniform distribution process of TiC particles in the stationary zinc melt was studied and analyzed using self-made experimental equipment, and the model of the uniform distribution process was built. The results show that zinc diffuses into the prepared Al/TiC alloy after it is placed in the zinc melt at temperatures below the melting point of aluminum, which leads to the decrease of the liquidus temperature of Al-Zn alloy in the surface layer of Al/TiC alloy. When the liquidus temperature of Al-Zn alloy is equal to or below the temperature of zinc melt, Al-Zn alloy melts and TiC particles drop with it from the Al/TiC alloy and then transfer into the zinc melt and finally distribute uniformly in it.

[Key words] prefabricated Al/TiC alloy; zinc alloy; TiC particle; uniform distribution process

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1 INTRODUCTION

Particle reinforced zinc-aluminum matrix composites have extensive applied prospects in the production of bearing, bush and die for their superiority in hardness, stiffness, wear resistance and dimensional stability over zinc-aluminum alloys^[1~5]. Among the different producing techniques of the particle reinforced metal-matrix composites^[6~8], XDTM is a newly arisen one which has been proved to be more efficient, for that the combination of the interface between particles and matrix alloy is excellent and the particle is tiny compared to other techniques^[9,10]. But how the particles in the preform transfer uniformly into the melt is a complex physical process, which will affect whether they can distribute uniformly in the matrix alloy as well as the mechanical properties of the composites. So how to control the uniformization of the particles in the matrix alloy is one of the keys to the research and development of this kind of composites. Meanwhile, analysis of the uniformization of TiC particles in the zinc melt plays a significant role in optimizing the process to fabricate zinc matrix composites. Hence this paper studies the uniformization process of TiC particle in the stationary zinc melt.

2 EXPERIMENTAL

Firstly titanium powder (99.2%, 45 μm) and graphite powder (99.8%, < 0.05 μm) were mixed with

aluminum powder (99.6%, 29 μm) according to 40Al + 30C + 30Ti (in mole fraction, %), and pressed into 40 mm (in diameter) $\times$ 25 mm (in height) column with 50% ~ 60% theoretical density. Then the column was placed in the vacuum SHS equipment and reacted to form the preform Al/TiC alloy, the XRD results of Al/TiC alloy is given in Fig. 1. It has been shown clearly that the present phases are Al and TiC, which shows that no physical and chemical reaction exists between Al and Ti. Then the experiments on the uniform distribution process of TiC particles in molten zinc alloy were carried out under different conditions. The schematic diagram of the experimental equipment is shown in Fig. 2. Finally the specimens were cut in the direction vertical to the interface of Al/TiC alloy and zinc alloy after the molten zinc alloy was solidified completely. The interface between the Al/TiC alloy and zinc alloy was analyzed using scanning electron microscope and electron probe, and the energy spectrum analysis of the content of Al, Zn and Ti elements near the interface tiny zone was carried out.

3 RESULTS AND DISCUSSION

3.1 Results

The SEM image of the interface between the Al/TiC alloy and zinc alloy solidified from the liquid maintained at 620 $^{\circ}\text{C}$ for 35 min is shown in Fig. 3.

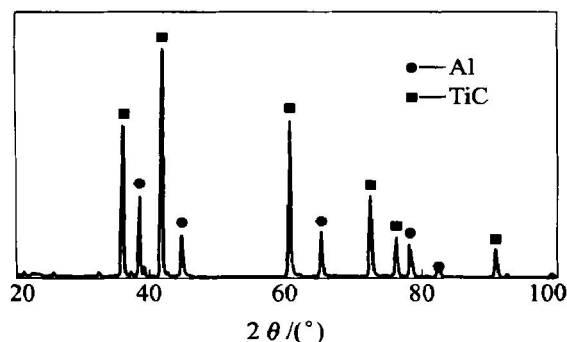


Fig. 1 The XRD result of Al/TiC alloy

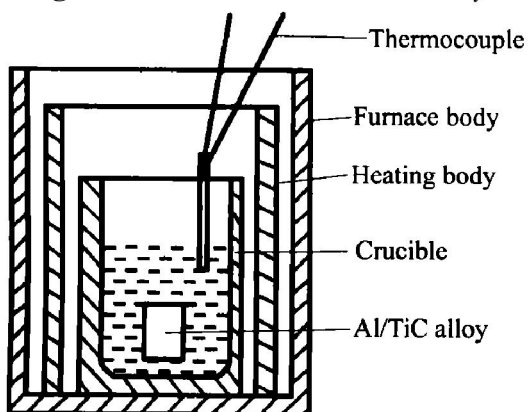


Fig. 2 Sketch of uniform distribution experiment equipment

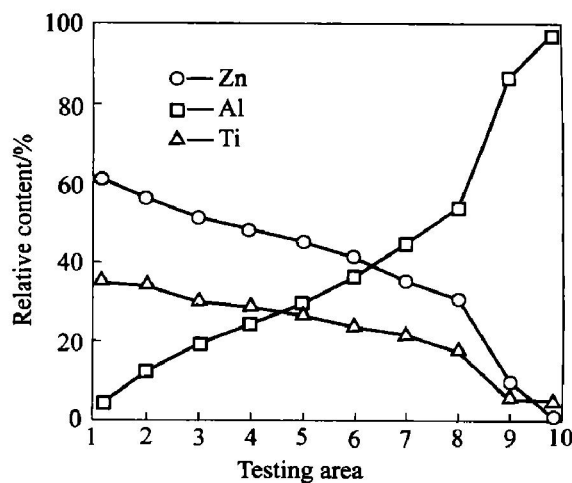


Fig. 4 Curves of Al, Zn and Ti relative content of area from 1 to 10 in Fig. 3

diffusion layer of aluminum into zinc alloy is thin.

Fig. 5 shows the SEM image for the interface between the prepared Al/TiC alloy and zinc alloy solidified from the liquid maintained at 620 °C for 3 h. It can be seen that the interface between the prepared Al/TiC alloy and zinc alloy is blurry, and there is a TiC particle accumulating zone in the front of the interface (as area 3 shown in Fig. 5). Energy spectrum analysis of elements was also conducted from area 1 to area 13, each area being 150 μm × 250 μm. The relative content of each element, as shown in Fig. 6, is calculated according to energy spectrum analysis. The content of Al, Zn and Ti element changes in a monotonous manner from area 1 to 6 but changes diversely from area 7 on. It indicates that there exist molten aluminum and TiC particles accumulating zone near the interface.

3.2 Model of uniform distribution process

The model of uniform distribution process was built according to the results mentioned above. The diffusion of zinc into the prepared Al/TiC alloy as well as aluminum into the zinc melt take place after Al/TiC alloy is placed in the zinc melt at a temperature below the melting point of aluminum. And then Al-Zn alloy is formed on the surface of the prepared Al/TiC alloy. In light of the phase diagram of Al-Zn alloy, its liquidus temperature decreases with the increase of zinc concentration. Fig. 7, the relationship between the liquidus temperature and zinc concentration in the initial uniform distribution process, shows that the liquidus temperature of Z2 decreases due to the diffusion of zinc into the prepared Al/TiC alloy, where T_0 and T_2 stand for the melting point of aluminum and zinc respectively, and T_1 the temperature of zinc melt.



Fig. 3 SEM image for interface of prepared Al/TiC alloy and zinc alloy
(Solidified from liquid maintained at 620 °C for 35 min)

An obvious interface can be seen between the two alloys. Energy spectrum analysis of the elements was conducted from area 1 to area 10, each being 250 μm × 350 μm in size. The relative content of each element calculated according to the energy spectrum analysis is shown in Fig. 4, which are inaccurate yet to show the changing tendency of the content of each element.

In Fig. 4 zinc has diffused into the prepared Al/TiC alloy and formed a thick diffusion layer, while the

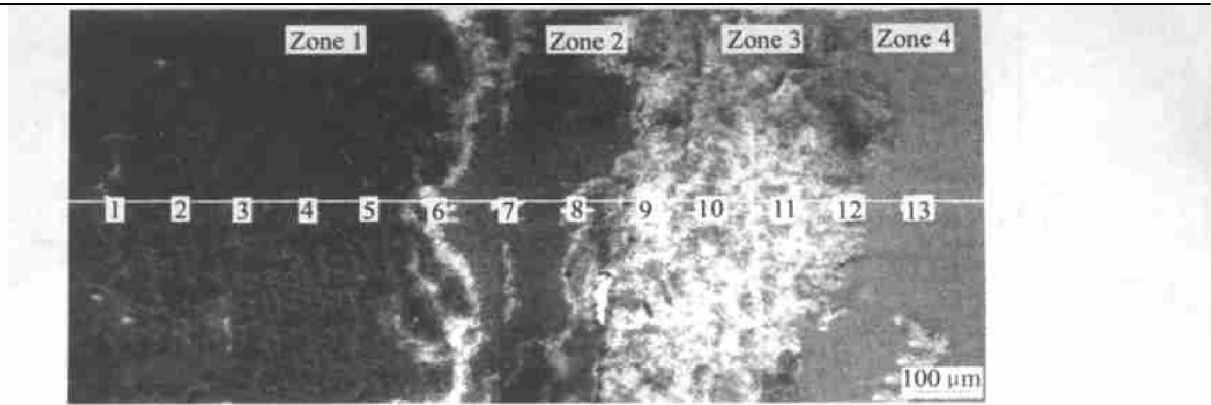


Fig. 5 SEM image for interface of prepared Al/TiC alloy and zinc alloy
(Solidified from liquid maintained at 620 °C for 3 h)

Zone 1—Al/TiC alloy; Zone 2—Zinc; Zone 3—Al and TiC dropping from Al/TiC alloy; Zone 4—Zinc

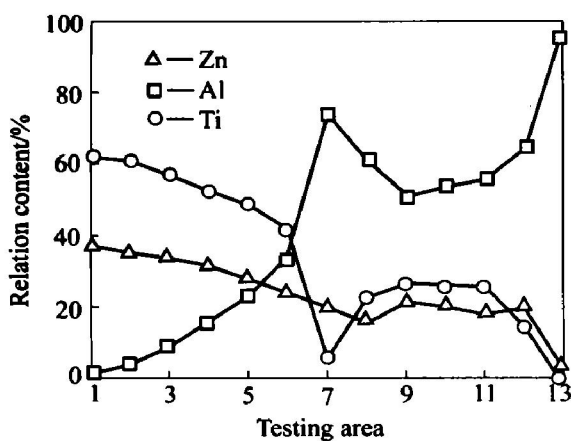


Fig. 6 Varying curves of Al, Zn and Ti relative content of area from 1 to 13 in Fig. 5

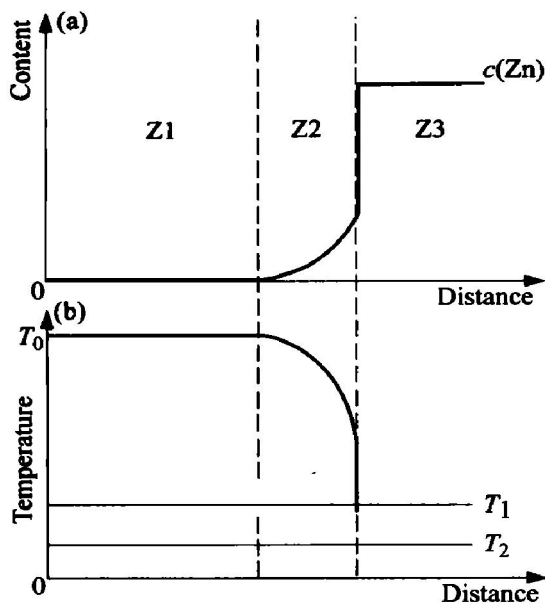


Fig. 7 Schematic of zinc content and liquidus temperature distribution of Al/TiC alloy (before TiC coming off)
(a)—Zinc content; (b)—Liquidus temperature
Z1—Al/TiC alloy; Z2—Diffusion layer of zinc;
Z3—Zinc melt

As the diffusion proceeds, the concentration of zinc in the Al-Zn alloy increases gradually so that the liquidus temperature decreases continuously. Fig. 8 illustrates relation between liquidus temperature and zinc concentration when the liquidus temperature of the Al-Zn alloy is equal to or below the zinc melt temperature. Now the Al-Zn alloy continuously melts and the combination of Al-Zn with the prepared Al/TiC alloy decreases, leading to the TiC particles dropping together with the molten Al-Zn alloy. The diffusion of zinc into Al-Zn alloy and aluminum into zinc melt carries on and the combination between TiC particles decreases gradually until to zero. So the TiC particles transfer into the zinc melt continuously until all the

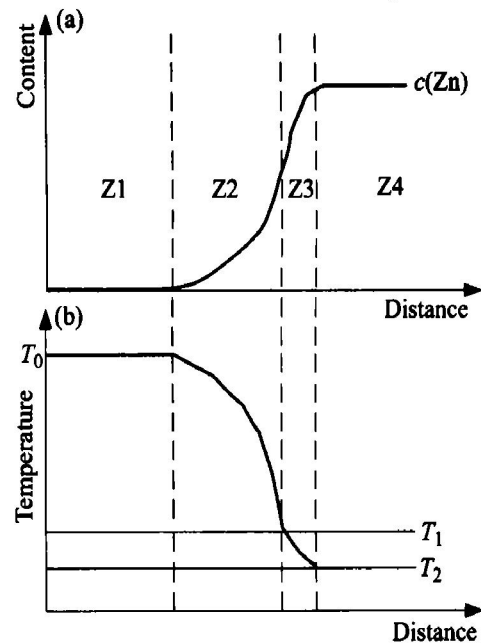


Fig. 8 Schematic of zinc content and liquidus temperature distribution of Al/TiC alloy (after TiC coming off)
(a)—Zinc content; (b)—Liquidus temperature
Z1—Al/TiC alloy; Z2—Diffusion layer of zinc;
Z3—Accumulating zone of dropped TiC and Al;
Z4—Zinc melt

particles in the prepared Al/TiC alloy are distributed in the zinc melt completely. Fig. 9 shows the microstructures of $\text{TiC}_p/\text{Zr-Al}$ composites with the TiC particles distributed uniformly in the matrix alloy through slight stirring.

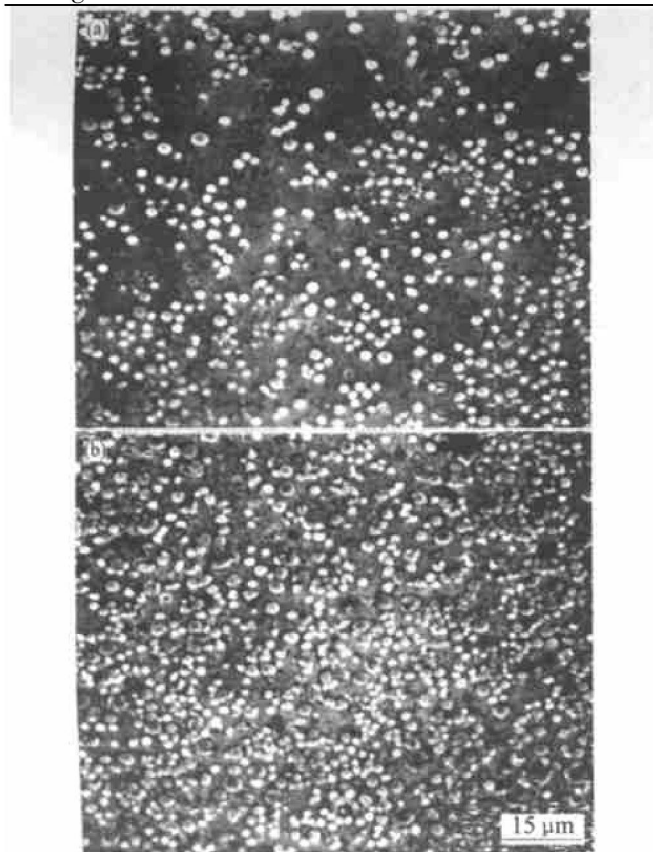


Fig. 9 Microstructures of $\text{TiC}_p/\text{ZA-12}$ composites
(a) $-5\% \text{TiC}_p/\text{ZA-12}$; (b) $-15\% \text{TiC}_p/\text{ZA-12}$

4 CONCLUSIONS

1) The uniform distribution process of the TiC particle in the zinc melt was analyzed by experiments, its model was built according to the experimental results.

2) The uniformization of the TiC particle in the zinc melt at temperatures below the melting point of aluminum has been studied. Once the prepared Al/TiC alloy has been placed in the zinc melt, Al-Zn alloy is formed in its surface because of the diffusion of zinc into it.

3) The liquidus temperature of Al-Zn alloy decreases gradually with increasing zinc concentration in the prepared alloy. When it is equal to or below the zinc melt temperature, the Al-Zn alloy keeps melting which results in the dropping of the TiC particle. Then the dropped TiC particles transfer into the zinc melt continuously until they distribute uniformly in zinc melt.

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