REPETITIVE SHOCK VIBRATION RISK ASSESSMENT FOR GUNSHOTS

Enrico Marchetti[1], Raoul Di Giovanni[1], Angelo Tirabasso[2], Alessandro Lunghi[1], Federica Morgia[1]
[1] National Compensation Authority (INAIL), Research Centre, Dept. of Occupational Hygiene,
Via di Fontana Candida 1, Monte Porzio Catone (Roma) 00040 (Italy).
[2] Univ. of Roma "Tor Vergata", Dept. of Otorhinolaringology, Viale Oxford 81, 00133 Roma (Italy).

1. INTRODUCTION

UNI EN ISO 5349-1:2004 states that it only temporary applies to shock or transient vibration [1]. This is so because data processing to produce root mean square (rms) acceleration is prone to underestimate effects of shocks. ISO/TS 15694:2004 has been proposed for studying these particular vibration exposures [2]. We have made use of this standard in the present work for processing measures of typical shock vibration such as those of firearms. Given the fact that in the cited standard [2] there are several suggestions of data post processing, those suitable for enhancing exposure assessment with respect to 5349 [1] have been adopted in present work. The selection of firearms has been done with regard of those mostly used by Italian police (including Carabinieri).

2. METHODS

We measured triaxial acceleration on the butt of three Beretta firearms (92FSB, PM12 and AR70/90) with an accelerometer (PCB SEN 026, sensitivity 10mV/g,) mounted in an adaptor (Figure 1). The adaptor was made in conformity with the prescription of UNI EN ISO 10819 [3]. Measurements were performed on seven male right-handed operators; since the full magazine holds 15 rounds (see Table 1) it nearly equals the weight of the 92FSB, and is a non marginal portion of the other weapons mass. In order to restrain mass variation during measurements, they have been done with the magazine always fully loaded. The firing distance was 10 m.

Table 1. Characteristics of the measured weapons.

	92 FS	M12	AR70/90
Length	217 mm	Fixed stock: 660 mm	998mm
Barrel lenght	125 mm	200 mm	450 mm
Unloaded Weight	970 g	3480 g	4070 g
Rate of Fire	Single shot	550 rounds/min	670 rounds/min
Muzzle velocity	365 m/s	380 m/s	920 m/s
Magazine	15 rounds	32 rounds	30 rounds
			

The signal was acquired and analyzed by an OROS OR 38. The sampling frequency (5.12 kHz) was selected for wide frequency range.

Figure 1. Adaptor with triaxial accelerometer.

Analysis and processing have been done with MatLab software. The processing rms and root mean quad (rmq) parameters proposed in [2] with a computation time window of either 3 or 30 seconds. The frequency weighting of the acceleration signal was either that of the UNI EN ISO 5349-1 (Figure 2), or the flat weighting of ISO/TS 15694 (Figure 3). All signals were processed in 1/ 3 octave bands.

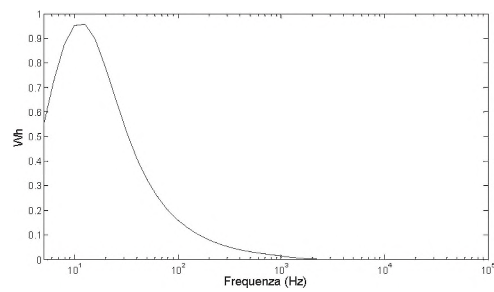

Figure 2. UNI EN ISO 5349-1 W_h weighting curve.

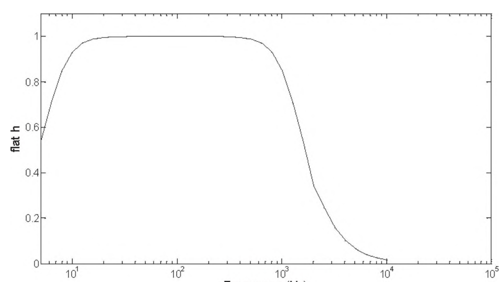

Figure 3. ISO/TS 15694 W_f flat weighting curve.

3. RESULTS

Firing with firearms, as it is expected from impulsive events, encompasses a far larger frequency range than usual vibration exposure. This is evident from Figure 4, which highlights the fact that high frequency acceleration is very relevant. This fact should be kept in mind when selecting

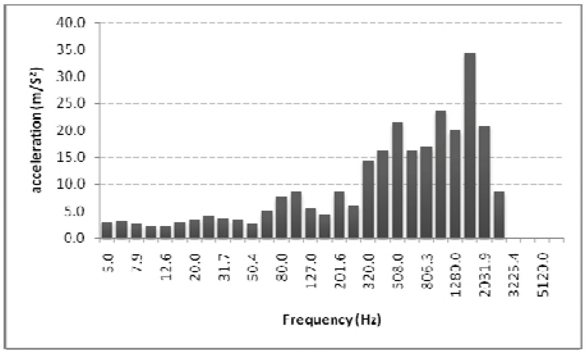

Figure 4. Acceleration versus frequency in 1/3 octave bands.

the weighting curve for that kind of exposure. Post processing gave exposure indicators reported in Table 2. As proposed in ISO /TS 15694, the rms and rmq were evaluated with two weightings: W_h and W_f. filters. Evaluation was done for 2 time windows: 3 and 30 seconds.

Table 2. Indicators assessing exposure evaluated as root mean square weighted by Wh (rms_{Wh}) and Wf (rms_{Wf}), and root mean quad weighted by Wh (rmq_{Wh}) and Wf (rmq_{Wf})

	# sec	rms_{Wh} (m/s^2)	rms_{Wf} (m/s^2)	rmq_{Wh} (m/s^2)	rmq_{Wf} (m/s^2)
92FS	3	10.74±1.15	65.48±4.42	3.85±0.48	10.51±0.86
	30	5.86±0.67	36.20±2.89	1.58±0.21	4.15±0.43
PM12	3	1.94±0.11	21.83±0.15	0.67±0.07	3.16±0.1
	30	0.98±0.04	11.02±0.45	0.24±0.02	1.130±0.05
AR90	3	4.4±0.3	81.0±4.7	0.9±0.08	12.6±1.1
	30	1.86±0.31	37.8±3.7	0.26±0.06	4.0±0.6

In addition, the maximum number of rounds per day was computed, respecting the European limit value for exposure to mechanical vibration (5.0 m/s^2). Tables 3A and 3B show these data for different exposure indicators and weighting curves.

4. DISCUSSION AND CONCLUSIONS

It is evident, from Table 2, that a wide range of values are covered by different indicators. The influence of various factors can be deduced. Widening the time window reduces the indicator value, as expected. But the effect of the fourth power (rmq) is not that of enhancing the exposure assessment. Instead it depresses it. This can be attributed to the impulsive shot and its very short time duration, which implies a wide spectrum in frequency domain and acceleration values below 1 m/s^2 in low frequency bands. Hence the double squaring reduces the result and this sums up to a total less than that for the simple square. This is not compensated by the weighting in the high frequency range for W_h. With a flat weighting, the exposure indicator recovers, but stays well below the rms. From this point of view, the flat weighting curve W_f seems to be better, giving equal weight to a larger range of frequencies. Hence it increases the exposure indicator value. This aspect is even more interesting because the rise in value is present even in rmq, showing that the frequencies involved are well beyond those cut by the W_h curve, as is evident from Figure 4. The indicator to be used seems to be rms_{Wf}.

Table 3 A-B. Number of admissible rounds fired per day not exceeding the European limit, using root mean square (A) and root mean quad (B) indicator.

A	**Max 5 m/s^2**	rms_{wh} (m/s^2)		rms_{wf} (m/s^2)	
		3 s	30 s	3 s	30 s
92FS (single shot 0.1 sec)	T_e	1.6	5.5	0.04	0.14
	Rounds per day	976	3300	26	86
PM12 (single shot 0.1 sec)	T_e	50.1	195.4	0.39	1.6
	Rounds per day	30035	117265	236	927
AR7090 (single shot 0.15 sec)	T_e	9.8	54	0.03	0.1
	Rounds per day	3903	21626	11	53
B	**Max 5 m/s^2**	rmq_{wh} (m/s^2)		rmq_{wf} (m/s^2)	
		3 s	30 s	3 s	30 s
92FS (single shot 0.1 sec)	T_e	12.6	75.5	1.7	10.9
	Rounds per day	7580	45280	6532	1020
PM12 (single shot 0.1 sec)	T_e	419.6	3296.7	18.7	146.8
	Rounds per day	251753	1978024	11236	88056
AR7090 (single shot 0.15 sec)	T_e	222	2749	1.2	11.6
	Rounds per day	88654	1099471	475	4655

Not having any definite indication of what the real danger is from that kind of working activity, it is reasonable to adopt a conservative restriction on the daily number of rounds that can be safely fired.

REFERENCES

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).

ISO/TS 15694 (2004). *Mechanical Vibration and Shock - Measurement and Evaluation of Single Shocks Transmitted from Hand-Held and Hand-Guided Machines to the Hand-Arm System* (International Organization for Standardization, Geneva).

UNI EN ISO 10819 (1998). *Mechanical Vibration and Shock – Hand-Arm Vibration – Method for the Measurement and Evaluation of the Vibration Transmissibility of Gloves at the Palm of the Hand* (UNI - Ente Nazionale Italiano di Unificazione, Milano).

ACKNOWLEDGEMENTS

We wish to heartily thank Italian Carabinieri (Lt.Col. A. Carella) and the Local Sanitary Service of Vicenza (Dr. F. Zanin and Dr. A. Cioffi) for their kind and cooperative collaboration.