Available online at www.sciencedirect.com
ScienceDirect
Journal of Hydrodynamics
2011,23(5):562-569
DOI: 10.1016/S1001-6058(10)60150-3
www.sciencedirect.com/science/journal/10016058

THE COUNTER-JET FORMATION IN AN AIR BUBBLE INDUCED BY THE IMPACT OF SHOCK WAVES*

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(Received January 6, 2011, Revised March 29, 2011)

Abstract: The interaction of an air bubble (isolated in water or attached to a boundary) with shock waves induced by electric sparks is investigated by high-speed photography. The interaction is closely related to the counter-jet induced by the impact of shock waves. The formation of a counter-jet in an air bubble is related to the liquid jet formed in the same air bubble, but the mechanism is different with that of the counter-jet formation in a collapsing cavitation bubble. The formation of a counter-jet in an air bubble is related to discharge energy, air bubble size and radius of shock wave. With a given energy of the spark discharge, the formation of a counter-jet in an air bubble is related to δ / ε (the ratio of the dimensionless bubble-bubble distance to the dimensionless air bubble radius). The counter-jet will only be produced when δ / ε is in the range of 1.2-2.2. The counter-jet in an air bubble is of an important nuclei-generating mechanism.

Key words: cavitation bubble, shock wave, counter-jet, high-speed photography

Introduction

In most practical situations, cavitation bubbles do not occur in isolation but coexist with cavitation bubbles or air bubbles in large numbers[1,2]. These cavitation bubbles grow and collapse continuously. The shock waves released by the cavitation bubbles may interact with boundaries, air bubbles or other cavitation bubbles[3,4]. The interaction of shock waves with air bubbles was investigated as issues in the area of medical treatment and hydrodynamics. Brujan[5,6] measured the shock wave emission after the optical breakdown in water experimentally. Philipp et al.[7] investigated the shock wave-induced collapse and jet formation of pre-existing air bubbles using high-speed photography. Kodama and Tomita[8] investigated the interaction of an air bubble attached to a gelatin surface with a shock wave. The interaction of an air bubble with a shock wave produces a liquid jet, with a speed of tens of m/s, towards the gelatin surface. Ding and Gracewski[9] and Jamaluddin et al.[10] simulated the air bubble responses to shock waves. It is found that for a weak shock ($P < 30$ MPa), the air bubble will collapse spherically without jet formation, for a strong shock ($500\text{ MPa} < P < 2\,000\text{ MPa}$) a jet will be created after the shock wave impacts the interface with a speed as high as 2 000 m/s. Tomita et al.[11] and Kodama et al.[12] investigated the motions of multiple

* Project supported by the National Science and Technology Support Plan of China (Grant No. 2008BAB29B04), the National Basic Research Program of China (973 Program, Grant No. 2007CB714105), the National Natural Science Foundation of China (Grant No. 11174315) and the National Science and Technology Major Project of China (Grant No. 2011ZX05032-003).
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