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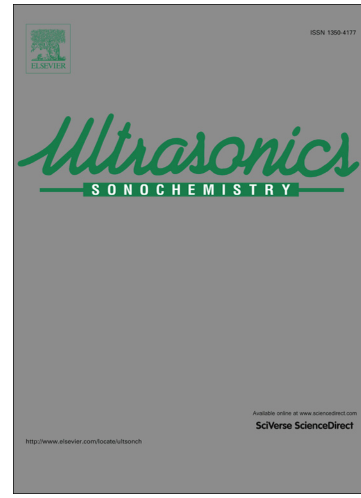

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Zongbo Zhang, Tiantian Gao, Xiaoyang Liu, Dawei Li, Jiawei Zhao, Yuqi Lei, Yankui Wang

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Influence of sound directions on acoustic field characteristics within a rectangle-shaped sonoreactor: numerical simulation and experimental study

Zongbo Zhang*, Tiantian Gao, Xiaoyang Liu, Dawei Li, Jiawei Zhao, Yuqi Lei，Yankui Wang

College of Mechanical and Electrical Engineering, China University of Petroleum (East China), Qingdao 266580, PR China

*Corresponding author at: 709 Engineering Building, No. 66 Chanjiang West Road, Huangdao District, Qingdao 266580, PR China

E-mail address: zzb001_0@163.com

Abstract

Acoustic field intensity and distribution are the most important factors for the efficiency of ultrasonic processing. Recent simulation studies suggested that sound direction could influence both acoustic field intensity and distribution, but this influence has scarcely been investigated experimentally so far. In this work, we systematically studied the influence of sound directions on the acoustic field with up to five directions via both simulation and experiment. Fluid-structure interaction (FSI) harmonic response simulation and aluminum foil erosion experiment were employed to study the acoustic field under different directional combinations of ultrasonic sources. Results of simulation coincided well with that of experiment, which indicated that acoustic intensity, uniformity and cavitation characteristics were significantly affected by sound directions. Based on the results, several influence rules of sound directions were proposed. Optimal acoustic field with sound intensity of 30 times higher than that of single-wall excitation and severe cavitation volume of 95% was obtained. This work provides useful guidelines for acoustic field design of high-intensity ultrasonic apparatus.

Keywords: High-intensity ultrasound, Sonoreactor, Fluid-structure interaction (FSI), Cavitation

1. Introduction

High-intensity ultrasound is widely used in various fields of modern industry such as chemical synthesis [1-2], cleaning [3-4], wastewater treatment [5] and metallurgy [6-8] mainly owing to the nonlinear phenomenon termed ultrasonic cavitation. The propagation of ultrasound in liquid will affect the pressure balance, producing numerous micro bubbles. When the sound pressure is higher than a certain threshold some of the bubbles will collapse, causing intensive micro-pressure-shock and micro-jet in the medium. Meanwhile, localized micro-regions with pressure of 1000 atm and temperature of 5,000 K could be generated within microseconds [9], which can dramatically enhance mass and heat transfer or even chemical reaction. Based on this mechanism of high-intensity ultrasound, sonoreactor is an extensively used apparatus for enhancing chemical reaction or physical process in recent decades [10-11].

Generally, there are two ways to introduce ultrasound into a sonoreactor, one is immersing an ultrasonic horn directly into the liquid (known as horn-based reactor) and the other way is mounting numbers of ultrasonic transducers onto the walls of a sonoreactor (known as bath-based reactor). The former way can produce very high sound intensity only within cubic millimeters nearby the horn,