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MACHINERY NOISE: A DRAFTING APPROACH

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Abstract

Demands pointed out by the industrial noise legislation become more and more restrictive. New regulations require that machinery be so designed that risks resulting from noise emission to be reduced to the lowest limit. More than that, low noise emission may be a favorable reason for the market success of the product. In these conditions, an important task for designers is to create low noise machines, with good acoustic characteristics over the whole period of their service life. The paper presents some aspects related to the assessment, in the design stage, of the noise emitted by machines and equipment. A simplified noise prediction method is presented. Having the 3D model of the product, developed with a solid modeling software, a noise evaluation can be performed, considering noise sources, propagation environment and virtual receiver position.

INTRODUCTION

The tendency in the machine building industry is to obtain powerful machines and equipment, with lower dimensions, working at high speeds and improved accuracy. New materials are used to manufacture the component parts, with the aim of optimise their working parameters, in order to ensure high productivity and wear resistance. In most cases, all these generate the amplification of the dynamic phenomenons that cause vibrations and noise during the working-cycle of modern machines. The generated vibrations and noise must be studied from the point of view of their negative effects on the operator, on the environment and on the quality of the manufacturing process. In order to find a convenient solution for these opposite requirements, the action must start in the design and development stage of the machine or equipment. It is most effective and least costly to implement noise control in the design stage. After a machine is already manufactured, with no consideration for noise levels, further reduction at source, without affecting the basic functioning of machine, is possible with limited effects and in a very few cases.

Noise control at source at the design stage is one of the most important objectives for enforcing less noisy machinery being put on the market. Part of a strong action at European and international level, focussing on the reduction of noise at the workplace, it was first mentioned by the Directive 89/392/EC, in 1989 [4] and emphasized by the Machinery Directive 98/37/EC, in 1998 [8]: “Machinery must be so design and constructed that risks resulting from the emission of airborne noise are reduced to the lowest taking account of technical progress and the availability of means of reducing noise, in particular at source”.

PROBLEM DEFINITION

In the classical drafting method, the evaluation of noise emission for a machine tool or equipment becomes possible only when the prototype is built and tested. The development in the past few years of the computer aided design software gives a new possibility: the 3D modelling of the product (machine tool, equipment, etc). More than that, starting from the 3D model, a virtual prototype can be developed and tested on the computer, with the help of specialized computer aided engineering software. Computer testing of virtual prototypes reduces the costs for building a physical prototype and limits its necessity.

The three-dimensional model of the product also can be a start point for the study of the emitted noise, taking into consideration the noise sources, properties of the propagation medium and positions of virtual receivers. It gives the possibility of evaluation and visual representation of the noise emitted by the machine. A further analyse will identify critical situations. As result, one can find noise reduction solutions and also verify and improve them even from the design stage of the machine.

It is quite obvious that a computer model for calculation of noise generated by a machine is flexible and easy to use. The machine geometry and, in relation with it, the input data of the computer model: noise sources positions and characteristics, propagation environment, etc. can be changed very quickly in order to study different noise situation and to find noise reduction solutions.

METHOD FOR NOISE EMISSION MODELLING

Starting from the 3D model of the machine, developed within a computer aided design (CAD) software, based on parametric solid modelling techniques, a method was conceived for modelling the noise emitted by an industrial equipment or machine. The main idea is to use the three-dimensional computer model of the machine to obtain the geometry from the point of view of noise generation, and then to use this geometry to model sound propagation from the source to the virtual receiver, by working in the same solid modelling software environment (figure 1). In order to develop the noise emission model, noise emission data for different industrial noise sources were collected into a database and also theoretical and empirical formulas for sound power calculation were considered.

Outlook of the method

The identification and positioning of the noise sources are made on the three-dimensional model of the machine. Noise sources are approximated as simple point sources, which radiate uniformly in all directions, considering that the properties of an idealized point source of sound will provide a sufficient description of the original, for the purpose of the method. In the noise model, sources are placed at the exact mass centres of their correspondents, identified on the CAD model of the machine.

The calculation related to the noise sources characteristics, sound propagation and combination is made by a package of computer programs, written in C language. Input data result from tree different sources: CAD model; database with noise emission data for a variety of mechanical equipment; sound power estimation, by calculus, for common industrial noise sources, using empirical formulas [1]. The outputs are transferred to the parametric solid modelling software, where the equal sound pressure surfaces are modelled, by using specific feature modelling techniques.

The presentation mode of the resulting acoustic environment consists of visual 3D scenes. This technique can be used to predict and analyze the spatial distribution of noise in a given volume surrounding the machine, to evaluate sound pressure levels in given points and also to estimate the sound power level radiated by the machine.

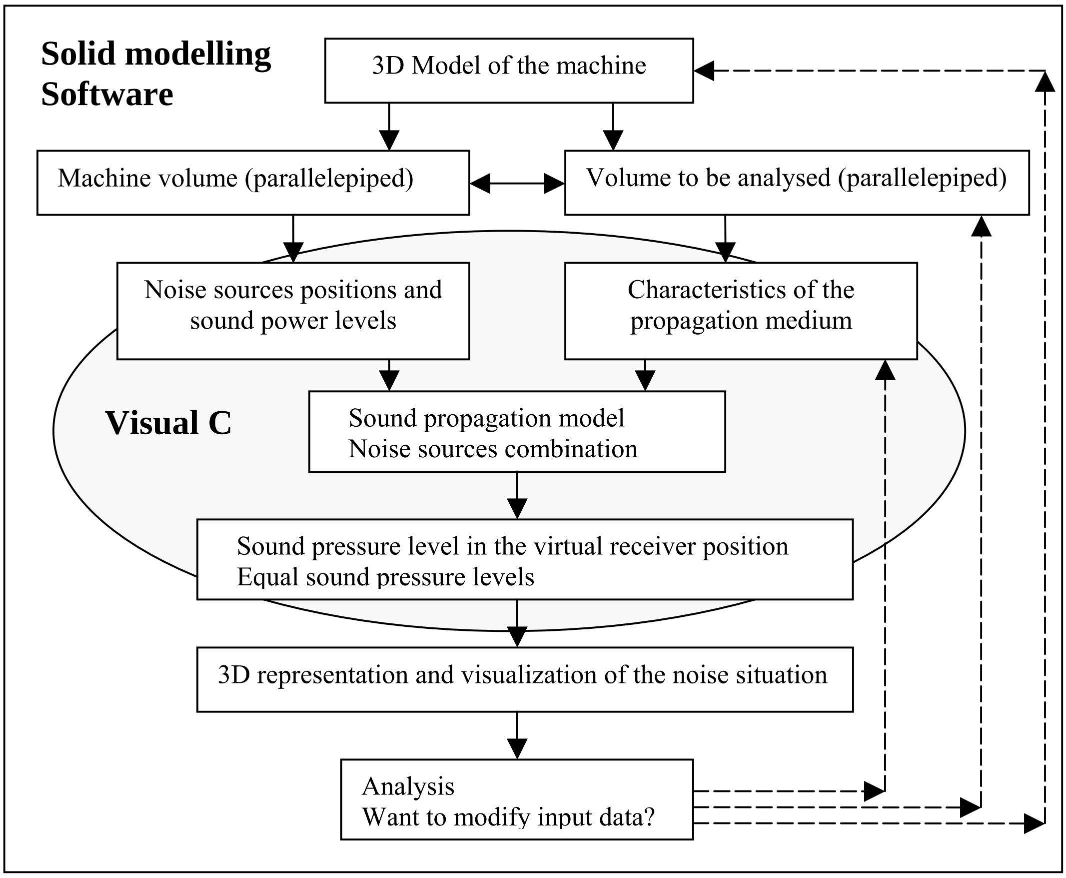

Figure 1 – Scheme of noise emission modelling method

CAD model towards noise model – main steps

During the design of the machine geometry, or starting from a given 3D model of the machine, developed inside a parametric 3D modelling software, different noise sources can be identified and also their geometrical and positional characteristics can be easily obtained. Starting from this point, it is possible to estimate the parameters of the acoustic field, in a given volume, surrounding the machine, taking into consideration three main elements: noise sources, characteristics of the propagation medium and receivers. For each of these elements, clearly input data must be supplied, aiming to ensure a good accuracy of the noise emission model. The following steps need to be considered in noise emission modelling (Figure 1):

1. Establish the volume to be analysed.
Two parallelepiped volumes are considered: the first one (V_1) is defined by the machine size: $L \times l \times h$ (length × width × high), the second one (V_2) includes the first one, at a distance D, its volume being calculated by: $(L + 2D) \times (l + 2D) \times (h + D)$.

2. Define noise sources and power levels.
Noise sources (S_i) positions are related to a coordinate system Oxyz (figure 2), attached to the previous defined parallelepiped volume V_1. They derive from the 3D geometrical model of the machine. The power level for each noise source is extracted from a database (developed on the bases of manufacturer or literature supplied data) or it can be calculated using theoretical or empirical formulas [1].

3. Define characteristics of the propagation medium
In order to estimate the parameters of the acoustic field in a given area, surrounding the machine, an acoustic model was associated, based on general concepts of sound propagation [1], [2], [7].

4. Insert equidistant planes in the model, as reference geometry
Planes P_1, P_2, … P_n are parallel with one of the faces of V_1 and will be used as construction planes for the curves of equal sound pressure level, through points calculated by the noise propagation calculation programs, written in C language. A rectangular mesh is defined on each plane. The width of the mesh cells may be establish by the user. Mesh points define positions for calculation of resulting sound pressure levels inside the analysed volume V_2.

5. Calculate sound pressure level at each point
The computer program for noise propagation, developed for this calculation, can place the virtual receiver in any point of the defined meshes. Also, for every mesh and for a given value of sound pressure level, points of equal sound pressure level are identified.

6. Present the acoustic environment as 3D or 2D scenes
Using the solid modelling software facilities for generating curves through points given by coordinates, curves of equal sound pressure level are created in every plane P_i. They give the support for the modelling of the surface of equal noise level, presented in three-dimensional view (figure 2) or in plane views, by plane sections.

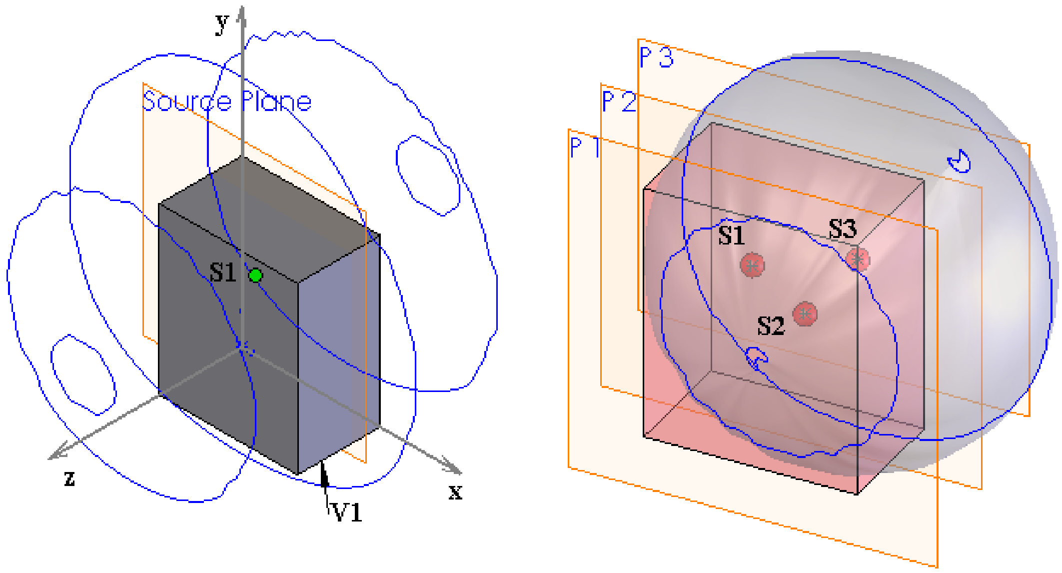

Figure 2 – Applications: curves and surface of equal sound pressure level

Significance of the method

The noise modelling technique, briefly presented before, is a simplified noise prediction method, useful for initial noise evaluations in the design stage. Since the numeric information is difficult to perceive intuitively and the audible information is for less use in this stage, the aim is to display noise field data on the 3D model of the machine, using the facilities offered by a solid modelling software. The calculated acoustic field and the spatial representation of noise distribution around the machine can be used for further noise control actions:

- predict the noise generated by a machine or equipment, on the basis of its virtual model, without building the physical prototype;
- identify the causes of high sound pressure levels and correct them by re-design the machine;
- calculate the noise exposure of the machine operator;
- estimate expected sound power level generated by machine or equipment;
- analyse different noise situations and action plans; etc.

The idea to build the noise model in the same environment where the geometric model of the machine was built before, make the noise model more flexible. It can easily be modified and adapted to derived geometric models, due to the parametric characteristic of the modelling software. During the presentation of the product to a new customer, both geometric model and noise model can be used.

The accuracy of the method may be improved by increasing the number of noise calculation points. It mainly depends on the input data and noise propagation algorithm used by the package of C language computer programs, which calculates the noise field.

CONCLUSIONS

The method described above enables the evaluation and 3D visual presentation of the acoustic field generated by a machine, based on its virtual model, before building the physical prototype. This method, when applied to an actual design project, should be useful for predicting the effects of the project on the working environment, for identification of noise problem situations and also for reducing noise by efficient countermeasures. Without leaving the working environment of the 3D modelling software, the designer may easily obtain basic information about noise emission data of the future product, presented in an intuitive manner.

While the method has been proven to be useful for aiding design, future work will be done for develop and improve associated algorithms and computer programs dedicated to the noise propagation calculus.

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