On the Height of Burst Gain For Small Arms

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Introduction

The physics of explosions in air close to a surface describe a phenomenon that is called the Height of Burst Gain (HOB gain). This effect considers the increase of the pressure peak and the overpressure impulse due to the so-called Mach-reflection of shock waves from explosives. The HOB gain basically depends on the charge size and the height of the burst above local ground and can be reliably scaled by the scaling laws of explosions.

Fig. 1 indicates the HOB gain versus HOB calculated for a charge of 100 g TNT using the HOB gain formula in ISO Technical Paper 13474, /1/. (Throughout this paper, all results are given for 100 g charges if possible.) ISO 13474 gives guidance to evaluate acoustical prediction levels of blasts including demolition and gun firing for environmental noise assessment. The correction yields significant decibel numbers and should be essential to any pressure prediction. Hence, the height of the source ought to be a very important feature of any source model for blast sources. As a consequence, source height should be recorded for any noise prediction and assessment. This would add up to operating expense at every civil and military shooting facility.

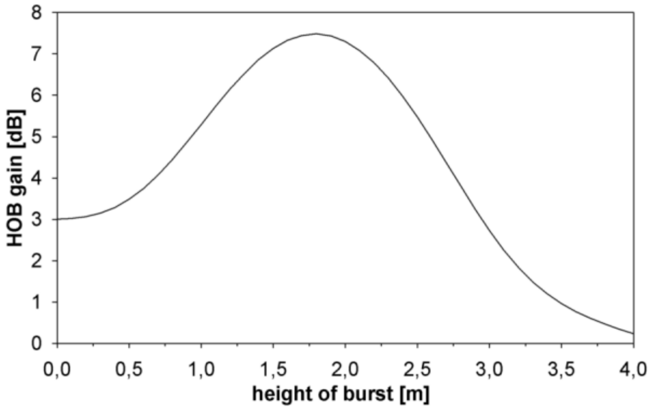

Fig. 1 HOB Gain for a 100 g TNT charge according to /1/

In contrast, measured blast levels at typical source-receiver distances around outdoor firing ranges do not give any evidence that the height of burst plays such an important role. This holds for demolitions and muzzle blasts from both small arms and large weapons. This paper reports on a dedicated test to show how the HOB gain influences acoustical receiver levels at larger distances. This paper only discusses the HOB gain with respect to sound propagation for noise control purposes. A more detailed description of the Height of Burst gain can be found elsewhere, for example in /2/.

Height of Burst laboratory test data

In air blast phenomenology, blast waves are characterized in terms of the peak overpressure, duration of the overpressure phase T+, the overpressure impulse I+ and a quasi-exponential factor. These data suffice to reconstruct the overpressure signature p(t) during overpressure phase with reasonable accuracy and thus facilitate the calculation of the integral P_+:

$$P_+ = \int_{T_+} p^2(t)\, dt \qquad \text{Eq. 1}$$

In eq. 1, let denote p the pressure, let denote t the time and let denote T_+ the time period of the first positive pressure phase of the burst. P_+ is equivalent to the sound exposure if the contribution of the remaining signal after that first positive phase is negligible. For the blast signals under consideration this approximation is rather good.

Fig. 2 indicates test data of the HOB gain in terms of P_+ versus HOB for an 100 g PETN charge at a nominal measuring distance of 7,4 m at the ground. The data are reconstructed from basic test data of the Ernst-Mach-Institute of a spherical 0,5 g PETN charge above a rigid, smooth, flat plate, /3/. The original data in fig. 2 are shifted by +8,7 dB in order to compare to the acoustical test data following. The measured HOB gain does not follow the prediction in fig. 1. However, the gain can reach also about 5 dB in the HOB range from 0 m to 3 m.

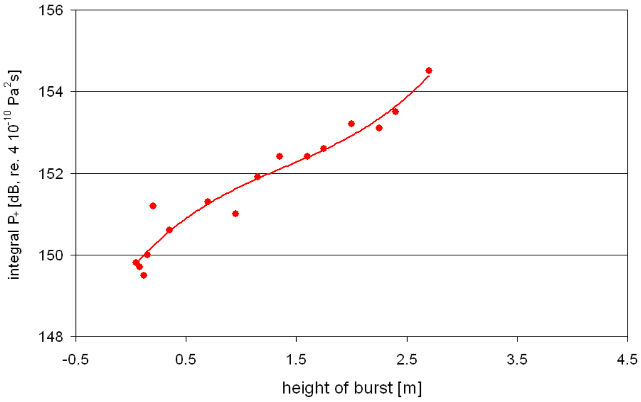

Fig. 2 HOB gain for a 100 g PETN charge according to /3/, decibel numbers rescaled for 1 m reference distance

Height of Burst outdoor test data

Test layout

In order to investigate the HOB gain in a typical environment of a firing range, measuring microphones were set up at distances of 8 m (east only), 50 m, 100 m, 200 m and 400 m to the east and to the west of a demolition site at two heights, at the ground and at 5 m. The opposite directions took into account the influence of the wind on the acoustical levels. At the demolition site series of five 100 g TNT charges were fired at heights above ground of 0 m, 1 m, 1,5 m, 1,75 m, 2,5 m, 3 m and 4 m. In the context of this paper only the target-oriented analysis is discussed, see reference /4/ for more details.

Data analysis

The basic idea of the analysis is to use a procedure according to ISO 17201, part 1, /5/. This procedure evaluates the source strength of a muzzle blast in terms of the acoustical source energy and the directivity pattern from a measured one-third-octave spectrum. Due to the small time gap between the arrival of the direct signal from the source and the ground reflection for this test layout, the separation of both signals is done in the frequency domain. Such a separation procedure is applicable if the source signal shape is known in all directions. For a blast signal from an explosion in air, which is an omni-directional source, the Weber model is sufficiently reliable, see ISO 17201 part 2, /5/. The model only needs one parameter, the Weber radius, to describe the whole signal including shape, spectrum and acoustical energy. In conjunction with a propagation model that considers ground reflections of spherical waves at complex impedance grounds and that includes phase shifts due to wind gradients, each measured signal predicts the source strength in terms of a Weber radius of that source that must have been present to produce the receiver signal.

Results

The measured spectra within a series are highly repetitive. Therefore, only the first shot of each series was included in the complex analysis to find the appropriate Weber radius. Each point in the following figures represents one of such calculations.

Fig. 3 indicates the resulting source strength in terms of the Weber radius versus the height of burst. The sound exposure level may be more convenient to discuss the results. Therefore, fig. 4 shows the respective un-weighted (LSEL) and A-weighted (ASEL) sound exposure level at 1 m reference distance as a measure of the source strength according to the Weber model. There is no indication for the measuring distance because the propagation model corrects for all propagation effects.

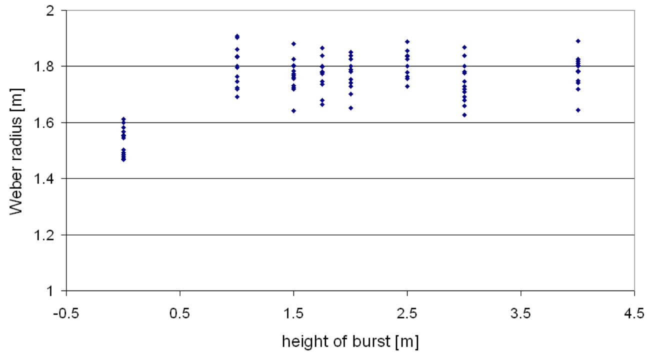

Fig. 3 Weber radius of 100 g TNT charges versus HOB

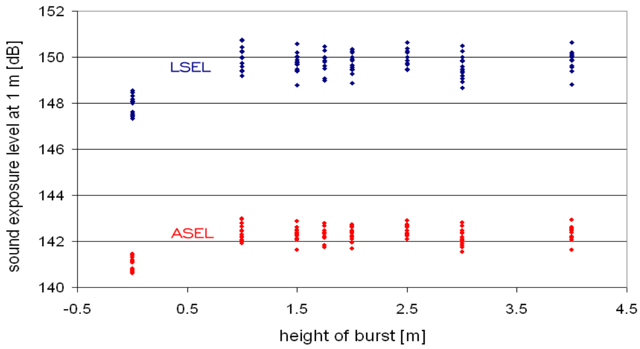

Fig. 4 Sound exposure levels of 100 g TNT charges at 1 m reference distance versus HOB

Neglecting the explosions at 0 m height, i.e. directly at the ground, the points scatter around a Weber radius of about 1,75 m or around a LSEL of 149,5 dB (ASEL ≈ 142,5 dB). The scatter range is rather narrow compared to typical outdoor measurement results due to the sophisticated procedure to calculate the Weber radius from measured one-third-octave spectra. Fig. 3 and fig. 4 conclude that there is no tendency that supports a HOB gain and there is not any dependency of the observed acoustical source strength on the HOB.

The explosions at the ground clearly indicate lower levels and a smaller Weber radius, respectively. One explanation may be that such explosions spend some energy to move the ground or to excite local vibrations. If this holds, this insight may be important for the noise prediction of explosions at impact areas on military training facilities and comparable situations. It is also important for the estimation procedure for the source strength given in ISO 17201, part 2.

Discussion

The comparison between fig 1, fig. 2 and fig. 4 yields a clear conflict. The re-scaled laboratory test data do not support the predictions of the ISO 13474 formula, though both results suggest that the HOB gain is a strong correction. The outdoor test data in fig. 4 do not show any HOB gain but the absolute decibel numbers are in excellent agreement with the laboratory test data at 1 m height considering that PETN provides round about 20% higher energy density than TNT.

There is evidence that the ground at the demolition site (roughness, elasticity, porosity) causes the conflict of the laboratory data with the outdoor measurement. Fig. 5 indicates the HOB gain by depicting the lines of constant peak pressure, /6/. The HOB gain here is the difference of the lines to a circle around the origin. The dashed lines hold for a smooth rigid surface, the solid lines hold for a rough and porous surface. The influence of the ground properties is significant in particular at those locations in the pressure field where the gain is rather high for smooth surfaces. Fig. 5 suggests, that the HOB gain is clearly reduced above a rough and porous ground.

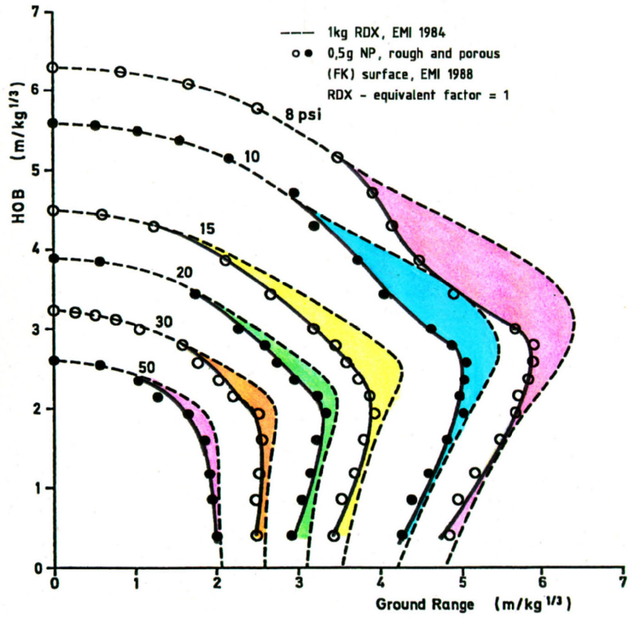

Fig. 5 Comparison of HOB-curves above a smooth surface and above a rough and porous surface, /6/

Conclusion

Prediction and assessment of shooting noise applies to firing outdoors. Firing ranges, demolition areas and other shooting facilities outdoors normally have porous, rough and elastic grounds like grass or sand, for example. In these cases, the HOB gain is not a significant effect and should be neglected. The HOB gain formula according to ISO 13474 should not be applied.

In cases where weapons are fired over a concrete or metal plate, a significant role of the HOB gain cannot be denied. As a consequence, it is recommended to avoid for instance tank firing on a concrete gun base. Source data of small arms mounted on a tank may also be different from source data acquired over grass ground.

Source measurements of weapons according to ISO 17201, part 1 should be performed over rough and porous ground to minimize the influence of the HOB gain in order to get representative data for shooting on real firing ranges.

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