

PHENOMENOLOGY OF SHOCK WAVE PROPAGATION IN WATER WITH BUBBLES OF REACTIVE GAS

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Abstract: Interaction of a shock wave (SW) with a reactive bubbly medium (BM) — pure water (without thickening additives) saturated with bubbles of stoichiometric acetylene–oxygen mixture has been studied experimentally. In experiments, the initial volume fraction of gas in water was varied from 0.5% to 10% with gas bubbles 1.5–4 mm in diameter and the propagation velocity of shock waves in the bubbly medium ranged from 260 to 580 m/s. It is shown that in water with reactive gas bubbles, a detonation-like mode of reaction front propagation can be realized: a pressure wave followed by the luminosity front caused by bubble ignition is registered in the experiments. The specific features of the behavior of bubbles in such waves have been studied. The results obtained can be used to develop a pulse-detonation hydrojet engine with thrust created by the momentum transfer from SW to BM.

Keywords: chemically active bubbly medium; shock wave; hydroshock tube; explosion; detonation; acetylene–oxygen mixture; experiment

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References

1. Frolov, S. M., F. S. Frolov, V. S. Aksenov, and K. A. Avdeev. 2013. Vodometnyy impul'snyy detonatsionnyy dvigatel' (varianty) i sposob sozdaniya gidroreaktivnoy tyagi [Hydrojet pulsed detonation engine (variants) and the method of hydrothrust development]. Patent application PCT/RU2013/001148 of 23.12.2013. Available at: <http://www.idgcenter.ru/patentPCT-RU2013-001148.htm> (accessed November 5, 2016).
2. Avdeev, K. A., V. S. Aksenov, A. A. Borisov, R. R. Tikhvatullina, S. M. Frolov, and F. S. Frolov. 2015. Chislennoe modelirovanie peredachi impul'sa ot udarnoy volny k puzyr'kovoy srede [Numerical simulation of momentum transfer from a shock wave to bubbly medium]. *Goren. Vzryv (Mosk.) — Combustion and Explosion* 8(2):57–67.

3. Avdeev, K. A., V. S. Aksenov, A. A. Borisov, R. R. Tukhvatullina, S. M. Frolov, and F. S. Frolov. 2015. Numerical simulation of momentum transfer from a shock wave to bubbly medium. *Russ. J. Phys. Chem. B* 9(3):363–374.
4. Avdeev, K. A., V. S. Aksenov, A. A. Borisov, S. M. Frolov, F. S. Frolov, and I. O. Shamshin. 2015. Momentum transfer from a shock wave to a bubbly liquid. *Russ. J. Phys. Chem. B* 9(6):895–900.
5. Hasegawa T., and T. Fujiwara. 1982. Detonation oxyhydrogen bubbled liquids. *19th Symposium (International) on Combustion Proceedings*. Hafia.
6. Sychev, A. I. 1985. Shock-wave ignition of liquid – gas bubble system. *Combust. Explo. Shock Waves* 21(2):250–254.
7. Sychev, A. I. 1985. Detonation waves in a liquid – gas bubble system]. *Combust. Explo. Shock Waves* 21(3):365–372.
8. Sychev, A. I., and A. V. Pinaev. 1986. Self-sustaining detonation in liquids with bubbles of explosive gas. *J. Appl. Mech. Tech. Phys.* 27(1):119–123.
9. Pinaev, A. V., and A. I. Sychev. 1987. Effects of gas and liquid properties on detonation-wave parameters in liquid–bubble systems]. *Combust. Explo. Shock Waves* 23(6):735–742.
10. Tereza, A. M., V. G. Slutskii, and E. S. Severin. 2009. Ignition of acetylene–oxygen mixtures behind shock waves. *Russ. J. Phys. Chem. B* 3(1):99–108.
11. Mitropetros, K., and P. A. Fomin. 2014. Shock-induced ignition of fuel-lean gas bubbles in organic liquids. *Transient combustion and detonation phenomena: Fundamentals and applications*. Eds. G. D. Roy and S. M. Frolov. Moscow: TORUS PRESS. 101–112.

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