Gunshot Power Absorption Field Measurement

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1. INTRODUCTION

Risk assessment and evaluation of impulsive vibration is an unfinished task with many unknown aspects. One of the questions that arises in the literature is whether the absorbed power is a suitable indicator of exposure. In order to contribute to the acquisition of a wider data collection on the topic, a measurement chain dedicated to impulsive vibration has been designed and tested for acquiring absorbed power in the field. The apparatus has been field tested on a firing range, while acquiring data on gunshots. The goals of the testing were to establish the reliability of the measurements and compare the acquired data with other available absorbed power data. The main difficulty is to capture the extreme dynamics of the gunshot and the subsequent difficulty of absorbed power post processing.

The selection of the accelerometer is crucial: it needs a fast response and wide dynamic range to follow the rapid rise in acceleration. Early measurements showed high acceleration on a time basis of some tenths of a second. This is very relevant because the acceleration will be integrated to give velocity for the computation of absorbed power. The acquisition of force is performed with a load cell at the same point of accelerometer. Absorbed power is evaluated in post processing. The high frequencies elicited by the shot require an adaptor that is non resonant even at those frequencies and a rigid attachment to the butt.

2. METHODS

The aim of present work is to measure acceleration and force on the butt of a gun (Beretta 92 FSB) with a triaxial accelerometer (PCB SEN026, USA; sensitivity 10mV/g) and a load cell (FGP Sensor & Instruments, FGPXFL212R, France) both mounted in an adaptor. That made the instrumentation portable. Numerical integration of acceleration gives velocity and its product with force gives absorbed power. The experimental setup has been shown in detail in another communication at this conference. The gun is the standard ordnance side weapon of the NATO Treaty. The bore is 9 mm, the caliber is 9 x 19 NATO; the magazine holds 15 rounds, and the unloaded weight is 975 g. Measurements have been done with the magazine always fully loaded. The distance between target and firing position was 10 m (training range). The firing position was with the arm fully extended. Subjects were asked to fire single shots, and three shots sequences. The force level was not shown to the subject, but it was recorded. Both signals (acceleration and force) were acquired by an OROS OR 38. The sampling frequency was 5.12 kHz. Analysis was done with MatLab software. Signals have been processed in a time windows of three seconds. We evaluated VPA on single and three shots. In addition we computed the crest factor and the root mean square (r.m.s) value of the weighted acceleration following the UNI EN ISO 5349 [1].

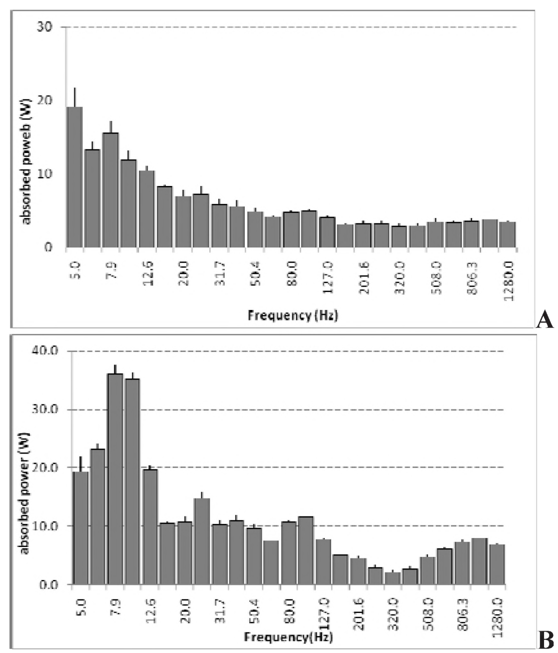

Figure 1. A: Frequency absorbed power for single shot; B: Frequency absorbed power for three shots.

3. RESULTS

Figure 1A shows a 1/3 octave band analysis for single shots, and Figure 1B for three shots. Figure 2 shows the time profile of the acceleration and its frequency-weighted value. Evaluation of the crest factor requires the signals to be weighted; weighting curve W_h has been used, [1] and leads to an attenuation of the extreme acceleration magnitudes. Finally, different levels of absorbed power for single and multiple shots are shown in Figure 3, from which was calculated the energy absorption. Power and energy absorbed, acceleration and crest factor values are listed in Table 1, either for single and multiple shots. The higher standard deviation of the crest factor is probably due to the variability of different subjects holding the gun.

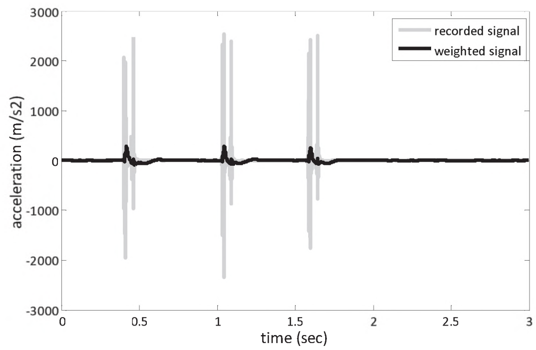

Figure 2. Acceleration signal recorded and its shape after applying weighting curve W_h.

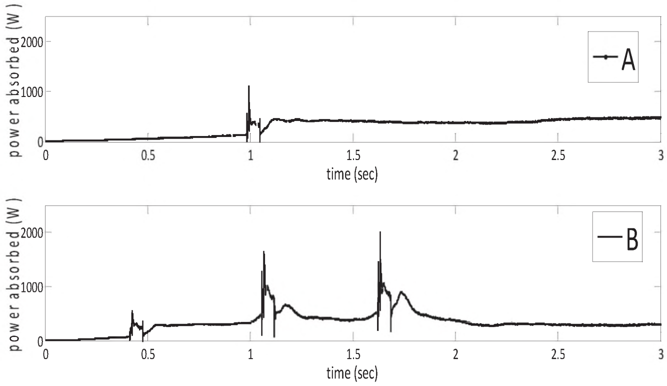

Figure 3. Power absorption for: A - single and, B - triple shots.

Table 1. Absorbed power, energy, acceleration & crest factor

	1 shot	3 shots
Absorbed power rms (W)	38.9±1.3	72.4±1.7
Absorbed energy (J)	14.5±1.9	174±2.3
Weighted acceleration rms (m/s^2)	6.62±1.5	10.4±2.1
Crest factor	10.1±5.1	8.6±3.2

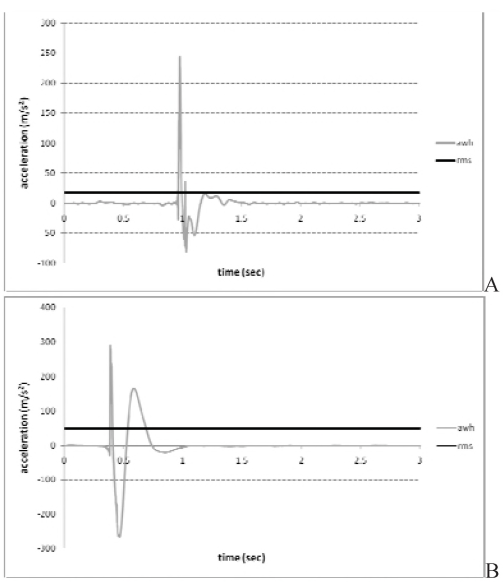

Figure 3. A: Maximum peak value of force - 425 N, B: Maximum peak value of force - 261 N.

Higher force values tend to increase the crest factor, while they reduce the r.m.s. value. Otherwise, there is the relative independence of absorbed power on the force exerted (38 W- 40W).

4. DISCUSSION AND CONCLUSIONS

Gunshot absorbed power has a rather high value, if compared with other working activity involving vibration exposure. The firing of a semi-automatic gun is a composite action. It can be divided in two phases: shooting and reloading. In both, there is an acceleration and a grip force, but the frequencies are different. As a matter of fact, the shot is a true impulsive vibration, while reloading is a mechanical movement. As illustrated in a companion paper at this conference, shooting has a wide frequency range while reloading is mainly concentrated at low frequencies (since it is essentially a motion). This difference can be seen in Figure 1 by comparing the spectra for one and three shots. Since both actions contribute to absorbed power, the three shots sequence produces an increase of both low and high frequency bands with respect to a single shot. This can also be seen in Table 1, where the crest factor for three shots is less than expected for a pure impulsive vibration with such energy. The increase of crest factor with higher grip force accounts for the stiffening of the gun motion while reloading. The absorbed power is, on the contrary, rather insensitive to increasing force because it is uncorrelated to the r.m.s. value.

The increase of absorbed power is not linear with the number of rounds shot, as can be seen from Figure 3 and from Table 1. This is probably due to the increment of grip force on subsequent shots. The hand is more relaxed when the shooter knows he/she will fire a single shot rather than a three shot sequence. The lower recoil (for the sequence) influences the absorbed power from the second phase (reloading).

Absorbed power measurement seems to be a promising parameter for the study of the risk assessment of gunshots and, more generally, impulsive vibration. This preliminary study will be followed by more extensive investigations, even with a revolving gun, to avoid the reloading phase and its consequences.

REFERENCES

1. UNI EN ISO 5349-1 (2004). *Mechanical vibration. Measurement and evaluation of human exposure to hand-transmitted vibration Part 1: General requirements* (UNI - Ente Nazionale Italiano di Unificazione, Milano).

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