Recent advances in underwater blast mitigation

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Abstract: *Underwater unexploded ordnances are subjected to aging effects in aggressive medium. They may leak and disperse toxic elements like heavy metals and carcinogenic substances. The best way of removing them would be to explode them on place. However, this method generates a huge noise pollution. This severe pollution comes in addition to an already existing ambient pollution introduced by human activities (from military activities, maritime operation or seismic prospection). The attenuation of the noise pollution into seas and oceans then becomes a concern. Indeed, these waves cause harmful effects on the marine ecosystem, particularly on Cetaceans. When these waves come from underwater explosions, they can provoke damages on marine structures. Harmful effects of these waves are pointed out by scientific workgroups and stir people's conscience. Our work aims at designing, from the study of the bubble/wave interaction, a device able to attenuate the underwater shock wave in order to protect persons, structures and the ecosystem (fig. 1).*

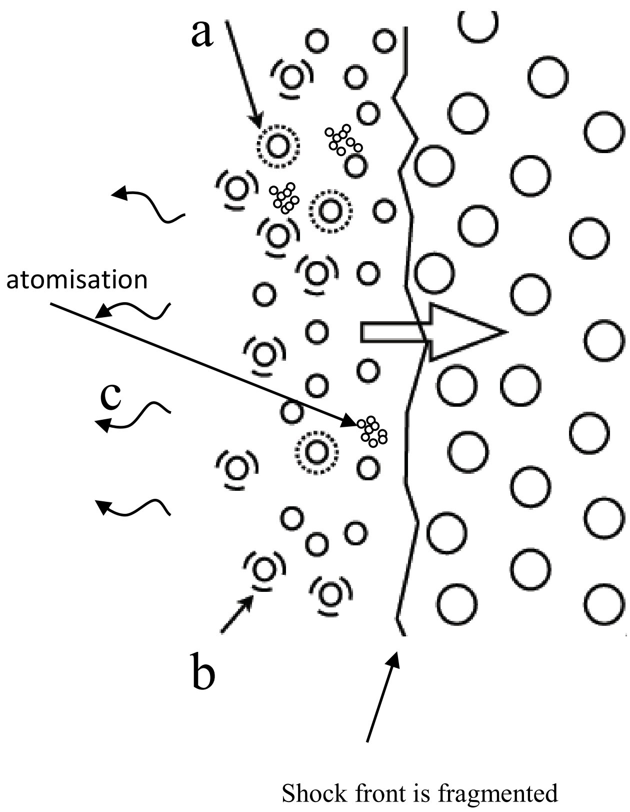

Figure 1: Principle of the underwater shock wave mitigation by bubble curtain. a) Adiabatic compression of bubbles that increase gas temperature and heat exchanges, b) inertial effects that dissipate energy due to viscosity, c) reflected energy by acoustic impedance mismatch, d) loss of energy by bubble atomisation.

Key words: *Bubble curtain – Bubbly Media – Underwater explosion – UXO – Shock wave mitigation – Optical probes – Numerical simulation*

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This concept finds an application to harbor safety and during mine clearance operations as well as during off shore windfarms installation. A physical model, based on a global porosity approach, able to describe the shock/bubble interaction has been developed. It involves a technique of scale transition and the definition of a representative volume element. This model has been implemented in the finite element code. It has been validated on experiments taken from the literature (Kameda et al, 1998). A parametric study shows the influence of the air volume fraction, the bubble size, pulse duration and magnitude, and of the barrier thickness on the blast attenuation.

In the present study, the transmission of a shock wave propagating through a bubble curtain is investigated experimentally on a water filled tank. A microporous pipe, connected to a compressed air supply system and a flowmeter, is placed on the floor in the tank. A dual-tip fiber optical probe is used to measure the gas fraction distribution, bubble rising velocity and bubble size distribution in the curtain. A calibrated shock wave is generated by plate impact, upstream of the bubble curtain, and recorded downstream with a hydrophone (fig. 2).

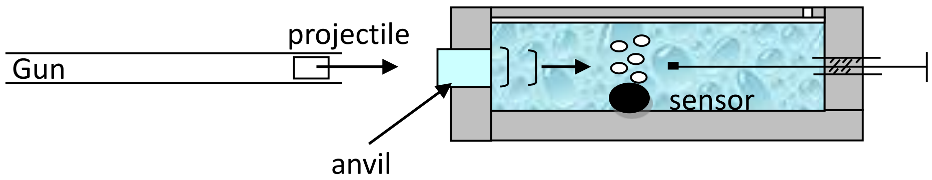

Figure 2: Experimental setup for parametric study of underwater shock wave mitigation by bubble curtain technique.

The mitigation of the pressure peak by the bubbly medium is evidenced by recorded pressure signals with and without bubble curtain. Experimental gas fraction profiles and bubble size distributions, measured in the bubble curtains, are finally used as input parameters in the numerical model developed by Grandjean et al. (2011). This numerical model enables prediction of shock wave mitigation and allows calibrating a suitable bubble curtain. It has been compared with pressure signal recorded during experiments.