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Influence of the Density of Liquid on the Acoustic Streaming for Ultrasonic Melt Treatment

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1. Introduction

Over the past several years, the production weight of aluminum alloys has increased dramatically and the process technologies for aluminum castings have been developed continuously. Hydrogen dissolved in the liquid melts leads to a decline in the mechanical properties of the castings. The application of ultrasound for degassing has been studied for the last decades [1]. It has been shown that the high intensity ultrasonic melt treatment (UMT) removes the hydrogen in the melts, and under some conditions, gets an ultimate low gas level. The degassing mechanism has been proposed that the diffusion of the hydrogen gas occurs from the melts to the cavitation bubble under the UMT and the grown gas bubble flows away at the melts surface due to the low density [2].

The amplitude and intensity of the ultrasonic wave decreases exponentially with the propagation distance, and the exponential factor is the loss coefficient or sound absorption or attenuation factor. The melts should be transferred to the effective volume, and the important para-meter to make melts transfer is the acoustic streaming induced by the UMT. The acoustic streaming is affected by the various fluid parameters. The modeling and experiments through a simulated solution, mostly water, have been carried to establish the parameters and predict the streaming. The viscosity of the water is similar to the aluminum melts; however, the density is very different, and thus, inaccuracy can be introduced into the results [3].

This study is focused on the effect of the density of the simulated solution on the acoustic streaming through the momentum conservation principle which can be induced into the simulated solutions with the different density.

2. Experimental procedure

Fig. 1 shows the schematic diagram of the experimental system for investigating the movement of the cavitation bubbles, especially the velocity with the density of the simulated solution. The frequency of the ultrasonic system is 15 kHz, the amplitude is 20 μm and the maximum power output is 2,500 W/cm^2. The piezoelectric device for the ultrasonic transducer and the sonotrode made by Ti were used for the experiments. The simulated solution was mixed with $ZnCl_2$ and distilled water, the density was controlled as 1.4, 1.6, and 1.8 g/cm^3 to characterize and quantify the effect of the density on the streaming. The ANSYS Fluent module was used to simulate the ultrasonic melt treatment, especially, streaming and the efficient range in the melt. The inlet condition was fixed as the medium velocity.

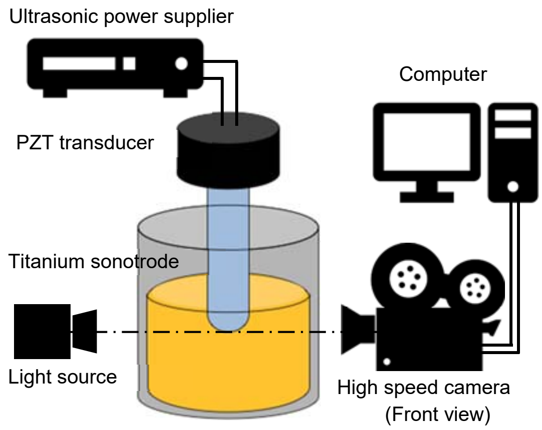

Fig. 1. Schematic diagram of high-speed camera system for investigating the movement of the cavitation bubbles.

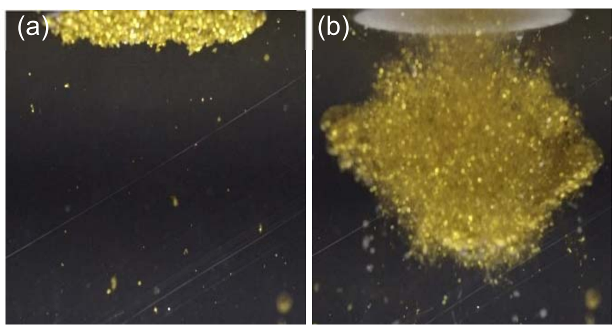

Fig. 2. Camera capture of moving reflectors in the simulated solution of 1.4 g/cm^3; (a) before and (b) just after the ultrasonic injection.

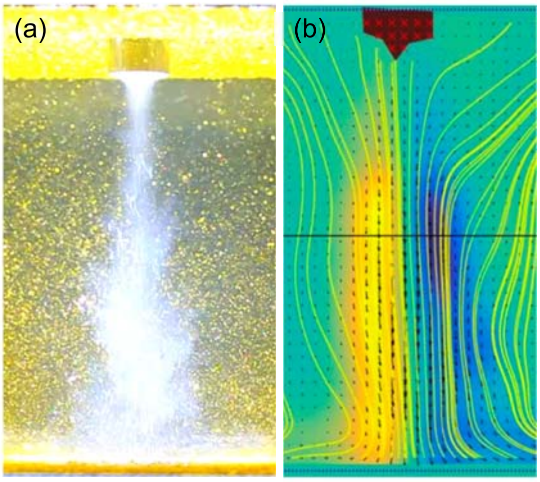

Fig. 3. (a) Camera capture of the acoustic streaming in density of 1.6 g/cm^3 solution and (b) velocity contour of the reflectors.

3. Results and discussion

The velocity induced by the ultrasonic injection of the liquid is the most important parameter to predict the acoustic streaming, especially, the velocity just after the injection revealed the initial momentum of the ultrasound. The reflectors and high-speed camera were used to quantify the velocity of the fluid as shown in Fig. 1 and Fig. 2, and the experimental results could be arranged as shown in Fig. 3. The initial velocity at the solution of 1.4 g/cm^3 was 27 cm/sec, and 23 and 21 cm/sec at 1.6 and 1.8 g/cm^3, respectively. The velocity of the fluid at the steady state flow was different with the density.

The momentum could be conserved if the sum of forces is not changed due to the same rate of momentum in and out. The momentum, p, was calculated as multiplication of the density, ρ, and the velocity of the fluid, v, at the initial and steady state,

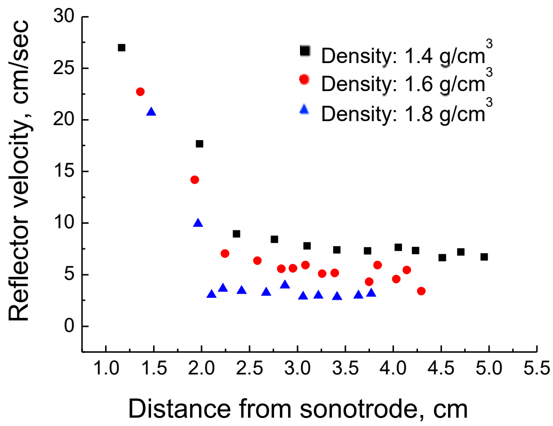

Fig. 4. Velocity of the reflectors after the ultrasonic injection with the distance from sonotrode bottom at different density of the simulated solution.

Table I. Momentum calculated as the velocity of the fluid at the initial state and steady state of the flow.

Density (kg/m^3)	Momentum (kg·m/s)		Reduction ratio (%)
	Initial state	Steady state	
1,400	378	104	72
1,600	375	82	78
1,800	377	54	86

and the results were shown in Table I. The initial momentum induced by the ultrasonic injection was similar with each density solutions as about 377 kg·m/s. However, the similar momentum at each condition was changed at the steady state of the flow. The reduction ratio of the momentum was increasing with increasing the density. This result means that the force induced by the ultrasound could be the same at the same ultrasonic injection condition, however, the acoustic streaming could be altered by the fluid parameter, especially density of the fluid. Thus, the impact factor on the density should be applied to improve the accuracy of the modeling because most of the experimental work on acoustic and induced convective flows has been done using water only.

4. Conclusion

This study is focused on the effect of the density of the simulated solution on the acoustic streaming through the comparing of the momentum at the initial and steady state of the flow. The properties of the acoustic streaming could be changed due to the fluid density.

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