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Comparison of International Standards for Measuring Sound Power in Tool-Machines

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Industrial noise is one of the most important contaminant agents in the industrialised countries due to its effects on health. Sound power is used in order to characterize the noise emitted by the machines because it does not depend on aspects like place or distance of the measurement. These measurements are handled by international standards like UNE-EN ISO 374x and UNE-EN ISO 9614-x.
The advantages and disadvantages of each one of these standards have been evaluated after making a representative number of measurements in several kinds of tool-machines and then, a set of recommendations have been derived to choose the best standard depending on the machine that is going to be measured.

1 Introduction

To determine the characteristics of a machine, it is important to measure its sound power, in relation with the measurement of its sound pressure. The sound power shows a typical characteristic of a machine, because it does not depend on aspects like place or measurement distance, but it depends on the working cycle of the machine, increasing or reducing with the revolutions per minute of the engine, or with the operation starting of some parts of the machine that were not in operation, as circuits of refrigeration. On the other hand, the sound pressure emitted by a machine, changes with the distance (loss of level if the distance increases) and with the characteristics of the place of measurement (influence of the reverberation of the place) [1].

The sound power lever is calculated with the equation Eq (1).

$$L_w = 10 \cdot log(\frac{W}{W_0}) \quad (1)$$

being W_0 the reference power ($W_0 = 10^{-12}$ W)

The measurement of sound power has some problems when the real operation of the machine needs that the machine is moving, given that the result will change regarding the real operation mode.

When we are going to measure the sound power emitted by a machine, we can chose one of the several standards of measurement, it depends on the place of measurement and on the working cycle of the machine, the available equipment...

Because of this, we can chose between two measurement standards for the sound power, the first one is based on the sound pressure emitted by the machine [2], and the second one is based on the intensity radiated by the machine [3, 4].

2 Sound power measurement

2.1 Sound pressure standard

This technique to measure the sound power is described on the standards family UNE-EN ISO 374x. It depends on the place where the machine is. The most used standard is the 3744 [2], that describes the method to measure the sound power using sound pressure in free field over a reflecting plane, or in places that were approximately in free field or whose reverberation were negligible with the direct field radiated by the machine. We will focus on this standard right now.

This standard for measuring sound power using sound pressure is based on the fact that the sound power of a machine is proportional to the mean square value of the sound pressure, averaged in time and space.

The first thing that we have to do is leading the machine to a typical working cycle, taking into account that the tool-machines must not touch any surface, as the produced vibrations by the contact between the machine and the surface can increase the level measured. Because of this, the tool-machines must be holded on with the hand in its normal mode of use, or they could be hanged as well as near as possible to the reflecting surface but without touching it.

Once the machine is placed in the measurement place and under the desired working cycle, we include the machine in a hypothetical surface-box of reference, that should be the smallest box that enclose the machine, excluding some parts of the machine that do not emit sound. This reference box will be included in the measurement box when we will define the required measurement points.

When we are doing the measurement, the one and only source that should be working must be the source under test. We must measure the sound pressure emitted by the machine and the background level existing in the place when the machine under test is not working. Both measurements must be done consecutively.

Once taken the measurements of sound pressure emitted by the machine, we will calculate the sound power with two kinds of corrections. The first one (K1) is related to the background noise existing during the measure. The second one (K2) is related to the characteristics of the measurement place to correct the error caused by the echos, and it depends on the size of the measurement surface, the measurement place, the reverberation time of the place...

2.2 Intensity standard

This technique to measure sound power is described on the standards family UNE-EN ISO 9614-X and is based on the fact that the sound power radiated by the machine is equal to the integral of the scalar product of the

acoustic intensity vector and the elemental area vector associated upon anything surface that totally enclose the machine.

To carry out the measurement using the intensity method, two possibilities are available: the first one uses different points to take the measurements (standard UNE-EN ISO 9614-1) [3] and the second one carries out two orthogonal scanners upon the segment of measurement (standard UNE-EN ISO 9614-2). We will consider next this later possibility [4].

When the measurement is taken using the intensity standard, the noise of the other machines must be reduced in the measurement place, the air or gas flows must be less than 2 m/s near the machine of interest, the sound intensity probe cannot be placed nearer than 20 mm to the surfaces with significant difference of the temperature regarding the air, and the sound emission of the machine under test must be stationary with the time.

As with the pressure method, once we have put the machine under test conditions, we will include the machine in a reference box and we will define a set of segments in each surface that make up the measurement box of the machine, considering the characteristic parts of the machine and with a size that we can do with a continuous scan. After that, we will do two orthogonal scans with the sound intensity probe, at constant velocity and without putting in the normal axis of the probe.

When we have measured all the segments in which the machine has been divided, the next step is the calculation of the sound power with the intensity levels measured.

3 Comparison of both methods

In order to show that both methods are equivalents, we have measured the sound power of a "mini-digger" with the two differents methods that have been just described and with the machine under the same working conditions.

In the case of the intensity method we have done one scan to every side of the machine, and two scans at the top of it.

In the other case, we have used fourteen microphone positions distributed according to the standard 3744, and we have measured the noise emitted by the machine and the background noise existing at the measurement place.

The results are showed in the Fig.1 where we can see that the results obtained with both methods are quite similar, but the sound power measure with the standard 3744 shows an upper level. This difference is due to the fact that this method is sensibler to the background noise than the intensity method.

Because of this, we can say that the results obtained do not depend of the method used to evaluate the sound power emitted by the machine.

How we can appreciate in the former, there do not exist meaningful differences about the results obtained with both methods, but the differences are in the measurement methodology of each one. This implies advantages and disadvantages of applying one or another method in each situation.

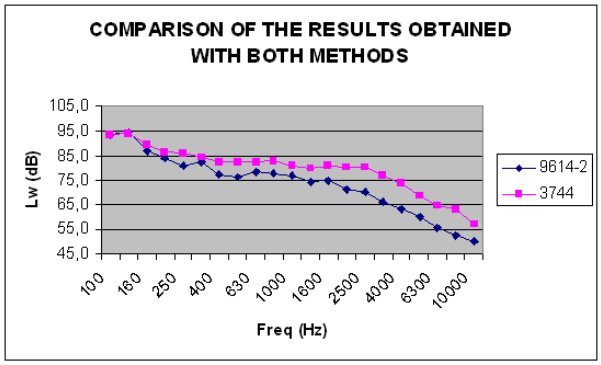

Figure 1: Comparison of the results obtained with the two methods of sound power measurement.

After the measurement of a very important number of machines, showed in the Table 1, we can extract some rules in order to choose one or another method for a certain situation, according to the kind of machine and the measurement place:

- To measure small machines, like tool-machines, the sound pressure standard is better. It is very difficult to do the scans for the intensity method in these machines because the surfaces are very little.

- If we want to measure the sound power of a big machine, the intensity standard is chosen because the number of measurement points of the pressure method is very high, and this requires a long time to take the measurement.

- When we want to measure machines whose noise is not constant with the time, it is better to use the pressure standard, with a measurement time long enough to register a complete working cycle of the machine. The intensity method is not applied here because the difference between the two scans may cause an incorrect measurement due to the non constant noise emitted by the machine.

- When the acoustic environment is not known or when the background noise is high, it is advisable to use the intensity method, because a small background noise does not affect to the measurement, but the less the noise is, better the measure is.

KIND OF MACHINE	UNE-EN ISO 3744	UNE-EN ISO 9614-2
COMPRESSOR	6	4
WEAVER MACHINE	0	10
MILLING MACHINE	3	7
PIERCE SAW	10	0
LINEAR GRINDER	10	0
DRILL	10	0
PANEL SAW	1	9
OWERLOCK	0	2
LAWNMOWER	4	0
GRINDING MACHINE	0	3
LATHE	0	10
POWER GENERATOR	0	10
PRINTING PRESS	0	6
CHAIN SAW	7	0
INCONER	0	1
MINI-DIGGER	1	1
TOTAL	52	63

Table 1: Measured machines

- If the technician‘s experience is not enough to use the sound intensity probe, it is advisable to use the sound pressure method, but in this case, we have to choose the moment with the less background noise, and we have to characterize the acoustic environment.

As there has been stated, the easier method is the sound pressure method, but we have the difficulty that we have a high number of microphone positions in big machines, and it is not possible to measure in noisy places, although this condition is applicable too to the intensity method.

4 Conclusion

When the sound power of a machine has to be measured, it is important to carry out a previous analisys to evaluate differents aspects: the technician's experience in this kind of measurements, the available equipment, the acoustic environment, the kind of noise that is emitted by the machine, the number of microphone mesurement points or the number of segments to scan. With this information we can choose the better standard to measure the sound power of the machine under test as have been stated before.

By choosing correctly the standard to be used, we will require less time and effort to do the measurement.

Acknowledgments

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