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# Effect of Holding Time and Solute Contents on Grain Refinement Induced by Ultrasonic Melt Treatment

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## 1. Introduction

The ultrasound is expected to be applied to many material processes, especially casting. The ultrasonic melt treatment (UTS) is very efficient in controlling the microstructure of alloys, and many researches have been taken to establish the using of ultrasound to the casting process. The outstanding effect by UTS on the microstructure of the alloys is grain refinement, which was able to make the mechanical properties progress. The UTS for grain refinement was very effective in injection during solidification or the state of coexistence of solid and liquid of the alloys. The mechanism of grain refinement is still under discussion. Many theories have been proposed, which could be divided in two groups: The first is based on the principles of grain multiplication by the broken dendrite. The second is the heterogeneous nucleation by the promotion of the non-wettable particles. The grain multiplication is based on the phenomenon that shock wave generated from the bubbles collapse by cavitation effect leads to fragmention of dendrites, with the dendrite particles being distributed by acoustic streaming within the melts. These dendrite particles could be the nucleation sites. The promotion of heterogeneous nucleation by the non-wettable particles is based on the role of cavitation on the particles, which there were always in melts. The cavitation makes the non-wettable particles wet in melts and be the solidification sites [1]. However, these theories couldn't explain the experiment results, the UTS in whole melts. In this study, high-power ultrasound is injected into melts not during, but before the solidification of the alloys to make up for the effect of the solute contents and the fading of UTS. Our experiments were focused on the investigation the effects of solute clusters in melts on grain refinement and the new theory was proposed.

## 2. Experimental procedure

**Table I** shows the experimental conditions for UTS. The ultrasonic frequency of the apparatus is 20 kHz and the maximum power output is 1,200W. About 1,260 g of Sn-Zn alloy ingots were melted in graphite crucible, when the temperature of the melt reached experimental condition, then the preheated injection horn was dipped about 20 mm

Table I. Experimental conditions

| | |
|---|---|
| Alloy composition (mass%) | Sn-3, 6, 9, 20, 30Zn, |
| Melting temperature ($^{o}$C) | Sn alloys: 250-290 |
| Melts holding time (min) | 0, 5, 10, 20, 60 |
| Ultrasonic frequency (kHz) | 20 |
| Ultrasonic power (W) | 1,200 |
| Ultrasonic injection time (min) | 0 or 10 |

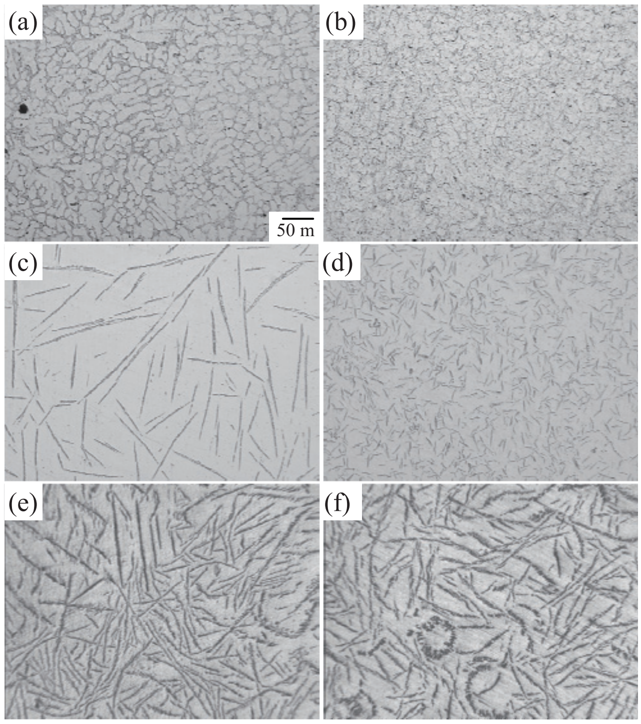


Fig. 1. Microstructure of Sn-Zn alloys with and without ultrasound injection in melt:
(a), (b): Sn-3Zn and (c), (d): Sn-14Zn alloy,
(e), (f): Sn-20Zn, (a), (c), (e) without and
(b), (d), (f) with UTS.

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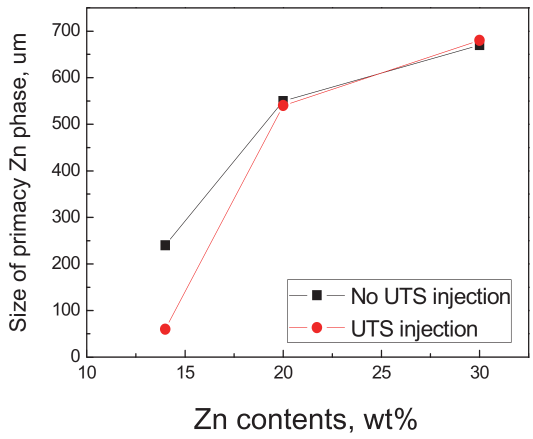


Fig. 2. The size of primary Zn phase of Sn-Zn alloys with the Zn contents

in the alloy melt. After ultrasonic injection, the melt was cast in a steel permanent mold.

## 3. Results and discussions

The optical micrographs of the samples from castings made with and without UTS into alloys melts are shown in **Fig. 1**. The microstructure refinement, especially primary alpha phase, could not be achieved in Sn-3Zn alloy with UTS as shown in Fig. 1 (a) and (b). Primary Zn of Sn-14Zn alloy with UTS was very small and dispersed uniformly in alloy matrix as shown in Fig. 1 (c) and (d). However, the effect of UTS on grain refinement was disappeared with the increasing the solute contents, Zn as shown in Fig 1 (e) and (f), and **Fig. 2**. The grain refinement by UTS would be affected the contents of the solute in alloy, and then there was a limit solute contents to influence on the grain refinement. Figure 3 shows the fading effect with the increasing the holding time after UTS. The primary Zn phase was coarsed more and more as

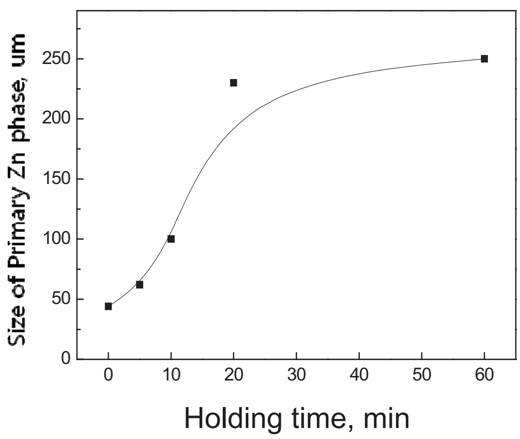


Fig. 3. Size of primary Zn phase with melts holding time before pouring into mold after UTS

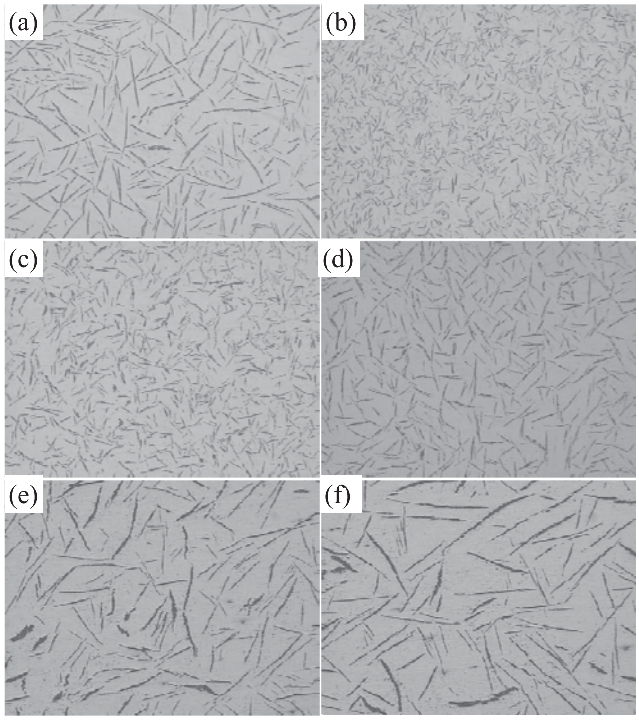


Fig. 4. Microstructure of Sn-14Zn alloys with and without UTS. (a) without UTS, (b) 0 min, (c) 5 min, (d) 10 min, (e) 20 min, and (f) 60 min holding after UTS.

time goes. The UTS effect on grain refinement was lasted about 10 minute. The results in this study shows the effect of melts homogeneities, especially solute homogeneity in melt, on refinement by UTS into melts, and based on experimental results, solute cluster theory could be suggested. The solute cluster theory proposed in this paper was based on the non-uniformity of alloying element (solute) in the melt. The UTS could make the distribution uniform, and then it takes a time to grow equilibrium size for progressing growth. Because of that, the supper cooling of melts should increase, and the refinement could be achieved. But if there were a lot of solutes in adjacent site, and then the solute could be grown without hesitation. As the same manner, the solutes more and more grow to an equilibrium size in melts, if they have a proper time after UTS.

## 4. Conclusion

The present investigation attempts to explain the mechanism of UTS on the grain refinement of Sn-Zn alloys. This is because that the distribution of solutes in melts, which controls the solidification procedure.

## References

1. G. I. Eskin: *Ultrasonic Treatment of Light Alloy Melts* (Gordon and Breach, Amsterdam, 1998)