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Effect of Liquid Height and Flowrate on Sonochemical Activity in 28kHz Sonoreactor

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1. Introduction

In the last decades, lots of parameters to improve various kinds of chemical reactions in am ultrasonic system have been studied.[1-4] The ultrasonic system has been tested under various experimental conditions(operating, liquid, and chemicals) to enhance sonochemical oxidation activities to applying pollutant removal system, material synthesis process, etc.

Some researchers concentrated on the optimization of geometric parameters, such as frequencies, power, and liquid volumes/height to increase sonochemical reactions and to design large-scale sonoreactor. [5,6] Generally, continuous liquid flow operation, violent agitation in liquid, and continuous gas dissolution can make more chemical reactions in typical chemical and environmental engineering processes. We found the air sparging and mechanical mixing make more sonochemical activities through spreading of ultrasound reaction field in the previous research.[7]

In this research, we examined the effect of liquid flowrate on sonochemical activity in the recirculated sonoreactor to give basic concepts for designing a large-scale sonoreactor. The sonochemical activity was measured using KI dosimetry for kinds of liquid heights and circulation flow rates.

2. Materials and Methods

The schematic of ultrasound system is shown in **Fig. 1.** The 28 kHz ultrasonic transducer module (Mirae Ultrasonic Tech., Bucheon, Korea) is equipped with the bottom of bath-type acrylic reactor (L × W × H: 130 mm × 130 mm × 290 mm). The liquid height was determined according to the wavelength of the ultrasound, 1.0λ (0.8 L) to 4.0λ (3.5 L), and the irradiation time was 30 min for all cases. The temperature was kept at 25 ± 3 °C using a cooling system. The input electrical power was measured using a power meter (HPM-300A, ADpower, KOR), which was 85 ± 5 W. The calorimetric power was calculated to evaluate energy consumption in the sonochemical reaction. The recirculation system including included a magnetic pump (MD-30RM-220N, Iwaki, Japan), a water flow meter (Hoosung, Korea), two acrylic flat nozzles, a ball valve, and connecting tubes is installed in the sonoreactor. The flow rates of recirculation system were controlled as follows: 1.5, 3.0, 4.5, and 6.0 LPM.

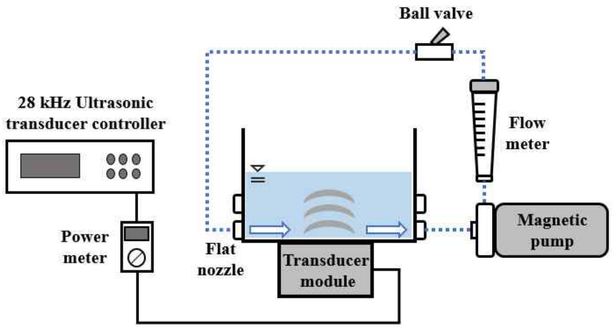

Fig. 1 Schematic of the ultrasound reactor with recirculation system.

The KI dosimetry was applied to quantify the radicals through sonochemical oxidation reaction.[8] The excess amount of iodide (I^-) in the KI solution(10g/L KI, Junsei, Japan) react with highly reactive radicals from cavitation, subsequently, iodine is formed, and then fully reacts with iodide to formed triiodide ions (I_3^-). The amount of I_3^- is using a UV-vis spectrophotometer (Vibra S60, Biochrom Ltd., UK). In each case, the generation of I_3^- ions followed the pseudo zero-order reaction owing to the presence of excess reactant I^- ions and the stable and continuous ultrasound irradiation. All correlation coefficient (R^2) values for each case were between 0.95 and 0.99.

3. Results and Discussions

The mass of generated I_3^- ions, and calorimetric power depending on liquid height are shown in **Fig.2.** To examine the optimal height conditions in the reactor used in this study, seven

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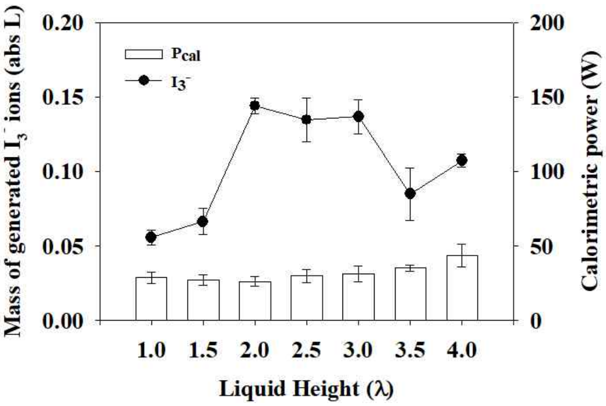

Fig. 2 Mass of generated I_3^- ions, and calorimetric power for various liquid height conditions.

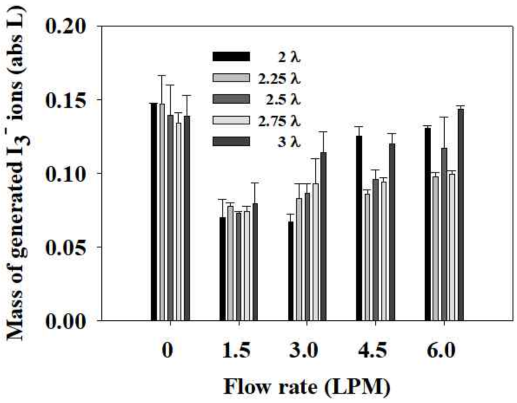

Fig. 3 Mass of generated I_3^- ions for various recirculation rates at liquid heights of 2λ to 3λ.

liquid heights with different geometric conditions were conducted. The mass means total amount of I_3^- in the final solution after 30 min of ultrasound irradiation.

The gradual increase was observed in the calorimetric power, while there were changes in the mass of I_3^- ions with an increase in the liquid height. Even though the high values of I_3^- ions were measured from 2.0 λ to 3.0 λ of liquid height, the maximum calorimetric power was founded at that of 4.0 λ. The pseudo zero-order reaction constants of 1.0 λ, 1.5 λ, 2.0 λ, 2.5 λ, 3.0 λ, 3.5 λ, and 4.0 λ are 2.3×10^{-3} abs·min^{-1}, 1.9×10^{-3} abs·min^{-1}, 2.9×10^{-3} abs·min^{-1}, 2.1×10^{-3} abs·min^{-1}, 1.8×10^{-3} abs·min^{-1}, 0.94×10^{-3} abs·min^{-1}, and 0.98×10^{-3} abs·min^{-1}, respectively. The liquid heights should be inversely proportional to The pseudo zero-order reaction constants and mass of I_3^- ions when the sonoreactor is a chemical reactor with a driving force(heat) and sonochemical effect(I_3^- ions) under the same calorimetric power.[9] However, the maximum sonochemical activity is not matched with maximum power condition, and higher sonochemical activity is observed in lower power conditions. In summary, the experiments for optimizing geometric parameters are needed in the designing of sonoreactors.

The various flow rates, 0 to 6.0 LPM was applied to find the effect of flowrate under 2.0 λ to 3.0 λ of liquid height in the recirculation sonoreactor as shown in **Fig. 3**. The different chemical reactions are observed when the flow is applied in the sonoreactor: First, the slight decrease of sonochemical reaction was occurred for 0-1.5 LPM changes with flow rate, Second, The enhancement of I_3^- ions for 3.0 LPM; Third, no significant difference was founded for 4.5 to 6.0 LPM. So, there is no direct relationship between liquid height and I_3^- under conducted experimental conditions. The direct inhibition of liquid flow near the ultrasonic plate makes low efficiency and a large flow rate is necessary to recover sonochemical activity compare to no flow rate condition.

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