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Effect of Ultrasonic Frequency on Attenuation Coefficient for Effective Nucleation Enhanced Ultrasonic Melt Treatment

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Increasing of ultrasonic intensity is very essential to acquire higher efficiency of melt treatment for treat more melts in same time. Attenuation factor is contribution parameter of the intensity that depends on medium, and determining the efficient range of the ultrasonic. For A356 alloy, there is no research about ultrasonic attenuation, especially the effect of ultrasonic frequency on that. This study is focused on the evaluation of attenuation factor and efficient range of the ultrasonic at different frequency to improve efficiency of ultrasonic melt treatment. Firstly, ultrasonic with different frequencies were injected into Si oil to visualize attenuation and measure efficient range. Relationship between frequency and attenuation phenomena were analyzed from the experiments. The results were revised and confirmed through experiments on A356 with various ultrasonic frequency.

Keywords: *A356 alloy, Ultrasound, Attenuation coefficient, Ultrasonic intensity, Microstructure*

1. Introduction

Ultrasonic melt treatment can achieve grain refinement and degassing of the alloy at the same time, so the quality of castings can be improved. The dominant mechanism for the effect of ultrasonic melt treatment are cavitation effect and acoustic streaming due to the ultrasound. Cavitation effect and acoustic streaming are both related to intensity of ultrasonic that propagating through medium. The intensity of propagating ultrasonic, I can be expressed as follows [1-3]

$$I = I_0 \exp(-2\alpha x) \tag{1}$$

where I_0 is initial intensity of ultrasonic, α is attenuation coefficient, x is propagated distance. Following this equation, as ultrasonic travels along the medium, the intensity of ultrasonic decreases. This phenomenon is called attenuation. Attenuation coefficient α is contribution parameter of the intensity that depends on medium, and determining the efficient range of the ultrasonic [4].

In this study, ultrasonic attenuation in different frequency and intensity is analyzed. Various conditions of ultrasonic induced to Si oil to measure penetration depth and analyze attenuation phenomena in medium for each condition. Also, ultrasonic induced to A356 melts to analyze attenuation by examine grain refinement efficiency.

2. Experimental

The ultrasonic inducing equipment is consists of an ultrasonic generator and control box, a transducer, a booster and a sonotrode. For each 15, 20 and 25 kHz frequency, boosters and sonotrodes have different length to match with resonant frequency. 350 cS standard viscosity Si oil was contained in transparent cylindrical acrylic container with 60 mm diameter. Ultrasonic sonotrode was dipped 20 mm in the Si oil. The penetration depth of ultrasonic was measured while inducing ultrasonic of each condition. Condition of each experiment is shown is Table 1. For following experiment, 2 kg of A356 alloy was melted in graphite crucible at 680℃. The prepared melt was withdrawn from the furnace and placed in air for ultrasonication. Ultrasonic was induced to melt at 660 ℃ for 180 s. Each ingot sample was cut perpendicularly. The grain size of each section was measured to analyze grain refinement effect of different ultrasonic inducing condition.

3. Result & discussion

Fig. 1 illustrates relationship of penetration depth and calculated intensity for each ultrasonic inducing condition. The result shows that, the penetration depth of ultrasonic is proportional to induced ultrasonic intensity. And at similar intensity, the penetration depth difference of each frequency is maximum 2 mm, so the difference is almost negligible. This means the effect of frequency to ultrasonic attenuation is relatively small than the effect of intensity. Fig. 2 shows the result of

Table 1 Conditions of induced ultrasonic in Si oil.

Frequency	Intensity (W/cm^2)	Amplitude (㎛)
15 kHz	2567	13
	3668	19
	4918	23
20 kHz	2406	9
	3053	13
	4196	15
25 kHz	1806	6
	2286	8
	3415	9

injection of different frequency and intensity to A356 melts. The condition of induced ultrasonic, calculated intensity and grain refinement fraction is shown in Table 1. The result is similar to Si oil, as intensity increases, the grain refinement fraction also increases. But, in condition of 15 and 20 kHz 9㎛ amplitude, ultrasonic injection could not refine the grain. These ineffectiveness in low intensity is evidence of cavitation threshold. Generation of cavitation is essential for grain refinement of A356 alloy. But in 15 and 20 kHz 9 ㎛ amplitude ultrasonic, the threshold intensity for cavitation bubble generation is unsatisfied, so refinement of grain did not occur. The cavitation threshold intensity is achieved over 1809 W/cm^2 intensity, and grain refining phenomenon expands by acoustic streaming. The acoustic streaming has tendency of proportional to intensity, so the ultrasonic intensity increases, grain refinement efficiency also increases.

4. Conclusion

In this study, an attempt has been made to analyze the effect of ultrasonic frequency on attenuation in A356 melts. The result of ultrasonic injection to Si oil revealed that ultrasonic frequency cannot affects attenuation. On the other hand, ultrasonic intensity can affect attenuation, as intensity increases, penetration depth also increases. The experiment for A356 melts supports this result. Grain refinement fraction of each ingot sample increases along the intensity. Additionally, intensity under 1157 W/cm^2, the grain did not refined. This is the evidence of existence for cavitation threshold in A356 melt.

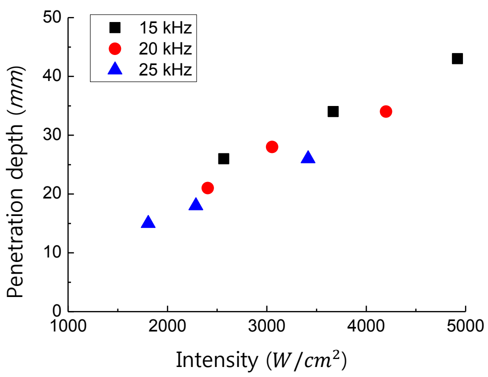

Fig. 1 Intensity vs. penetration depth in each frequency.

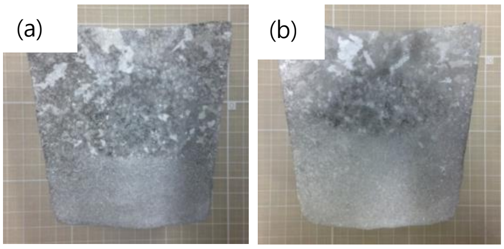

Fig. 2 Ingot sample of different ultrasonic condition: (a) 25 kHz 9 ㎛; (b) 20 kHz 15 ㎛.

Table 1 Ultrasonic inducing condition and calculated intensity and grain refinement fraction.

Inducing condition	Intensity (W/cm^2)	Grain refinement fraction (%)
15 kHz 9 ㎛	651	0
20 kHz 9 ㎛	1157	0
25 kHz 9 ㎛	1809	37
20 kHz 15 ㎛	4069	50
15 kHz 23 ㎛	5381	96

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