2P6-3

Proceedings of Symposium on Ultrasonic Electronics, Vol. 35 (2014) pp. 341-342
3-5 December, 2014

Measurements of the depth-dependent characteristics of light bulb implosion

Sungho Cho[1†], Donhyug Kang[1], Suntaek Oh[1], Seom-Kyu Jung[1], and Jee Woong Choi[2]
([1]Korea Institute of Ocean Science and Technology; [2]Dept. of Marine Science and Convergence Technology Hanyang Univ.)

1. Introduction

The acoustic signatures of imploding light bulbs have been suggested as an alternative sound source due to their strong broadband energy below 1 kHz and short pulse length [1]-[3]. Recently, several studies have presented measurements of the geoacoustic properties and long-range sound propagation in shallow water using light bulbs [4]-[7]. The implosion of the bulb generates bubbles in the water; the expansion and contraction of the bubbles create subsequent bubble pulses [1], [5]. Measurements of the acoustic properties of underwater implosions have been conducted in recent experiments with incandescent bulbs at variable depths. In this study, 105 shots were deployed in a shallow depth (< 100 m) to determine the depth-dependent characteristics of bulb implosions in water, including the peak source level and primary resonant frequency with depth.

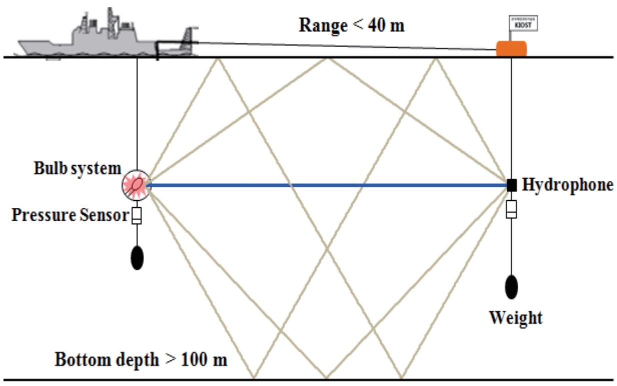

Fig. 1 Experimental geometry for measuring the characteristics of an imploding light bulb.

2. Field Measurements

In a series of experiments to evaluate the acoustic transmission environment in shallow water, we applied a mechanical bulb breaker, which was designed for use at a water depth of < 100 m. Representative one of the depth-dependent experiments for the imploding light bulb were carried out in the Korea Strait, where the water depth at the measurement position was more than 100 m (Fig. 1). Incandescent bulbs of 500 W were used in the experiments and imploded in depth ranged from 10-80 m. The acoustic signal was received by a calibrated hydrophone being closely deployed within a range of 40 m. The horizontal distance was measured using a laser range finder. To avoid overlap between the direct-path signal and surface- or bottom-reflected signals, we controlled the receiver depth according to the implosion depth.

Figure 2 shows an example of the direct-path signal received at an implosion depth of 40 m, which was normalized by the maximum energy of the first positive peak. The direct-path signal represents the typical shape of bubble oscillations in water. The data show that the oscillation energy disappeared within ~30 ms after the bulb implosion.

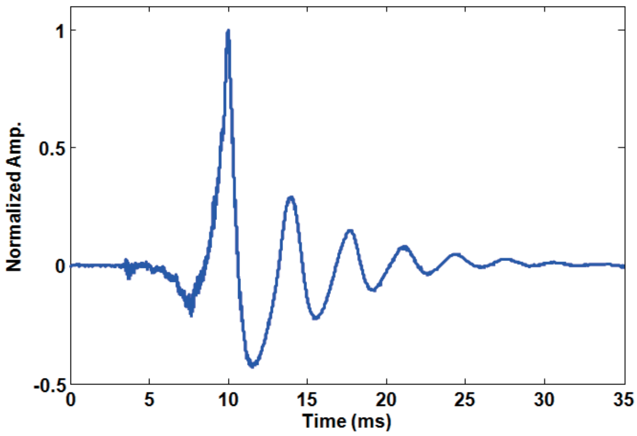

Fig. 2 An example of the received waveform imploding at a depth of 40 m.

3. Results

Figure 3 shows the estimated P_{SL} (peak source level) as a function of depth; the P_{SL} increased from 195 dB re 1 μPa at a 10 m depth to 230 dB re 1 μPa at an 80 m depth. The P_{SL} of the imploding light bulbs can be estimated by

---

Correspondence to shcho@kiost.ac

$$P_{SL} = 20\log_{10}(P_R) + 20\log_{10}(R),\ dB\ re\ 1\mu Pa @ 1m$$

where P_R is the peak pressure for range R (m), the direct-path range between the source and receiver. Spherical spreading is assumed; the other paths (the surface-reflected and bottom-reflected signal paths) did not overlap. The fitted equation (solid line corresponding to P_{SL}) for the 500 W light bulbs is as follows:

$$P_{SL} = 151.5 + 39.6\log_{10} H, (r^2 = 0.93)$$

where H is the water depth (m) and r^2 is the determinant coefficient.

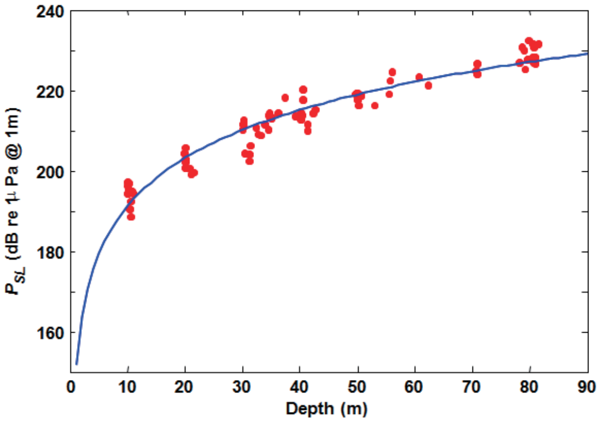

Fig. 3 Estimated P_{SL} (solid circle: measured value) at depths ranging from 10-80 m. Regression curves are plotted for the measured values (solid line: $151.5 + 39.6\log_{10}H$).

Figure 4 presents the primary resonant frequency as a function of depth, in which the solid circles represent the measured value of 83 bulbs imploded at depths ranging from 10-80 m. As the implosion depth increased, the primary resonant frequency increased almost linearly as a result. This outcome can easily be explained using Minnaert's [8] resonant frequency expression, in which the resonant frequency varies as the square root of the ambient pressure corresponding to the water depth. Heard et al. [1] and Ghiotto and Penrose [2] also derived an expression for the relationship between the primary resonant frequency and implosion depth, using both Minnaert's expression and Boyle's Law. According to theory, the resonant frequency is defined as

$$F_0 = A(g(H+10))^{5/6}$$

where A is a proportionality constant and g is gravitational acceleration (9.8 ms^{-2}). The solid line in Fig. 4 represents the relationship for primary resonance using a 500 W light bulb. The value of A is 1.44 for the 500 W bulbs. As the implosion depth increased, the primary resonant frequency also increased.

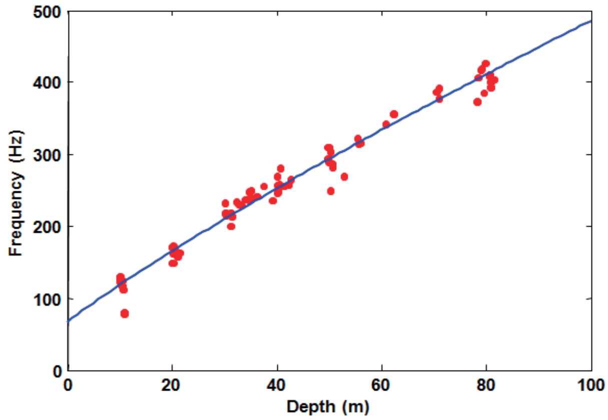

Fig. 4 Primary resonant frequency as a function of implosion depth.

Acknowledgment

This study was supported by the "Study on the relationships between the geological environment and acoustic propagation in shallow water" grant (PE98978) promoted by the Korea Institute of Ocean Science and Technology (KIOST).

References

1. G. J. Heard, M. McDonald, N. R. Chapman, and L. Jashke: Proc. IEEE Oceans '97, 1997, p. 755
2. A. Ghiotto and J. D. Penrose: Australian Acoustical Society Conf., 2000, p. 223.
3. J. P. Hoffman, J. D. Penrose, and D. R. McMahon: Australian Acoustical Society Conf., 2000, p. 173.
4. N. R. Chapman, L. Jaschke, M. A. McDonald, H. Schmidt, and M. Johnson: Proc. IEEE Oceans '97, 1997, p. 763.
5. C. W. Holland, R. Hollett, and L. Troiano: J. Acoust. Soc. Am., **108** (2000) 997.
6. S. A. Stotts, D. P. Knobles, J. A. Keller, J. N. Piper, and L. A. Thompson: J. Acoust. Soc. Am. **120** (2006) 3607.
7. J. Bonnel and N. R. Chapman: J. Acoust. Soc. Am. **130** (2011) EL101.
8. M. Minnaert: Phil. Mag. **16** (1933) 235.