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Effects of solid deformation and melt vibration on structure and refining performance of Al5Ti1B master alloy①

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Abstract: Grain refinement can offer significant benefits to both continuous casting and cast-to-shape products, and Al5Ti1B master alloy containing mainly $TiAl_3$ and TiB_2 particles in Al matrix has been proven to perform well for giving the best refinement, but the working method of adding Al5Ti1B rod to the furnace during casting are often related to solid deformation, and melt vibration may help to reduce the size of $TiAl_3$ and improve the distribution of TiB_2. Therefore the effects of solid deformation and melt vibration on the structures and refinement performance of Al5Ti1B master alloys were studied. The experimental results show that both solid deformation and melt vibration can improve the distribution of TiB_2 in Al5Ti1B master alloys, increase the interface energy and nucleation activity of TiB_2 particles. In the meantime, solid deformation can store deformation energy and melt vibration can break fragile plate-like $TiAl_3$ compounds. So both methods can improve the refinement effectiveness of Al5Ti1B master alloys.

Key words: Al5Ti1B master alloy; solid deformation; melt vibration **Document code: A**

1 INTRODUCTION

Grain refinement offers substantial benefits in both continuous casting by direct chill (DC) and in cast-to-shape products[1]. Al-5% Ti-1% B master alloy, which mainly contains $TiAl_3$ and TiB_2 particles in Al matrix[2, 3] has been proven to give the best grain refinement[4, 5]. Addition of 0.01% Ti is usually made if commercial pure Al is refined by Al5Ti1B master alloy. It is shown that TiB_2 phases play a dominant role in grain refinement[6~8], its morphology, size, distribution and surface characteristic have remarkable effect on α-Al nucleation[9].

Al5Ti1B master alloy was firstly supplied in the waffle form and is normally added directly to the holding furnace where it must be stirred. The TiB_2 in the waffle is present in the form of agglomerates at the grain boundaries and the TiB_2 particles are sedimentated on the furnace bottom. Al5Ti1B master alloys added in the form of rods during casting are significantly smaller than those under traditional furnace treatments, in which some gravitational separation (for $TiAl_3$ and TiB_2 particles) is not infrequently experienced. The master alloy rod is introduced to a transfer system by a feeding machine at a predetermined rate. There are many working methods for Al5Ti1B rod and most methods are related to solid deformation[10]. This paper will investigate the effects of solid deformation and melt vibration on the structures and refinement performance of Al5Ti1B master alloys.

2 EXPERIMENTAL

Al5Ti1B master alloy was prepared by 99.7% commercially pure Al, K_2TiF_6 and KBF_4 in a resistance furnace at 850 ℃, and was poured into a permanent mold (named Al5Ti1B-i sample). The Al5Ti1B-i sample was heated to 480 ℃ or so and forged from a thickness of 20 mm to 5 mm (named Al5Ti1B-f sample); the Al5Ti1B-i sample was remelted and vibrated until the melt was solidified (named Al5Ti1B-v sample).

The samples for macrostructure observation were prepared by adding Al5Ti1B master alloys into 99.7% commercially pure Al melt (730 ℃, 0.01% Ti) and pouring into another permanent mold, and were etched by aqua regia.

3 RESULTS AND DISCUSSION

3.1 Effects of solid deformation and melt vibration on microstructures of Al5Ti1B master alloys

Fig. 1 shows the microstructures of Al5Ti1B master alloys before and after forging deformation.

TiB_2 particles are in the form of agglomerates at the grain boundaries before deformation, as shown in Figs. 1(a) and (c); after deformation, TiB_2 particles are distributed along with the deformation direction,

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as shown in Figs. 1(b) and (d). In addition, not only the distribution of $TiAl_3$ compound crystal is improved, but also the plate-like $TiAl_3$ crystal is broken, thus the number and surface energy of $TiAl_3$ are increased.

In order to improve the morphologies and distribution of $TiAl_3$ and TiB_2 particles, it is found that melt vibration can help to reduce the size of $TiAl_3$, and largely improve the distribution of TiB_2 particles. Experimental results also show that remelting temperature and vibration frequency are two key factors affecting the microstructures of Al5Ti1B master alloys. Fig. 2 shows the effect of melt vibration at 30 Hz on the distribution of TiB_2 particles in Al5Ti1B-i sample remelted at 950 ℃.

Experimental results also testified that the maximum length of $TiAl_3$ decreases with increasing remelting temperature and vibration frequency. Fig. 3 shows the effects of remelting temperature and vibration frequency on the maximum length of $TiAl_3$ particles in Al5Ti1B-i sample remelted at 950 ℃.

3.2 Effects of solid deformation and melt vibration on refinement performance of Al5Ti1B master alloys

Fig. 4 shows the comparisons of refinement performance of Al5Ti1B master alloys before and after deformation for commercially pure Al. It can be seen that the refinement efficiencies of Al5Ti1B master alloys treated by deformation and vibration are obvious

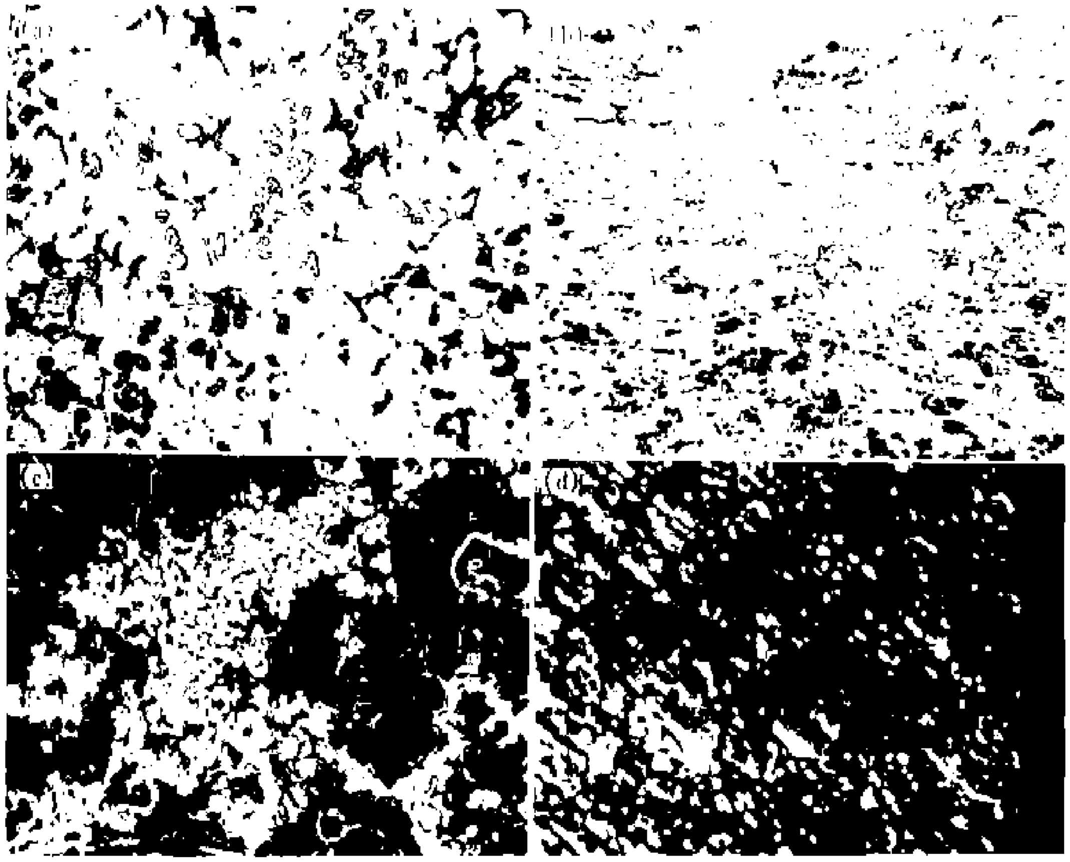

Fig. 1 Microstructures of Al5Ti1B master alloy before and after forging treatment
(a) and (c) —Before forging (Al5Ti1B-i); (b) and (d) —After forging (Al5Ti1B-f)

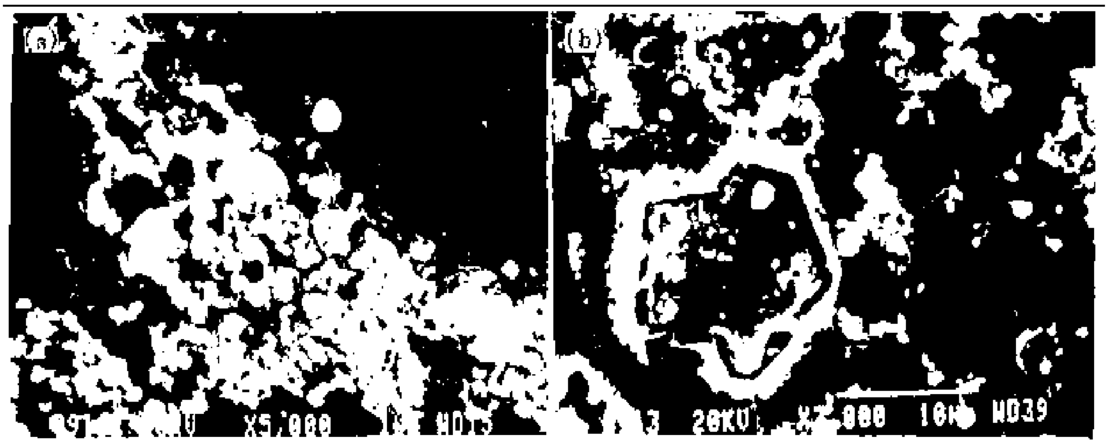

Fig. 2 Effect of melt vibration on TiB_2 distribution in Al5Ti1B master alloys (30Hz, 950 ℃)
(a) —Before vibration; (b) —After vibration

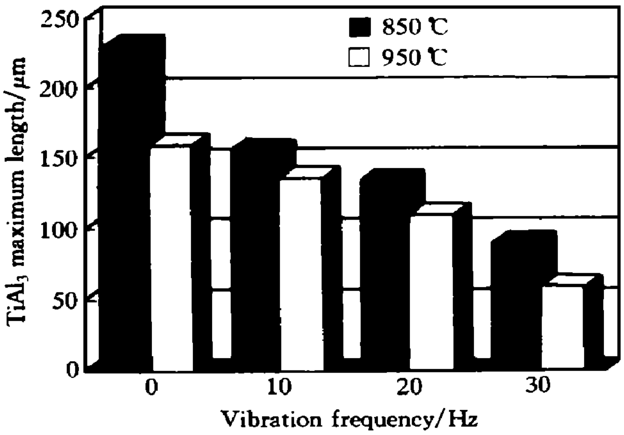

Fig. 3 Effect of vibration frequency and remelting temperature on maximum length of $TiAl_3$ in Al5Ti1B master alloys

ly improved.

4 DISCUSSION

4.1 Effect of solid deformation on microstructure and refinement performance of Al5Ti1B master alloy

There are $TiAl_3$ and TiB_2 particles in the Al5Ti1B master alloy. Solid deformation can improve the distribution of TiB_2 in Al5Ti1B master alloys, thus increasing the interface energy and nucleation activity of TiB_2 particles. In the meantime, solid deformation can store deformation energy and break flake-like $TiAl_3$ compounds. So the melting rate of the master alloy and spreading rate of the nucleated phases are obviously increased after addition of the master alloy into commercially pure Al melt, thus increasing the nucleating rate of TiB_2 phases.

4.2 Effect of melt vibration on microstructure and refinement performance of the Al5Ti1B master alloy

Fig. 5 shows the refinement performance comparison of AlTiB alloys before and after melt vibration, it can be seen that the melt vibration can improve the distribution of TiB_2 in Al5Ti1B master alloys and increase the interface energy, so the nucleation activity of TiB_2 particles is increased. TiB_2 particle are very fine and have high surface energy, so they tend to gather in the form of agglomerates at the

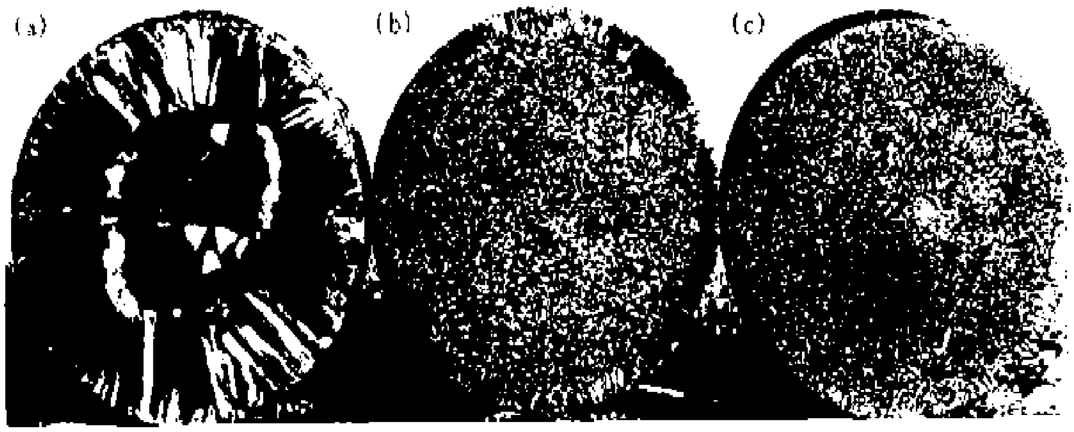

Fig. 4 Refinement performance comparisons of AlTiB master alloys before and after forging (0.01%Ti, 0.002%B, permanent mold)
(a) —Without addition; (b) —With addition of Al5Ti1B-i; (c) —With addition of forged Al5Ti1B-f

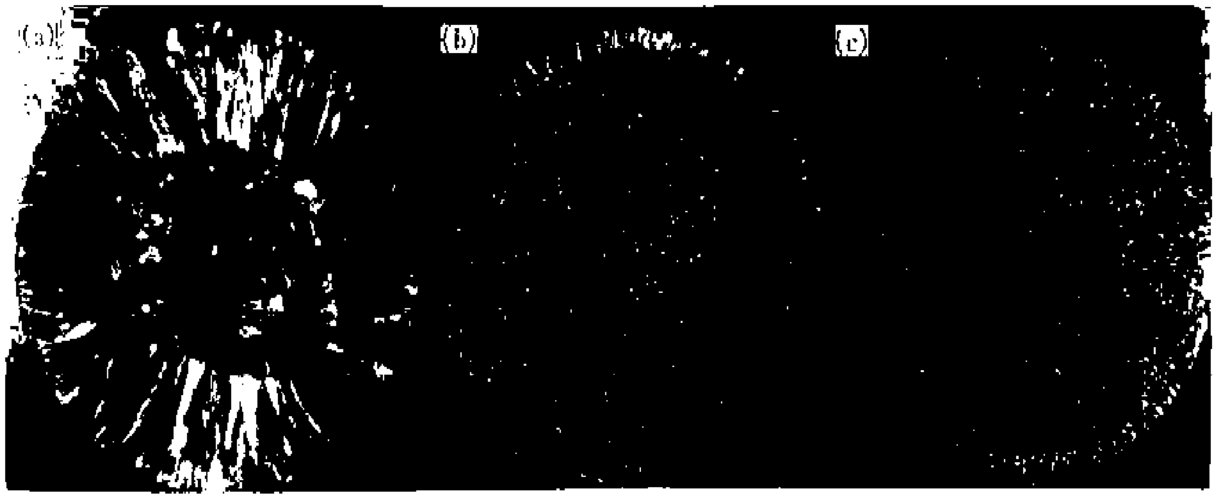

Fig. 5 Refinement performance comparisons of AlTiB master alloys before and after vibration (0.01%Ti, 0.002%B, permanent mold)
(a) —Without addition; (b) —With addition of Al5Ti1B-i; (c) —With addition of Al5Ti1B-v

grain boundaries in order to reduce their surface energy. Under vibration condition, the TiB_2 particles tend to be dispersed as a result of gaining outside energy, and the microstructure characteristic of the melt can be retained until being solidified. The higher the remelting temperature and vibrating frequency, the higher the dispersion degree of TiB_2 particles. In the meantime, melt vibration can break fragile plate-like $TiAl_3$ compounds, thus reducing their size and increasing the $TiAl_3$ number.

The grain refinement performance of Al5Ti1B master alloy largely depends on the size and distribution of TiB_2 and $TiAl_3$ compounds, so melt vibration can improve the microstructure and refinement effectiveness of Al5Ti1B master alloy.

5 CONCLUSIONS

1) Solid deformation can make TiB_2 particles in Al5Ti1B master alloy distribute directionally, increase the interface energy and nucleation activity of TiB_2. In the meantime, solid deformation can store deformation energy and break flake-like $TiAl_3$ compounds. Therefore the refinement efficiency of Al5Ti1B master alloy is increased.

2) Melt vibration can improve the distribution of TiB_2 in Al5Ti1B master alloy and increase the interface energy, so the nucleation activity of TiB_2 particle is increased. In addition melt vibration can break fragile plate-like $TiAl_3$ compounds and improve the structure and refinement effectiveness of Al5Ti1B master alloy.

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