



NOISE IMPACT EVALUATION FROM MOVING SOURCES

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G. Alfaro Degan, D. Colasanti, M. Pinzari.
University Roma TRE, Dept. of Mechanical and Industrial Engineering
79, Via della Vasca Navale.
00146 Roma. Italia
Tel: +39 06 55173297
Fax: +39 06 55173252
E-mail: alfdeg@hotmail.com

ABSTRACT

In the last few years noise emitted from moving sound sources is considerably increasing because of means of transport on wheels. Aim of this study is purpose an evaluation method of human health risk coming from noise emitted by moving sources.

The risk evaluation has been done using the f.a.s.t.^[8] technique, accurately modified, so that the danger space of action (moving noise source) becomes a function of the vehicle's speed.

After the study of the acoustical characteristics of the sound sources (L_W), we obtained, by using an engineering calculation method, the sound pressure level which arrives to the receiver expressed in terms of $L_{EQ,A}$.

Finally has been done a comparison between forecated and measured values.

INTRODUCTION

The engineering forecasting method is essentially based on the results shown in the ISO 9613^{[5],[7]} and in the " Interrupted traffic noise"^[1] method. The purpose it has been developed is to forecast the noise emitted from moving sound source and to evaluate its dangers by the functional spaces technique FAST^[8].

Our prevision method aims at being a complete instrument, where parts about noise prevision and the noise risk evaluation inevitably will be linked together. Therefore the method uses link of acoustics' equations with the risk evaluation techniques.

1. DESCRIPTION OF THE METHOD

We are now going to study how the prevision method is composed and how the Fast technique is combined in it. The basic equation of acoustics used in prevision is taken from the ISO 9613(2):

$$L_{pAeq}(t) = L_W + D_c - A \quad (1)$$

where we remind

L_w is the machine 's power level ¹;

D_c is the directivity correction term and is given by:

$$D_c = D_I + D_\Omega \quad (2)$$

where D_I is the directivity index given by:

$$D_I = L_p - L_{pm} \quad (3)$$

L_p is the sound pressure level measured where the source is emitting with more energy;

L_{pm} is the medium sound pressure level of the source;

D_Ω is the correction term used when a source is emitting into angles less than 4π steradians;

A is the sum of various different attenuations;

$$A = A_{ATM} + A_{DIV} + A_{SOL} + A_{BAR} + A_{RIF} + A_{MISC} \quad (4)$$

The only term used is A_{DIV} that represents the attenuation due to geometrical spreading for a point sound source emitting into a solid angle of 4π

$$A_{DIV} = 20 \log \left(\frac{d}{d_0} \right) + 11 \text{ DB} \quad (5)$$

The other terms of attenuation have not been considered in the experimentation because at low distances they didn't result influential.

2. CALCULATION OF SOUND POWER LEVEL BY INTEGRAL

The sound power of the studied machines has been calculated basing on the results obtained by the "Interrupted traffic noise" prevision method. The equivalent continuous A-weighted sound pressure level is:

$$L_{AEQ} = 10 \log \left\{ \left[\left(\frac{1}{T} \right) \int_0^T p_A^2(t) dt \right] / p_0^2 \right\} \quad (6)$$

where P_A is the instantaneous A-weighted sound pressure, P_0 is the reference pressure.

We also remind the link between sound power and sound pressure so that:

$$W = I * S = I * 4\mathbf{p} * r^2 \quad (7)$$

and

$$I = p^2 / r * c \quad (8)$$

isolating the fraction of pressure we shall obtain:

$$\frac{P^2}{p_0^2} = \frac{W}{W_0} * \frac{1}{4\mathbf{p} * r^2} \quad (9)$$

we put it in the equation (6) where instead of using normal terms thus having:

$$L_{AEQ} = 10 \log \left\{ \frac{1}{T} * \int_0^T \frac{W_A}{W_0} * \frac{1}{4\mathbf{p} * r^2(t)} dt \right\} \quad (10)$$

In the term in the integral the sound power emitted is independent from time, as we are evaluating a machine moving at constant speed, so that W is constant. The time dependence of R (source–receiver distance) is a function of the machine's movement and of its speed. The only term inside the integral depending on the integration variable is the source–receiver distance. This result can be obtained when the machine's speed is constant. Now we change the variable of integration T , having:

$$dt = \frac{dx}{V} \quad (11)$$

Thus in the integral we have:

¹ This term may be previously known or, as we did, may be calculated using ISO standard^[2].

$$L_{AEQ} = 10 \log \left\{ \frac{1}{T} * \int_0^T \frac{W_A}{W_0} * \frac{1}{4p * r^2(t) V} dx \right\} \quad (12)$$

Is important to stress that the physical phenomenon is described by the term density of the radiation energy:

$$S_0 = \frac{W_A}{V_0} \quad (13)$$

The unit of measure is Joule/m.

The term S_0 describes the sound emission characterizing the segment of road considered and which the source is moving on. It is evident that the car's emission at constant speed is characterized by a constant density of radiated energy and independent from machine 's position. The extremes of the integral are modified as follows:

For:

$$T = 0 \quad X = 0; \text{ if } T \neq 0, \text{ then } X = V * T$$

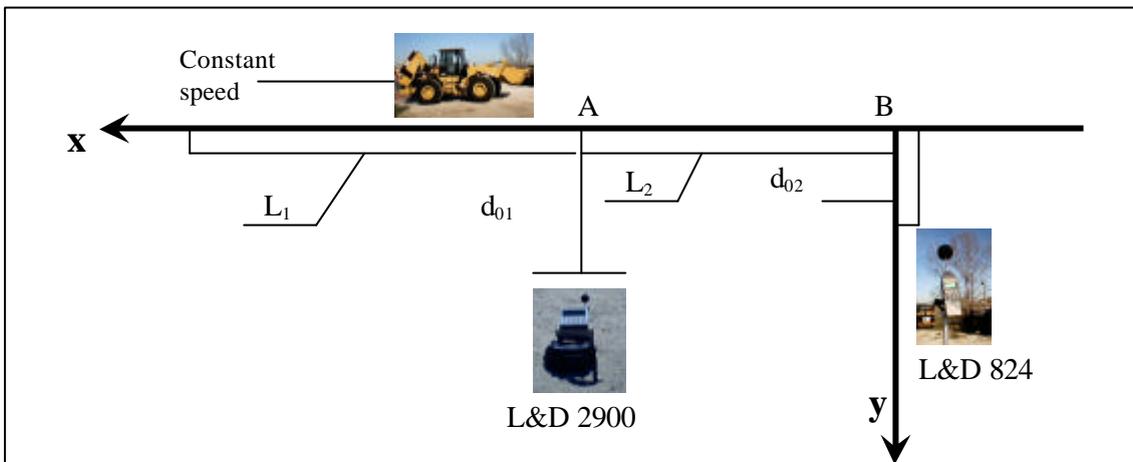


Figure 1: Shape for studying noise coming from moving sound sources

Replacing the term of distance, by posing $r^2 = d_0^2 + x^2$

$$L_{AEQ} = 10 \log \left\{ \frac{1}{T} * \int_0^{V * T} \frac{W_A}{W_0} * \frac{1}{4p * (D_0^2 + x^2)} dx \right\} \quad (14)$$

The solution of the integral is quite simple:

$$L_{AEQ} = 10 \log \left\{ \frac{1}{T} * \frac{W_A}{W_0} * \frac{1}{4p * V} \left[\frac{1}{D_0} \arctan \left(\frac{x}{D_0} \right) \right]_0^{V * T} \right\} \quad (15)$$

Thus remembering the definition of the power level, we have:

$$L_{WA} = L_{AEQ} - 10 \log \arctan \left(\frac{V * T}{D_0} \right) + 10 \log \{ T * V * 4p * D_0 \} \quad (16)$$

3. FAST TECHNIQUE

In order to evaluate health risks, Fast technique defines the Functional Space (FS) as the minimum space for the fulfilment of a worker's activity; in the FS the worker is considered as always present in each point of the FS.

The technique also uses the definition of the space of action (SA) of the danger (material agent) as a space where the danger is characterized by means of its range of action and its duration

time span. We can say worker is exposed to the danger if it is possible to appreciate a superposition of the two spaces (FS and SA).

The peculiarity introduced in our study, is considering that the SA moves together with the moving sound source. Thus the time of the worker's exposition is linked to the machine's permanence nearby the worker and to the machine's speed in the segment considered. This change from the original Fast technique allows us to evaluate risks coming from moving sound sources, because we can evaluate the time length of noise's action. For risk's evaluation now we consider even the superposition of the spaces, but we can remember that now the material agent's space is moving with the machine's speed.

3.1 Method of division in influence areas and Fast technique

The method of division in influence areas is the technique by which it is possible to study the real moving sound sources, like for example a lorry, as fixed point sound sources. The equation of the acoustics used, indeed, can allow us to calculate the pressure level emitted by fixed point source. The initial data we have are: the car's speed, the length of the segment considered (car's route) and the receiver's position. The entire route is then divided in influence areas (segments) of constant length.

Thus the sound source is the segment of road considered as linear source. The linear source is replaced with an equivalent power point source, put in centre of the area. The point source inside the single area emits following the machine's movement, so it emits only during the period of the machine's permanence inside the same area. Whenever the machine enters into the following area, the equivalent source linked to this next area, starts emitting.

The choice about the subdivision in influence areas depends both on Fast technique and on the precision we need for the forecasting method.

Indeed, considering a single fixed car speed, if we increase the areas length we can see a successive increase of the permanence time length in the single area and a larger time action of the material agent (danger) on the receiver. For the risk evaluation, we use the equivalent sound pressure level $L_{EQ,A}$, because this parameter let us compare, on a common time length, the equivalent level due to the car's presence, related to different speeds.

It is evident, indeed, that the sound power emitted by the machine changes according to the speed, gear ratio and number of RPM. We can thus compare the various situations understanding that it is more dangerous a moving sound source that moves at low speed, with low emission, and whose action on the receiver is major in duration, than a source emitting at superior levels, but whose time of action on the receiver is lower, been its speed higher on the considered road span.

4. EXPERIMENTAL RESULTS

In the phase of development we have studied the division in influence areas both with constant length and variable length. The comparison of the experimental results has let us understand that the second method of subdivision was more indicated for the shape used in the experimental phase.

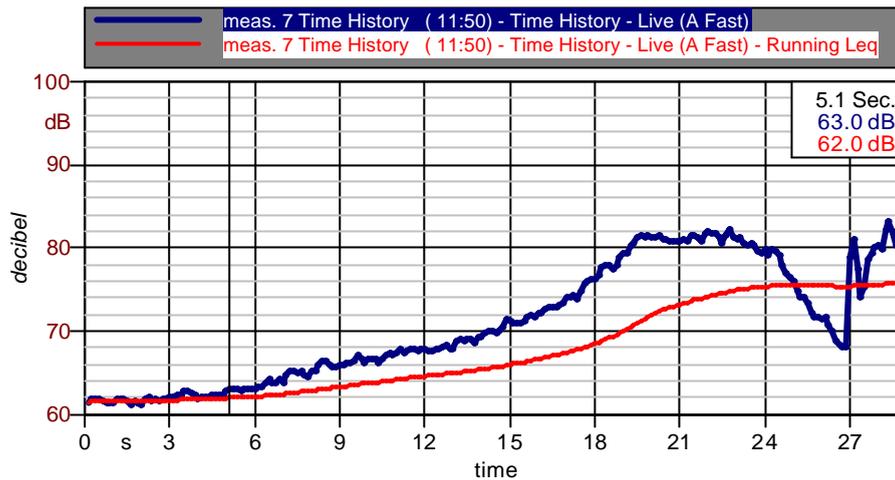


Figure 2: Sound pressure level and equivalent continuous level

The phonometric tests have been developed using simultaneously two analyzers (Larson & Davis 2900 and Larson & Davis 824). In this way we could compare the forecast and the measured values, using the data coming from an instrument to infer a prevision about the point where the other sound level meter was, and to compare directly the results obtained with the values read on the second sound level meter.

In the first phase of experimentation, the tests have been done using a fixed scheme for two sound level meters position (fig1), thus having the chance of repeating comparing the tests made at different time and places. Through the fixed scheme it had been possible to calibrate the algorithm of provisional method.

In each test the machine passes many different times along the segment of road considered at constant speed. This permits us to evaluate the measurement objectivity, being sure that no external factors have modified it.

The test have been made changing the machine's speed so as to stress the changing of the sound power level according to the speed and to the gear used.

The choice of subdivision in influence area number is the most delicate part, because both the accuracy of prevision and the following risk evaluation through the Fast technique, depend on it.

Therefore the calculation program operates in an iterative way, making a comparison between the prevue level and the measured one each time increase the number of areas influence increases. The iterative way goes on until the difference doesn't come to a fixed value below 0,2 dBA.

The integral calculation changes in the case as the machine passes in front of the first sound level meter station and continues in his run as the picture shows. It can be noticed that the fault in the prevision compared to the value given to the sound level meter floats a lot even of 2 or 3 dBA according to the areas number division. When the number increases the floating decreases in intensity, until when the forecasting fault becomes negligible.

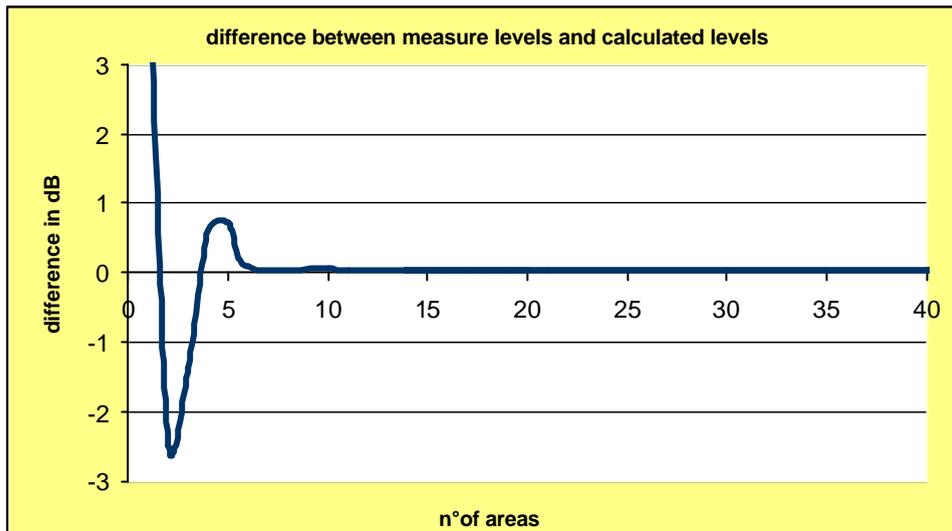


Figure 3. Difference in dB linked to n° of areas in the point A

This relationship between the measured value and the prevision difference cannot be noticed using the same method in the second sound level meter's position. In this case, indeed, the trend of the difference decreases as the number of influence areas increase, and the floating previously observed cannot be seen. We can also stress that when we study the floating phenomenon of the differences, the prevision calculated in the point A of the figure (1), moves more rapidly to the real value.

The difference of the influence areas number we have to use in both cases, shows the shape called "pass by" where the car just moves in front of the receiver is more sensitive to the geometrical distances variation of the point sources considered, but the prevision moves at highest speed to real value. Therefore, the study of the number one sound level meter shape has to use a greater number of influence areas to obtain an acceptable prevision. Another important aspect to consider is the distance d_b , the receiver's distance from the car's transit line, and the test way's length.

Through the experimental values we observe that increasing the distance d_b and maintaining constant the way length, the prevision reaches a high degree of accuracy even with allowance of the influence areas number.

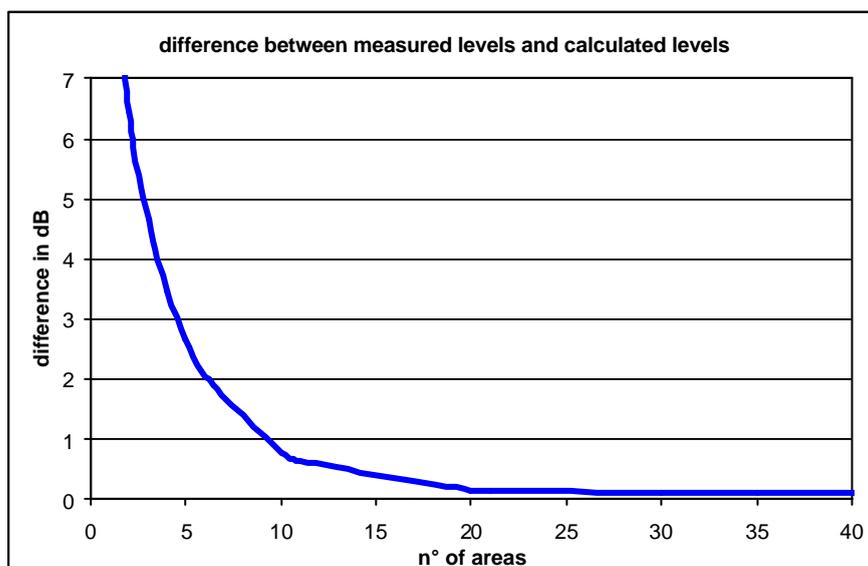


Figure 4. Difference in dB linked to n° of areas in the point B

It is now more evident than before that the increase or the decrease in the way's length , brings respectively to an increase or decrease of the influence area' s number necessary for the prevision.

CONCLUSION

Since many years noise is considered an important pollution element for people of industrialised countries. In this contest forecasting with a sufficient accuracy and evaluating the possible risk on human health is more and more necessary. Our work, starting from the state of art about the acoustic field' s prevision method, links the ability in foretelling with sufficient accuracy the impact caused by the sound propagation together with the ability in evaluating the risks to which exposed people can incur. This method shows its potentialities in all those sectors where man is in deep touch with moving sound sources. We can thus state that many things can still be done in this field, by the help of a wide experimentation, to answer and solve in a satisfactory way the majority of the existing problems.

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