Risk mitigation for sea mammals — The use of air bubbles against shock waves

E. Schmidtke, B. Nützel and S. Ludwig

WTD 71 — Research Department for Underwater Acoustics and Marine Geophysics, Berliner Strasse 115, D–24340 Eckernförde, Germany, Email: EdgarSchmidtke@bwb.org

Introduction

Many thousand tons of ammunition were disposed in the baltic sea in the years after 1945 by sinking. Nowadays these explosives (e.g. torpedoes and mines) pose a risk, especially near to the shore. Such huge amounts of explosives cannot be salvaged but have to be blown up. A typical view of a detonating 300-kg–mine in a depth of 20 m is shown in figure 1. When some hundreds of kilogramms detonate under water shock waves are emitted, which can be dangerous for humans and sea mammals, even over long distances. The NATO Undersea Research Center (NURC) proposes a minimum safety distance of 2000 m for sea mammals when using explosives [1].

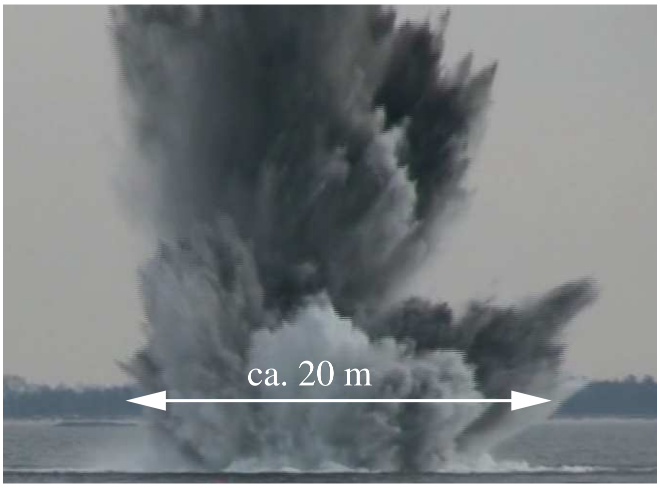

Figure 1: Detonation of a 300–kg–mine in a depth of 20 m.

In a first series of experiments small amounts of different explosives were blown up in a shallow basin. These experiments have been already presented [2]. To damp the resulting shock waves two kinds of experiments were realised. In the second trial shock waves were measured in the Baltic Sea close to the shore, with and without an air bubble curtain. For these experiments relatively small charges of 1 kg were used.

Frequencies up to 100 kHz have to be taken into account because these frequencies are used by the harbor porpoises which are to be protected.

The third trial was to measure the shock waves of mines (300 kg) with and without an air bubble curtain.

Small charges in the Baltic

Experiments were conducted in the Baltic Sea in april and june 2008 in order to determine the appropriate size of a bubble curtain[3]. On the seafloor in a depth of approximately 13 m three pipes were positioned as concentric semicircles with diameters of 7.5 m, 9.5 m and 11.5 m. The air flow through these pipes was 20 m^3/min in total in order to establish the bubble curtain. The distance between the charge of 1 kg and the hydrophones was 115 m.

Since only the relative attenuation was of interest no absolute pressure values were calculated from the collected data. The frequency dependent sound levels are shown in figure 2. The reference (black line) was calculated

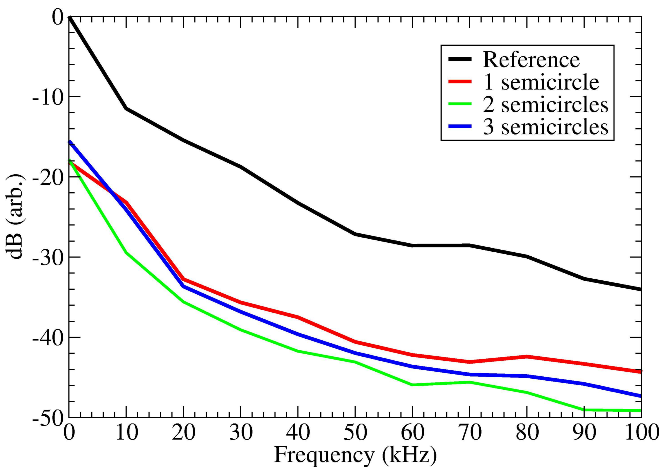

Figure 2: Relative sound levels of the detonation of a 1 kg charge with different bubble curtains.

from a sequence of five charges (1 kg each) without a bubble curtain. After that five charges were blown up in each of the following series. During the first series all three semicircles were used for the bubble curtain (blue), in the second sequence the innermost semicircle was not used (green) and in the third sequence only the outer semicircle was air filled (red). In all cases attenuation of more than 10 dB up to 16 dB was achieved. A further result of this experiment is that the number of bubble curtains is not of crucial importance but the total amount of of air flow. For the next experiments only a single circle was planned.

Mines

For the safety of personnel and equipment a prediction of the absolute pressure level was neccessary, because the charges that should be blown up were standard mines (EMC, Einheitsmine Typ C) with 300 kg of so called "Schiesswolle 39", an explosive that consists of about 45% TNT. For the prediction of the maximum $p_{\max}$ of the pressure pulse emitted by an explosion the formula from ref. [4] was used.

$$p_{\max} = 52,4 \times \left(m^{1/3}/r\right)^{1.13} \tag{1}$$

where $p_{\max}$ is pressure in MPa, m is mass in kg and r is the distance in m. With the full mass of 300 kg and the safety distance of 800 m a pressure pulse of $p_{\max} = 0.25$ MPa was expected. The mine was positioned on the sea floor in a depth of 20 m, the hydrophone in a depth of 12 m. The circle for the air bubble curtain had a diameter of 22 m and the air flow was 40 m^3/min. The time signal of an undamped explosion is shown in figure 3. The small signal that arrives before

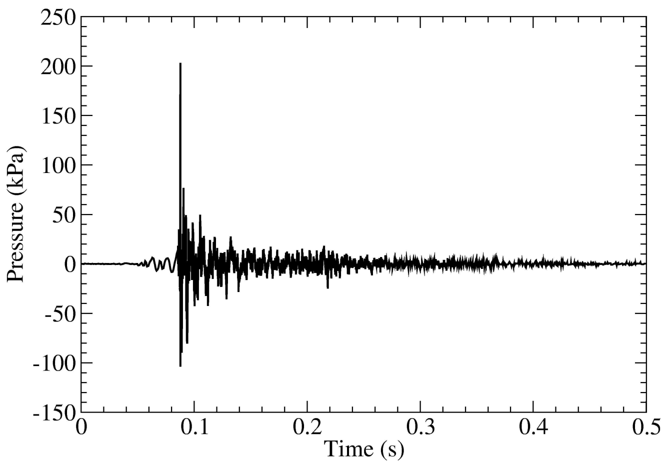

Figure 3: Time signal of a detonation of a mine with a charge of 300 kg in a distance of 800 m.

the pressure pulse results from the detonation signal travelling through the sea floor. The prediction for the absolute value of the pressure pulse using eq. (1) is in good agreement with the experimental value. The shape of the pulse is different from the ideal form due to the acoustic shallow water conditions.

The third octave spectrum levels for an explosion without a bubble curtain and two explosions with a bubble curtain are shown in figure 4. An integration time of one second is used.

Below 1 kHz there seems to be no attenuation at all, above 1 kHz there is some attenuation of about 2 dB which varies to values up to 8 dB in one case at 100 kHz. This is much less attenuation than the values of 16 dB when using small charges.

A peak pressure resulting from a very fast expanding gas sphere (with a speed greater than the speed of sound) is a high frequency phenomenon and is attenuated by the bubble curtain by approyimately 4 dB (not shown here).

Sound damping by bubbles in water is a well known effect for compression waves. Pressure changes can also result from the motion of the water that is displaced by the hot

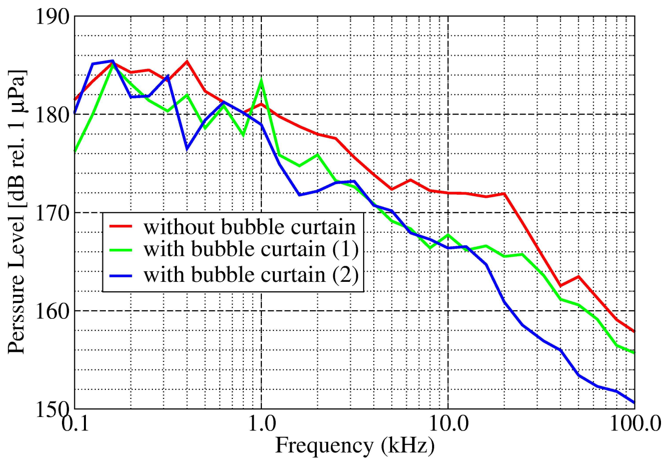

Figure 4: Third octave spektra of measured data with and without an air bubble curtain. Integration time is 1 sec.

expanding gas globe. Because of larger time scales this is an effect of lower frequencies. This motion cannot be suppressed by the bubble curtain. Thus, damping effects below 1 kHz are neglectable. It can be expected that this effect decreases with larger distances between the bubble curtain and the point of explosion.

Summary

The shock waves emerged from explosions cause a risk for marine mammals even over long distances. The effect of an air bubble curtain for the attenuation of shock waves was examined. For small charges attenuations of up to 16 dB could be achieved. Larger charges in sea mines contain ingredients that produce much more gas than it is expected for TNT, so the flow of displaced water produces a significant part of the pressure that cannot be damped by the air bubbles. The achievable attenuation is reduced to approximately 4 dB for the peak pressure and for all frequencies. A larger circle for the air bubble curtain is suggested to suppress the effect of flow of displaced water.

References

[1] Staff Instruction 77, NATO URC Human Diver And Marine Mammal Risk Mitigation Rules (2004), La Spezia, Italy

[2] E. Schmidtke and S. Ludwig
Sprengungen – Abschätzung einer Gefährdung für Meeressäuger,
Fortschritte der Akustik (2008), 887 – 888

[3] B. Nützel
Investigations to protect harbour porpoises from shock waves,
FWG Technical Report TB 2008–7, Kiel, Germany, 2008

[4] N. R. Chapman,
Measurement of the waveform parameter of shallow explosive charges,
J. Acoust. Soc. Am. **78** (2) (1985), 672 – 681