Measurements analysis for impulsive events individuation

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The European Parliament and the Council adopted the Directive 2003/10/EC regarding minimum health and safety requirements for workers exposure to risks arising from physical agents (noise).
This directive is intended to ensure health protection for each worker, and to create a minimum guaranteed level of protection for all Community workers.
Nevertheless it is very far from be the solution for the problem.
Indeed the most important lack showed in this method consists in the choice of the C-weighted curve (for the identification of the level of peak pressure).
The second weakness of the method is the absence of procedures for determining the effects of multiple impulsive events, that have levels below the threshold level, and that may be irrelevant for the determination of the daily exposure dose.
In this paper we are going to highlight these weaknesses by studying sound pressure level evolution and the un-weighted instantaneous sound pressure, that allows to detect presence of high energetic events of short duration.
The analyses are referred to various work activities and allow to detect the interactions between exposure and pathological effects on exposed people, to identify the value of the physical parameters which could determine the onset of physical damage.

1 INTRODUCTION

In Europe workers protection from damages coming from extended exposure to noisy working activities is committed to Directive 2003/10/CE[1]. It supplies the minimum safety

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prescriptions to ensure workers health care from the risks arising from physical agents (noise), whereby all member States must adapt their national directives.

According ISO 1996-2:1987[2] the linear peak setting of selected type 1 sound level meter is used to assess high-energy impulsive sounds with respect to both annoyance analysis and structural damage[3]. It is characterized by a response time of 30 μs.

The new European norm, among physical parameters indicating risks, includes C-Weighted peak sound pressure p_{Cpeak}, which is the maximum value of instantaneous C-Weighted sound pressure. The directive provides for analyses is carried out by sampling the maximum value of instantaneous sound pressure level without recording physical quantity temporal evolution, therefore for the measurement to determine p_{peak} value is enough. This procedure is not much reliable because it does not allow recognition of events that are repeated in very short time period. These events sometimes cannot reach the threshold value indicated in the norm for adoption of protective proceedings, but nevertheless they are potentially harmful because characterized by high energy content and because they can get to tympanic membrane before defensive mechanism (contraction of stapedius muscle that works as a reflex) can be activated.

The directive fixes, referred to 20 μPa, that the maximum admissible value (limit value) for peak sound pressure is p_{peak} = 200 Pa [140 dB(C)], the maximum value for which usage of individual hearing protection devices is not necessary (lower value of action) is p_{peak} = 112 Pa [135 dB(C)], while the maximum value for which usage of individual hearing protection devices is obligatory (upper value of action) is p_{peak} = 140 Pa [137 dB(C)].

It is possible to highlight how this setting is actually unreasonable. Indeed analyses of the normalized audiogram of human ear show how threshold of pain is less than 140 dB for all those frequencies in sound audibility range; in addition many medical diagnoses have demonstrated that repeated exposures for middle-long periods to impulsive noise, even significantly lower than 140 dB, can produce irreversible damages to hearing organ.

The particular anatomic structure of ear and the complex sound transmission and decoding mechanism makes essential to study temporal evolution through analyses of all acoustic descriptors, also including those allow controlling impulsive events.

All the consideration made above will be examined showing the circumstances emerged from observation of a large number of measures.

2 WORKING ACTIVITIES ANALYSES

In the last few years, researchers at Lab of TCA, Università della Calabria, Italy have conducted a large number of analyses regarding many working activities in different field of the industrial sector. It was made on demand of medical specialists that wanted to know more about sound field peculiarities during working activities, to determine the possible causes of pathological phenomena onset in workers.

The situation appearing from every single analysis done is that, in almost all cases being studied, the sound characteristics of workplaces are not well represented with descriptors pointed out in the directive. This means that, sometimes, risk situations which cause irreversible damages over time to workers are considered as harmless and therefore health protection procedures are not putted into practice.

European directive prescribes that evaluations on the signal must be done by using the C-weight curve, which corresponds to inverse of 100-phon equal-loudness curve on ISO R-226 diagram. The C-weighted signal has been corrected in low frequencies up to 100 Hz and in medium frequencies from 1600 Hz on. Practically the resultant sound level is lower than that obtained when the instantaneous sound pressure is measured un-weighted; this guides to less

protection for workers. Correction coefficients are significant in low frequencies field (up to 20Hz) and in high frequencies field (over 10 kHz). The peak value determination is strongly underestimated when the sound is made of very low and very high frequency emissions and therefore, in these situations, it is possible to run the risk to omit the necessary defense interventions. These are actually important when the sound presents low frequency components, because in that range the human ear defense capabilities are modest.

Another element of confusion and ambiguity introduced in the norm regards the usage of weighting curve that should be adopted for highlight peak sound pressure level; indeed the definition section of the norm refers to C-weight curve, while in the rest of the directive A-weighted curve became the reference. In addition peak sound pressure value p_{peak}=200 Pa is equivalent to an A-weighted sound pressure level L=140 dB(A), while it should be calculated by using the C-weight curve.

Moreover, the possibility to determine effects given from multiple impulsive events misses; these having levels below the threshold do not influence the daily absorbed dose, but they can cause, in long periods, damage to ear because of their energy.

In these paper sound characteristics produced by industrial systems working phases were studied. In Fig.1 is shown a measurement done during the preparation phases of cast iron melting crucible[4]. It represents the time history of equivalent continuous A-weighted sound pressure level L_{Aeq} and un-weighted sound peak p_{peak}.

It is possible to notice the presence of extremely high energetic events, short in time, that determine an instantaneous un-weighted sound pressure levels trend characterized by high level values.

It is even possible to note that, despite p_{peak} trend influences the evolution of sound pressure level, the equivalent continuous sound pressure level and the daily personal exposure level. Since the last one never overcomes the lower value of action [80 dB(A)] no one protection intervention is obligatory. Nevertheless statistical analysis shows that these phenomena are relevant from an energetic point of view as L_{A90} values, recorded during measurements, can confirm.

2.1 Surveys

More detailed analyses has been implemented after ascertaining these situations; in the following parts are reported and commented some measurements carried out into two different workplaces: a garage for repairing and replacing tires and a joiner's workshop.

The garage has last generation equipping; it is realized in accordance to European norm for tools machineries construction and employment. To realize the measures a special device, worn by worker, was used. It allowed the real time microphone to be maintained near the operator's ear and at the same time it assured opportune provisions to minimize perturbation caused by the presence of the worker to sound pressure field. For this reason, that system allow keeping the microphone to not less than 0.1 meters from the head and in correspondence with operator's ear.

The measures, executed at the end of working time, regard an operation of tires reversal and an operation of rims hammering on a medium-powered car. During the measure also parameters not required from the current standard were sampled. The garage in which measurements were made is characterized by a fair amount of work; the simulated operation usually requires, for its execution, a time between 20 and 40 minutes depending on the interventions. On average 4 or 6 interventions are made in a day; however in the rest of the paper the calculations regarding the adsorbed doses have not been performed because a whole working day has not been monitored.

During the whole working phases the measured peak values, both C-weighted and un-weighted, resulted far below those reported in the norm.

Maximum peak levels were recorded during the rims hammering phases, they are the following: p_{Cpeak}124 dB(C); p_{peak} = 124.8 dB. The modest difference between these two values is due to the fact that sound spectral composition at the instant in which there is the maximum value is characterized by the absence of low frequency components and by modest consistency of high frequency components. Figure 2 shows the 1/3 octave bands spectral composition for the sound at the instant in which p_{peak} maximum value was recorded.

It is possible to notice the presence of low value of levels, if compared to the other components, in the range 16÷125 Hz (point from which corrections become to be irrelevant, -0.2 dB). From 125 Hz to 4 kHz the signal has the bigger energetic content, while from 4 kHz to 20 kHz (when C-weighted curve starts again to penalize significantly the signal) the levels fall gradually and they assume values comparable with those assumed in the middle-frequency field and therefore their contribute to global level become negligible.

In these conditions, the use of one or another weighting curve is trifling, because of the result does not diverge significantly. However this is typical example in which proposed model shows its limitations.

Let us consider Fig. 3, in which are reported linear peak and maximum impulsive level time histories with sampling time equal to 60 ms. It is possible to notice that peak level changes faster than impulsive signal (that anyway represents a signal capable of stressing hearing organ and to prime defense mechanisms in a time longer than that characterizing the signal).

In the same interval in which impulsive signal decreases, before instrumentation can survey a new impulse, there is the presence of many energetic inputs. They anyway reach tympanic membrane, with no possibility that protection of stapedius muscle can be activated, and they causes imaginable effects when exposition is prolonged for long times. The energy quantity connected to peak level is on average 11% greater than that connected to impulsive one.

The situation is different when phenomena with wider spectral composition are studied. In Fig. 4 is shown the sound pressure level time history for a signal sampled into a joiner's workshop during the usage of a squaring machine and a compressor. Un-weighted and C-weighted profiles were marked out and the following values were calculated: p_{Cpeak} 111.5 dB(C); p_{peak} = 113.9 dB. The wider difference between the two values, if compared to the previous case, is due to the different sound spectral composition. In Fig. 5 is shown the 1/6 octave bands spectral composition when the maximum value of peak is reached obtained through FFT analysis. It is possible to observe the presence of components having low frequencies and frequencies bigger than 10 kHz that justify the result obtained.

After all, the usage of C-weight curve leads to underestimate the value of maximum peak level joined during the activity; this may cause mistakes in the individuation of right measures to protect the health of workers. This negative aspect must be added to the other highlighted in the underestimation of the energy incident on the auditory system.

3 CONCLUSION

The conduced analyses, of which a brief summary has been reported, show that to determine risks, faced by workers during the performance of their jobs, is necessary monitoring the phenomena dynamics, studying their temporal evolution through the analysis of sound pressure level and of instantaneous un-weighted sound pressure. This to determine the presence of particularly energetic events with short length.

Indeed, in many very common situations, carrying out the analyses according to Directive 2003/10/CE all the terms for the application of precautionary an protection measures, considering the nature of exposure actually indispensable, may not be so clear. What is stated before makes

no longer delayed the review of criteria for the protection of workers from the risks of exposure to noise.

To individualize the right solutions it is indispensable to carry out analyses with medical specialists. The solution could be the determination, by the medical specialist in otolaryngology, of the maximum energy both for the single event and for the daily dose, that can be absorbed from workers and then in the individuation of physical parameters that make explicit the achievement of that threshold.

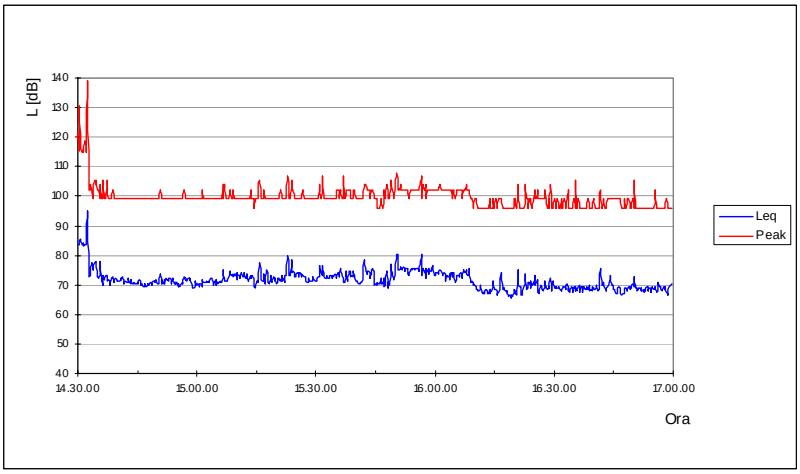
4 REFERENCES

1. Directive 2003/10/CE of the European Parliament and of the Council (2003) – The minimum health and safety requirements regarding the exposure of workers to the risk arising from physical agents (noise).

2. ISO 1996-2:1987 – Description and measurement of environmental noise. – Part 2: Acquisition of data pertinent to land use. – Amendment 1-1998.

3. Leo L. Beranek, "Noise and vibration control", *McGraw-Hill (1971).*

4. A. Reda, A. Sabato, "Innovative risk assessment with impulsive events", *Internoise 2006, 3-6 December 2006, Honolulu, Hawaii, USA.*



L_{AE}	L_{eq}	$L_{ep,d}$	L_{max}	L_{min}	Max Peak	L_{10}	L_{30}	L_{50}	L_{70}	L_{90}
115,3	77,2	72,2	113,4	65,4	139,1	75,1	72,5	70,9	69,7	67,5

Fig. 1 – Time history of L_{eq} and L_{peak} during a working day

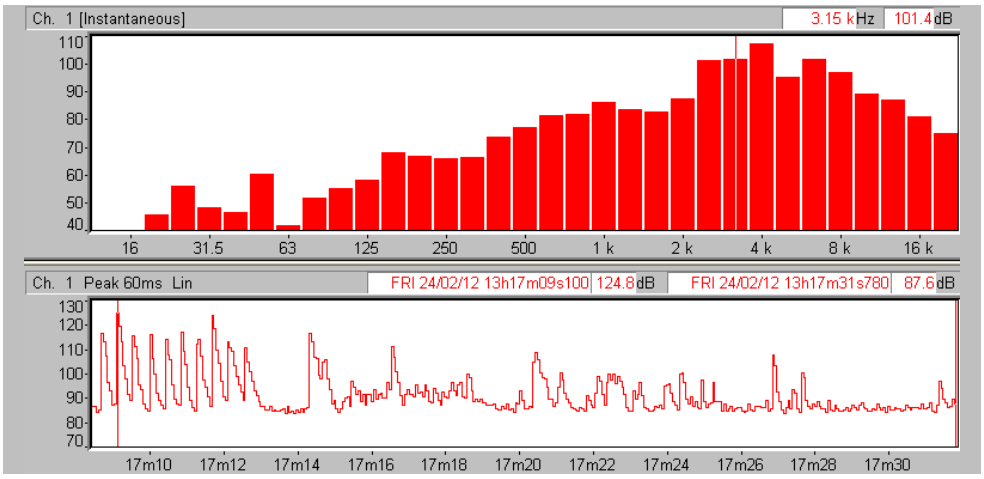


Fig. 2 - Spectral composition (1/3 octave bands) of p_{peak} maximum value

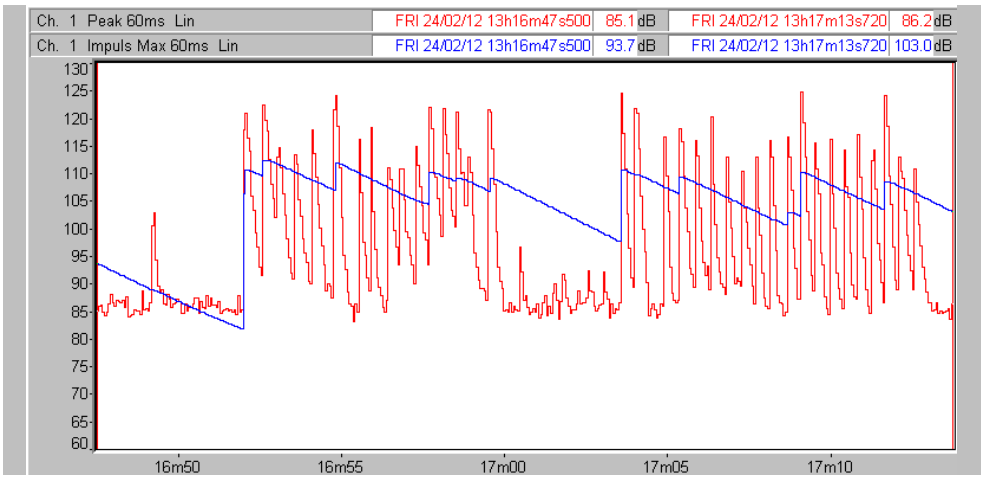


Fig. 3 - Time histories of linear peak and maximum impulsive level with sampling time equal to 60 ms

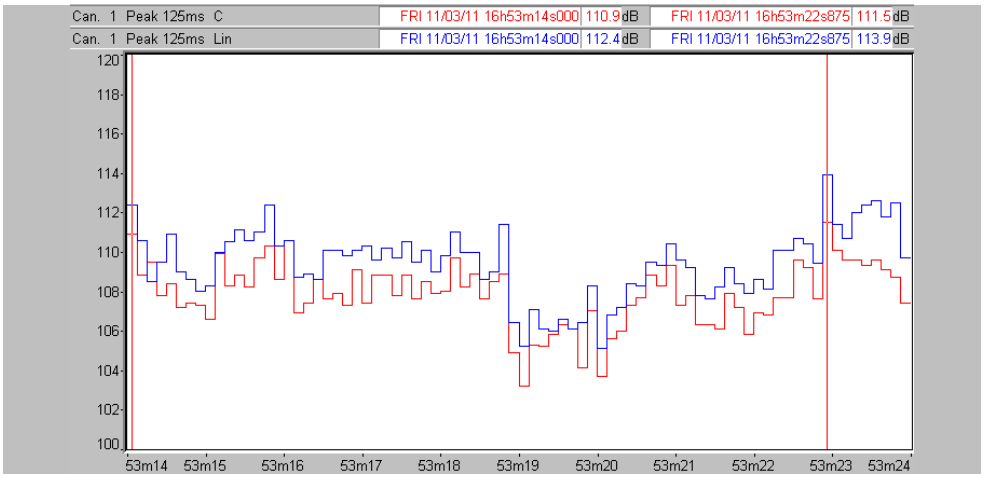


Fig. 4 - Sound pressure level time history for a signal sampled during the usage of a squaring machine and a compressor

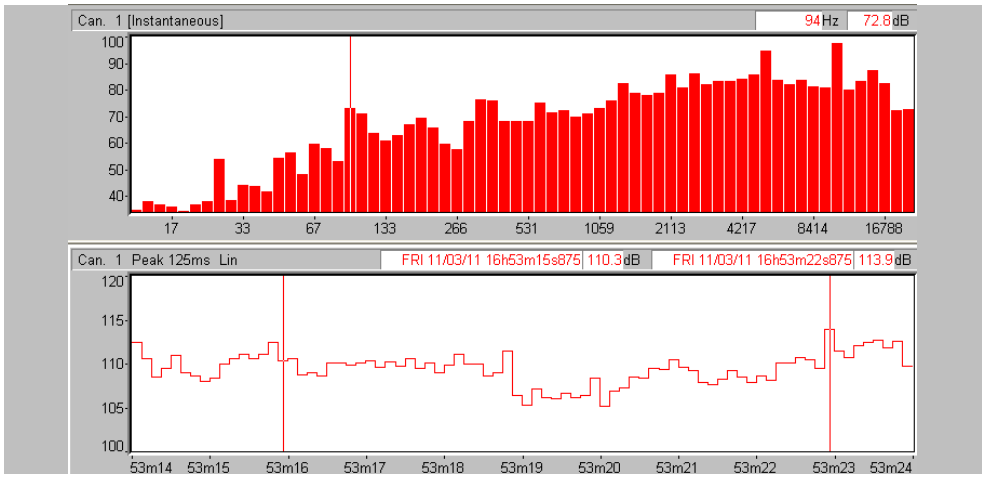


Fig. 5 - 1/6 octave bands spectral composition of p_{peak} obtained through FFT analysis