inter•noise 96
25th Anniversary Congress – Liverpool

INCE: 76

PREDICTION OF THE OCCUPATIONAL NOISE EXPOSURE

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1 INTRODUCTION

Predictive models, based on geometrical acoustics[1,2] are currently used to calculate noise maps in factories. The choice of the best solution to reduce the sound level in the factory is obtained by comparison of noise maps calculated for different configurations (treatment of walls, screens, enclosure..).This procedure is well adapted when sound sources run continuously all over the day or when workplaces are fixed. On the other hand, when the presence of a worker at a particular location is linked to a particular operating mode of the machine, this approach is not sufficient to choose the best solution to reduce the sound exposure level.

This paper presents a method for the estimation of the sound exposure level. A software integrating this method has been developed. Thanks to this software, the area of application of existing predictive tools can be extended. The contribution of each sound source in the sound exposure level for each worker can be estimated using information concerning the machines' operating modes, work analysis as well as the sound propagation in the hall Thus, the technical solutions to be implemented to reduce the sound exposure level can be optimised.

2 DESCRIPTION OF THE METHOD

The method that has been developed allows estimation of the contribution of each sound source to the exposure level of a worker. It is based on a modelisation of the sound sources, the hall and locations of the workers.

Input data

Sound sources. The analysis of each noise source leads:-1- to notice its location in the hall, -2- to identify its various operating modes (machine in operation or stopped, enclosure closed or opened ...), -3- to evaluate the daily duration of each of these operating modes. The acoustic caracterization of noise sources consists in evaluating the acoustic power of each source according to each mode. Thus, the following parameters can be defined for each sound source:

- its location in the hall (x,y,z))
- the number of different operating modes: Np
- the relative daily duration of each mode : $tm(p)(p=1,Np)$.
- the acoustic power for each mode of operation: $Lw(p)(p=1,Np)$

Work analysis. At first, working areas are identified and the time spent by the worker in each one is assessed. Then, for each working area, the work analysis permits to establish links between a precise activity and a particular operating mode of one or several noise sources. For example, the use of a nozzle in a given place is linked to the presence of a worker. Thus, the following parameters can be defined for each worker:

- the number Nl of different areas in the workshop, knowing that a precise workplace will be distinguished from a more extensive area
- the location of each work area: $x\min(l), y\min(l), x\max(l), y\max(l)$
- the relative daily duration $tw(l)$ spent by the worker in each area.
- the link between the presence of the worker in an area l and an operating mode p of the noise source:

A link is modeled by: $\delta(p,l)=1$

If there is no link: $\delta(p,l)=0$

Characteristics of the sound propagation. Input data are attenuation maps obtained for each sound source located in the hall. The attenuation map is the noise map calculated for a sound source power level of 0 dB. Such a map can be obtained by different ways:

- using a predictive software that calculates sound levels generated by a source located in the hall. Thus, according to the degree of modelisation used ,the following parameters can be taken into account: the position of the sound source, the real geometry of the hall, the acoustic properties of walls, the fitting and its distribution in the hall
- from a spatial decay curve giving $Lp-Lw(dB)$ according to the distance from the source [3]. This curve can be obtained experimentally or by simulation, but it has to be representative of the average propagation in the hall. This method presumes that the hall is homogeneous (large hall, flat ceiling, homogeneous fitting, ...)

One obtains thus for each source, a table named: $Att(x,y)$

Contribution of a sound source in the sound exposure level.

Average attenuation $Am(l)$ **in a limited area l:** it is given by the energetic mean value of the attenuation values $Att(x,y)$ for all points of coordinate (x,y) included in the area l.

Operation time of the source in its phase p t(p, l) for the worker located in an area l. it can be expressed as the sum of two partial times:

$$t(p,l) = to(p,l) + tr(p,l)$$

- $to(p,l)$ is the time prescribed by a link between the operation mode p of the source and the presence of the worker in a given area l. It is given by the following expression:

$$to(p,l) = \frac{\delta(p,l)tm(p)tw(l)}{Max\left[\sum_{i=1}^{Np}\delta(i,l)tm(i), \sum_{j=1}^{Nl}\delta(p,j)tw(j)\right]}$$

- $tr(p,l)$ is the residual time of operation of the source in its mode p for a worker located in a given area l. It depends on the existence of links between the source and the worker. It is given by the following expression:

$$tr(p,l) = \frac{\left[tw(l) - \sum_{i=1}^{Np} to(i,l)\right]\left[tm(p) - \sum_{j=1}^{Nl} to(p,j)\right]}{\left[1 - \sum_{i=1}^{Np}\sum_{j=1}^{Nl} to(i,j)\right]}$$

Contribution of the source to the sound exposure level

A- General case The contribution of a sound source to the sound level exposure of a worker is obtained by adding the contribution of the source in each operating mode for all the areas associated to the worker. It is given by the following expression:

$$Lp(dB) = 10\log\left(\sum_{i=1}^{Np}\sum_{j=1}^{Nl} t(i,j) 10^{\frac{(Lw(i)+Am(j))}{10}}\right)$$

B- Particular Case: No link between the sound source and the worker. In the absence of links between a source and a worker, the preceding expressions show that for each area l and each operating mode of the source p:

$\delta(p,l)=0$;

$to(p,l)=0$

$t(p,l)=tr(p,l)=tm(p)tw(l)$

The contribution of the source to the sound level exposure is then given by:

$$Lp(dB)=10\log\left(\sum_{j=1}^{Nl} tw(j)\,10^{\frac{Lpo(j)}{10}}\right)$$

with $Lpo(l)=Lwm+Am(l)$ representing the average sound level obtained in each area l for a source of mean sound power level Lwm:

$$Lwm(dB)=10\log\left(\sum_{i=1}^{Np} tw(i)\,10^{\frac{Lw(l)}{10}}\right)$$

In this case, the contribution of the source is obtained from the average sound levels generated by the source in different areas $Lpo(l)$,weighted according to the length of stay of the worker in the different areas $tw(l)$.

3 CONCLUSION

Thanks to the presented method, the contribution of a particular source to the sound level exposure of a worker can be calculated. Taking into account the work analysis, the field of application of current predictive methods can be extended using this method. A software integrating this method has been developed. Knowing the contribution of each sound source to the sound exposure level of each worker, the acoustical gain of different technical solutions on the sound exposure level of one worker can be calculated. A procedure such as the one proposed by Moorhouse [4] can then be implemented: it allows both identification of important technical solutions to reduce the sound exposure level of workers, and evaluation using a single indicator, of the gain brought by a set of solutions, for all the personnel of the workshop.

References

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