Editorial Corner

Review of Underwater Shock Waves and Their Interactions with Bubbles

Kazuyoshi Takayama*
Tohoku University, Sendai, Japan

Sutthisak Phongthaanapanich
Department of Mechanical Engineering Technology, College of Industrial Technology, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

* Corresponding author. E-mail: k.takayama@mac.com DOI: 10.14416/j.asep.2020.01.005

Shock waves are pressure waves representing gas dynamic non-linearity occur in nature and artificial events such as high speed flights [1]. To supplement multifaceted shock wave phenomena, quantitative visualizations are presented [2]. Shock speeds are defined, in general, by the ratios of the shock speeds to the sound speeds of the media under study as Mach numbers Ms. In gases, the shock waves are created associated with supersonic flows, Ms > 1.0, while, in liquids, a shock wave is generated by the energy deposition at a spot. It was spherical and supersonic only at very early stages. It soon attenuated to the sonic speed of Ms ≈ 1.0.

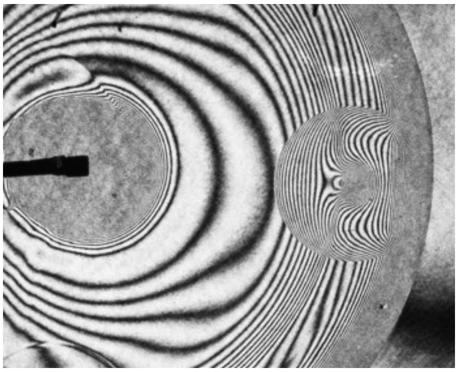
Glass and Heuckroth [3] abruptly ruptured a pressurized glass sphere having a very thin wall and generated a weak underwater shock wave in a controlled manner. Bowden and Chaudhri [4] attached a minute air bubble on a silver single crystal and a lead azide single crystal and observed their sympathetic explosions by impinging the air bubble with an underwater shock wave. These experiments [3], [4] were pioneering works that initiated the underwater shock wave research on a laboratory scale. Unlike shock waves in gases, underwater shock waves are always spherical and behave like spherical linear waves. In liquids, sudden pressure decreases incept vapor bubbles interacting with the underwater shock waves. Therefore, underwater shock wave research is coupled with the bubble dynamics.

Chaussey *et al*. [5] applied, for the first time during the history of shock wave research, underwater shock wave focusing to non-invasive disintegration of kidney stones in human bodies and named this lithotripter as extracorporeal shock wave lithotripsy (ESWL). This is a peaceful application of shock wave dynamics to human welfare and is widening the scope of shock wave applications.

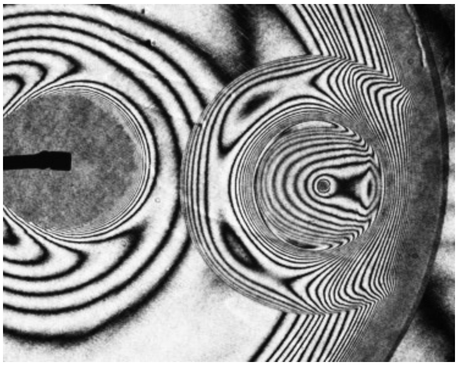
The first author was interested in coupling the shock dynamics and the bubble dynamics. He succeeded to generate underwater shock waves on a small scale. Lead azide pellets and silver azide pellets weighing from 3 μg to 100 mg in liquids were precisely detonated by the irradiation of pulse laser beams [2]. A quantitative visualization was conducted using double exposure holographic interferometry. Figure 1 shows the evolution of a 1.5 mm diameter air bubble in 10 cSt silicone oil interacting with spherical shock waves. The bubble was positioned at the 20 mm stand-off distance from the center of silver azide pellet weighing 10 mg attached at 0.6 mm diameter optical fiber through which a few mJ and 7 ns pulse duration Nd:YAG laser beam was transmitted. Dark fringes indicate density variation integrated through the light path, from which the density distribution was readily estimated. The shock wave hit the air bubble from the left hand side. The bubble spontaneously contracted and created a spherical reflected expansion wave in Figure 1(a). The secondary shock wave was created when the bubble became its minimum volume in Figure 1(b). The contracting bubble started to expand

Please cite this article as: K. Takayama and S. Phongthaanapanich, "Review of underwater shock waves and their interactions with bubbles," *Applied Science and Engineering Progress*, vol. 13, no. 1, pp. 1–2, Jan.–Mar. 2020.

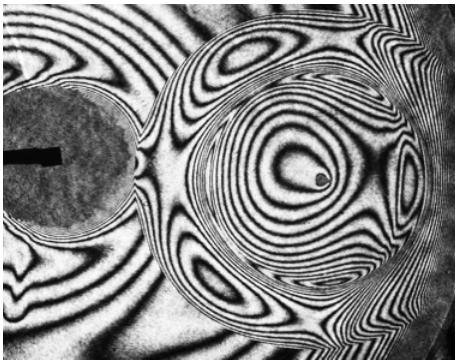
Applied Science and Engineering Progress, Vol. 13, No. 1, pp. 1–2, 2020



(a)



(b)



(c)

Figure 1: Interaction of a 1.5 mm diameter air bubble in 10 cSt silicone oil with shock waves created by the explosion of 10 mg silver azide at the 20 mm stand-off distance. The shock overpressure was about 25 MPa. [2]

forming a jet which moved at relatively high speed toward the direction of the shock wave propagation in Figure 1(c).

We look forward to quantitative numerical simulation of shock wave/bubble. If such efforts are achieved it would decisively contribute to the future applications of underwater shock waves to medicine and biology.

References

[1] I. I. Glass, *Shock Wave and a Man*. Canada: Toronto University Press, 1975.

[2] K. Takayama, *Visualization of Shock Wave Phenomena*. Heidelberg, Germany: Springer-Verlag, 2019.

[3] I. I. Glass and L. E. Heuckroth, “Low-energy spherical underwater explosions,” *Physics of Fluids*, vol. 11, pp. 2095–2107, 1968.

[4] F. P. Bowden and M. M. Chaudhri, “Initiation of explosion in AgN_3 and β-PbN_6 single crystals by a collapsing bubble,” *Nature*, vol. 220, pp. 690–694, 1968.

[5] C. Chaussey, J. E. Schmidt, D. Joachim, G. Ferbes, W. Brundel, B. Forsmann, and W. Hepp, *Extracorporeal Shock Wave Lithotripsy*. Muenchen, Germany: Karger, 1986.

Emeritus Professor Kazuyoshi Takayama

Professor Dr. Sutthisak Phongthaanapanich
Editor