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Optimization of 28 kHz Double-Bath Sonoreactors for the Applications in Heterogeneous System

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1. Introduction

Ultrasound irradiation in aqueous phase induces concentrated high energy formation inside micro-sized bubbles and various sonochemical and sonophysical effects can be obtained when the bubbles collapse. Previous researchers have focused on the optimzation and maximization of theses effects under various operating conditions including frequency, input power, and irradiation mode and environmental conditions including temperature, pH, dissolved gases and ions, and additives.[1-3)]

Recently it has been revealed that slight change in geomteric factors including transducer type, transducer location/array, irradition distance, and reactor shape/maetiral can induce siginficant differences of sonochemical and sonophysical effects.[3)] Asakura et al. tested various liquid heights for various frequencies and found sonochemical effects could greatly vary depending on the applied height under the same input power condition.[4)] Son also reported the effect of liquid height on sonochemical reactions and provided sonochemiluminescence (SCL) images showing the cavitation-active zone changed.[5)]

As one of the baisc steps to design ultrasonic soil washing reactors, the effect of liquid height in a double-bath-type sonoreactor was investigated to optimize the geometric factors in heterogeneous system (glass bead and water). The energy distribution of an ultrasonic bath and a vessel placed inside was analyzed using the calorimetric method. The sonophysical effect was quantitatively analyzed using the aluminum method under various conditions.

2. Materials and methods

Figure 1 shows the schematic of the sonoreactor used in this study. The transducr module including five 28kHz transducers were equipped on the bottom of the stainless-steel bath (20×20×20 cm^3) and the stainless-steel vessel (15×15×15 cm^3) was submerged (placed 2 cm above the bottom) in the bath. The sonoreactor was filled with 2 L of water and the temperature was maintained at 20–25 ℃. The electrical input power was 300 W.

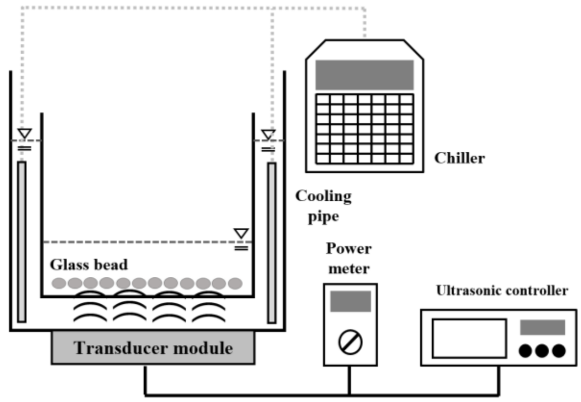

Fig. 1 Schematic of the sonoreactor used in this study.

To investigated the effect of the liquid height in bead/water system, glass beads (the diameter was 4 mm.) were placed on the bottom of the vessel and the liquid height in the vessel increased from 0.5 to 7 cm. The calorimetric energy was obtained using the following equation:

$$P_{cal} = \frac{dT}{dt} C_P M \quad , \qquad (1)$$

where P_{cal} is the calorimetric energy, dT/dt is the rate of increase of the liquid or soil temperature, C_p is the specific heat capacity of the liquid or soil (4.2 J/(g·K) for water and M is the mass of the liquid.[5)] To quantitatively analyze sonophysical effects in the vessel, a 150×150 mm^2 aluminum foil (the thickness was 0.015 mm.) was placed on the bottom of the vessel. The ultrasound-induced damaged foil was dried, scanned, and then analyzed using an image program.[7)]

3. Results

Figure 2 shows the calorimetric energy for the sonoreactor and the vessel under various liquid height conditions. The calorimetric energy in the vessel increased as the liquid height in the vessel increased when the input power was constant.

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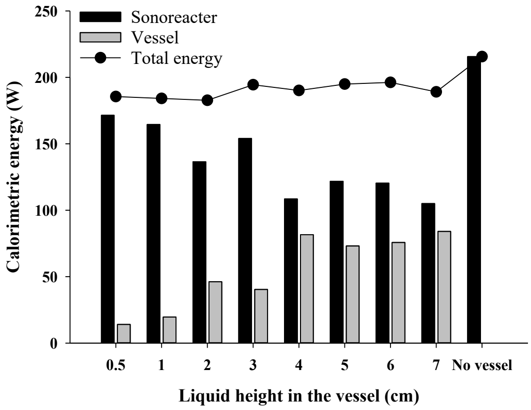
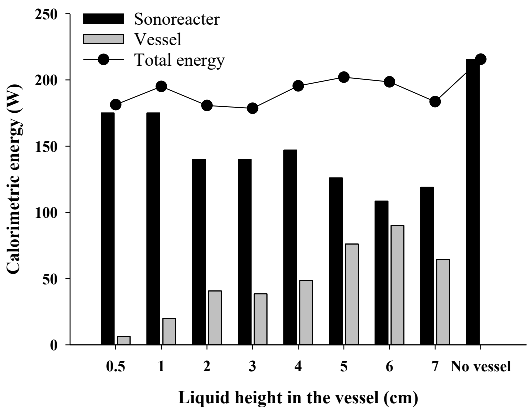
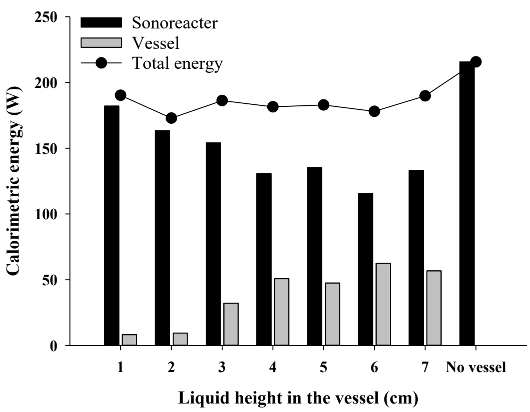
Interestingly, the total energy (the calorimetric energy in the sonoreactor + the calorimetric energy in the vessel) maintained approximately constant except when the sonoreactor was filled with the same volume as the 7 cm liquid height condition without the vessel. Thus it seemed the total calorimetric energy was distiributed to the calorimetric energy in the vessel and in the sonoreactor.



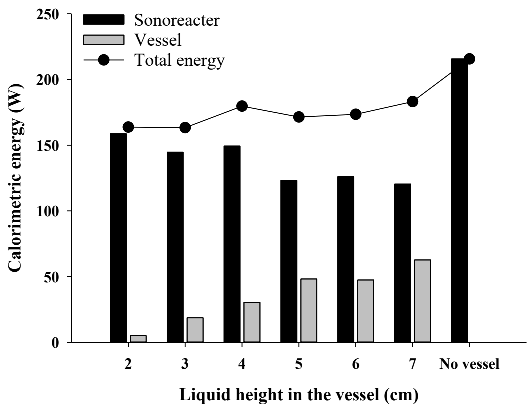
(a) The height of glass beads in the vessel: 0 cm



(b) The height of glass beads in the vessel: 0.5 cm



(c) The height of glass beads in the vessel: 1.0 cm



(d) The height of glass beads in the vessel: 2.0 cm

Fig. 2 Calorimetric energy in the vessel and in the sonoreactor for various conditions.

Significant attenuation of ultrasound due to the vessel placed in the reactor was observed. However no significant decrease in the calorimetric energy was observed in spite of the presence of the glass beads in the vessel. It might be due to compensation of following mechanisms: 1) ultrasound can attenuate due to the presence of the glass beads; 2) the presence of glass bead and the change of liquid height can increase calorimetric energy. Previous researchers reported higher calorimetric energy at higher liquid height conditions under the same input power.[3-5] In addition, Tuziuti et al., reported that a significant calorimetric energy increase was obtained when particels were present in a sonoreactor.[6]

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