CALCULATION OF THE ACOUSTIC RADIATION OF A PARALLELEPIPEDIC STRUCTURE BY USING ACCELERATION MEASUREMENTS

PART 2: Determination of the acoustic radiation contribution of each vibrating side

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In the case of an existing machine, it is important to know the contribution of each part of the machine to the total acoustic radiation. One can thus identify main phenomena and estimate the gain earned by such or such way of noise reduction. A simple calculation software based on the vibrating measurements on the machine body is proposed to reply there. The theory has been presented in the first part of the article. The software has been used in the case of the radiation of a rectangular box, located on a rigid baffle, with two vibrating faces.

The calculated and measured pressure at one point is similar in the [0–3000] Hz frequency range except in some narrow frequency ranges.

The measured and calculated acoustic power does not present such zones, and the contribution of each plates to the total acoustic radiation can be obtained from the calculation of partial and total acoustic powers on the [0–4000] Hz frequency range.

In the chosen experimental case, the calculation of total and partial acoustic powers based on the only vibrating data knowledge, can be a performant tool for vibroacoustic diagnostic.

1. Introduction

The calculation of the acoustic radiation, based on the distribution of monopole sources (only vibrating measurements) solely valid in the case of the acoustic radiation of baffled plane structure, has been used in the case of a rectangular box, located on a rigid baffle, with two vibrating faces. The first part of the article has presented the calculation model and the main assumptions attached to the simplified theory (monopole sources and baffle condition) and to experimental conditions (measurement mesh, signal of phase reference).

This second part proposes to calculate radiated acoustic quantities (pressure and power) to allow to obtain a reliable tool of vibroacoustic diagnostic.

2. Experimental setup

The rectangular box studied is constituted of a rigid frame in full steel tubes (600 by 400 by 300 mm) on which them six faces are fixed. Two of steel faces (upper plate

and one of the vertical plates, Fig. 1) are considered as vibrating (thickness 5 mm). The four other faces are considered as rigid (steell plates of thickness 20 mm). The upper plate (600 by 400 by 5 mm) and the vertical one (400 by 300 by 5 mm) are each excited by an electrodynamic actuator supplied by a random signal (normal point force applied to the point $x=250$, $y=120$, $z=300$ mm and $x=0$, $y=290$, $z=150$ mm respectively). The two forces can be coherent or non-coherent.
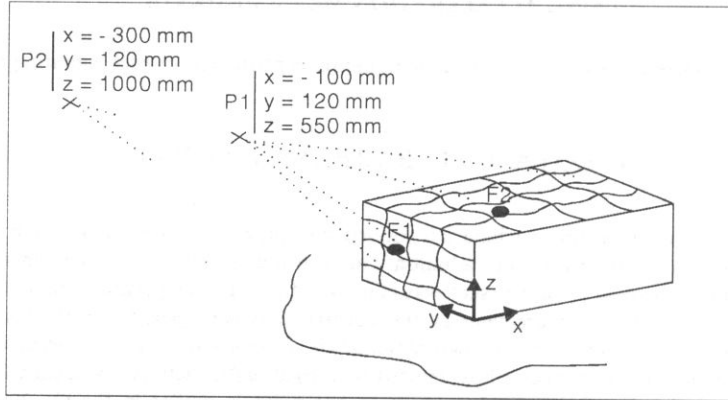

Fig. 1. Description of the box and position of the two points P1 and P2.

The vibrating velocity has been measured by a LASER vibrometer POLYTEC OFV 3000, the optical probe being placed automatically in each point of a mesh of 117 points (13 by 9) and 63 points (9 by 7) for the upper and vertical plates respectively. The distance between two consecutive points of the mesh is less than the half of the bending wavelength in the plates, this allows to cover the [0, 4000] Hz frequency range.

3. Calculation and measurement of the acoustic pressure

One proposes to test the simple calculation based on the concept of monopole sources. The acoustic pressure has been measured (microphones 1/2" B&K 4133) and calculated at two points P1 ($x=-100$, $y=120$, $z=550$ mm) and P2 ($x=-300$, $y=120$, $z=1000$ mm) (see Fig. 1). The Figure 2 shows the superposition of the calculated and measured acoustic pressure in the case where the upper plate is excited alone (Fig. 2a and 2b respectively at point P1 and P2), and in the case where the vertical plate is excited alone (Fig. 2c and 2d respectively at point P1 and P2).

Measured and calculated results are very close up to 3000 Hz except in some particular narrow frequency ranges. Trends are respected in the [3000—4000 Hz] frequency range.

The Figure 3 shows the superpositon of the calculated and measured acoustic pressure in the case where the two plates are excited simultaneously:

a) The two forces are coherent and the complex pressure is calculated from vibrating velocity of each of plates with a common phase reference (Fig. 3a and 3b respectively at point P1 and P2).

b) The two forces are non-coherent and the calculated pressure is the sum of quadratic pressures calculated separately for each of faces (Fig. 3c and 3d respectively at point P1 and P2).

Preceding conclusions can be renewed in the case of the two simultaneously excited plates by forces coherent or non-coherent.

The contribution of each of plates to the total radiated noise can be evaluated by calculation, by comparing the total acoustic pressure and the acoustic radiated by each of plates separately. The bad results obtained in narrow frequency range raised previously could generate an erroneous diagnostic.

The calculation of the total acoustic power and the partial acoustic power radiated by each face has then been studied. The acoustic power integrates a certain number of values of pressure and smooth local calculation problems put in obviousness in the case of a single value of pressure.

4. Calculation and measurement of the acoustic power

A first test has been undertaken in the case where only the upper plate is excited to compare the acoustic power obtained by calculation and by measurement.

The measurement of the acoustic power has been obtained by the intensimetry technic. The intensity probe (12.5 mm space microphones) has been placed in a regular mesh of 165 points (15 by 11), the measurement surface being thus bigger than the plate surface.
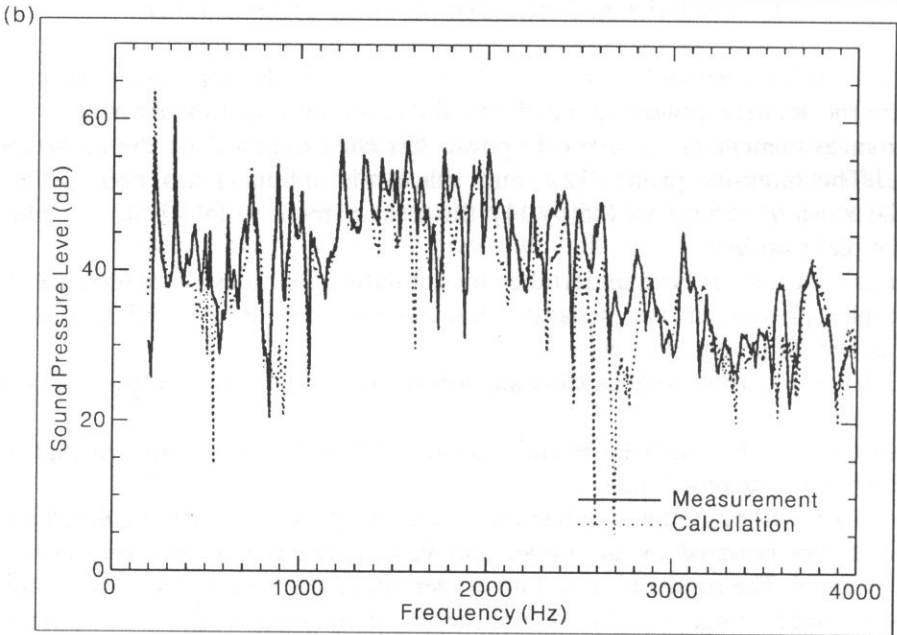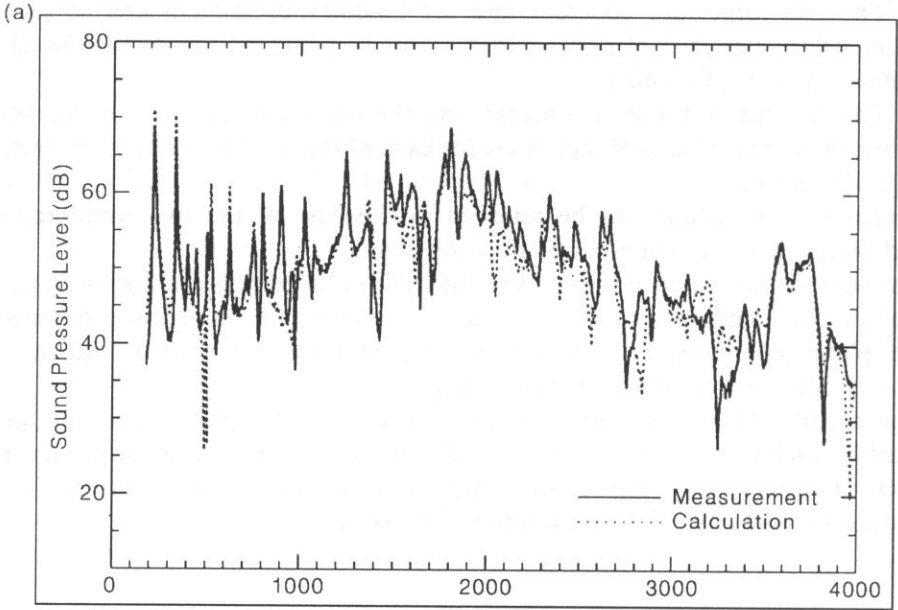
The calculation has been undertaken by simulating an intensimeter (calculation of the complex pressure in two separate close points separated by 12.5 mm) at each points of the same regular mesh.

The Figure 4 shows the flawless superposition of the measured and calculated acoustic power.

A second test has then been undertaken in the case where the two plates are excited by non-coherent forces.

The superposition of the calculated total acoustic power and the calculated partial acoustic power radiated by the upper and vertical plates is shown respectively in Figures 5 and 6. The results obtained no longer put in obviousness the gaps located in narrow frequency range as in the case of the calculation of a single value of pressure. The useful frequency range is similarly repelled up to 4000 Hz.

The participation of each of faces to the total acoustic radiation can then be analyzed. In this precise case, the upper plate mainly contributes to the total acoustic radiation and the vertical one contributes in some few frequency narrow ranges well identified.

(a) — Sound Pressure Level (dB) vs Frequency (Hz): Measurement (solid), Calculation (dotted)

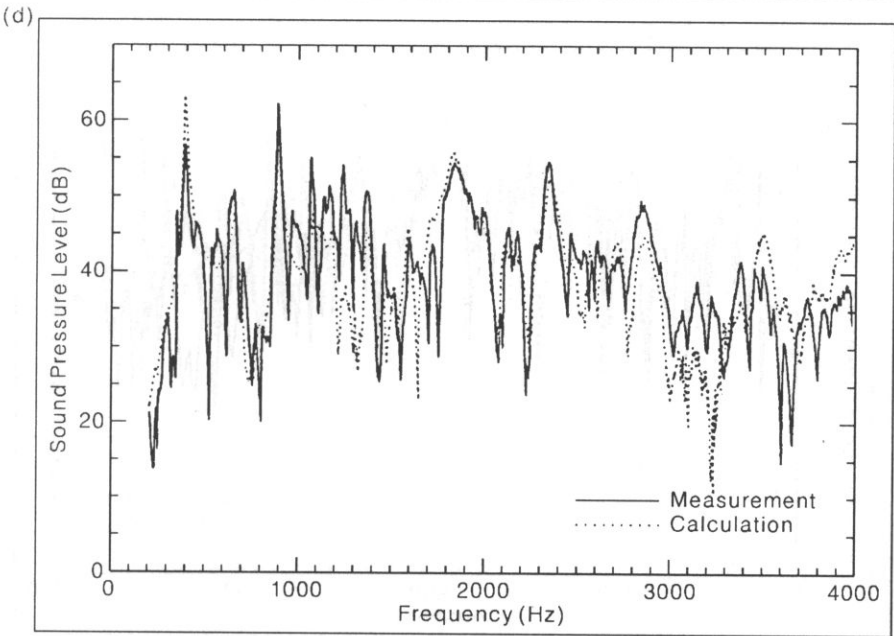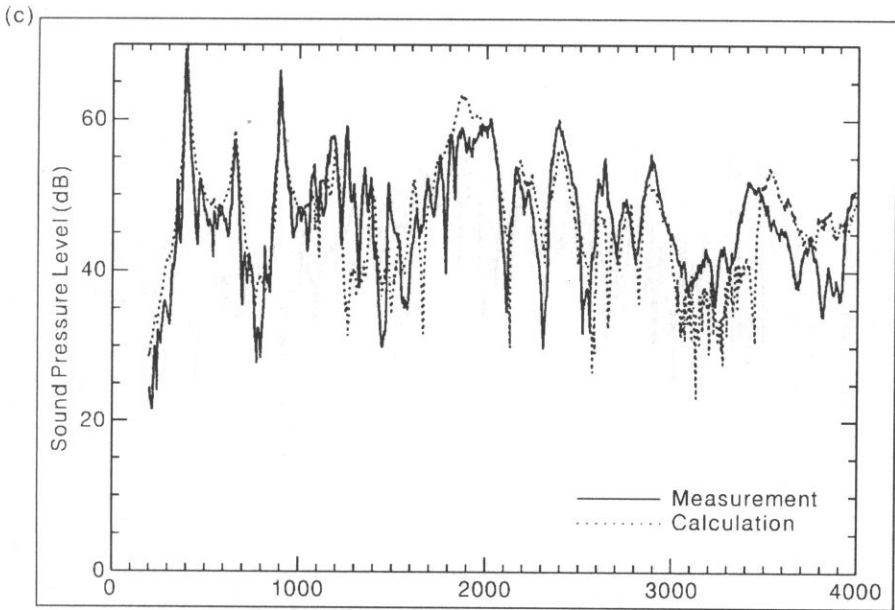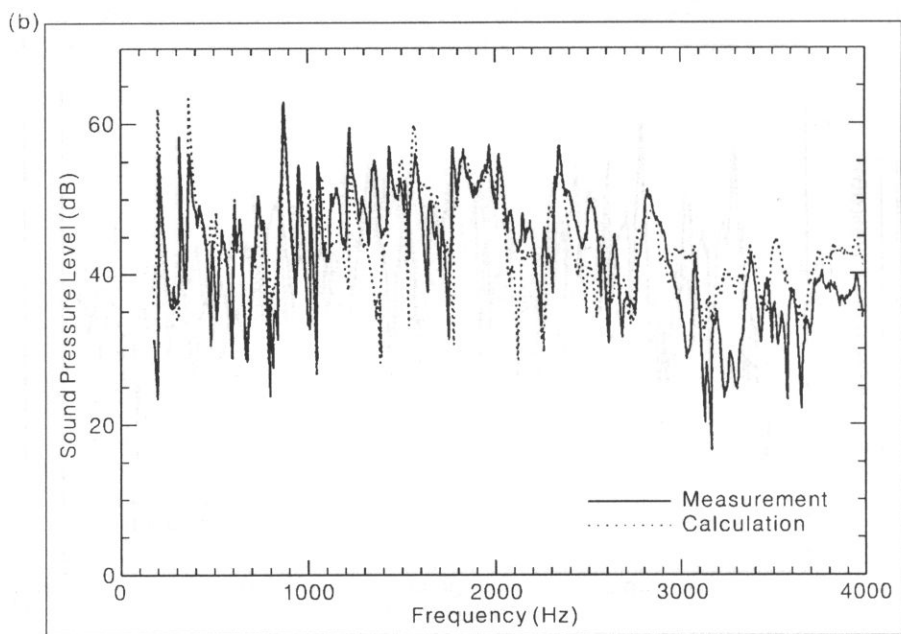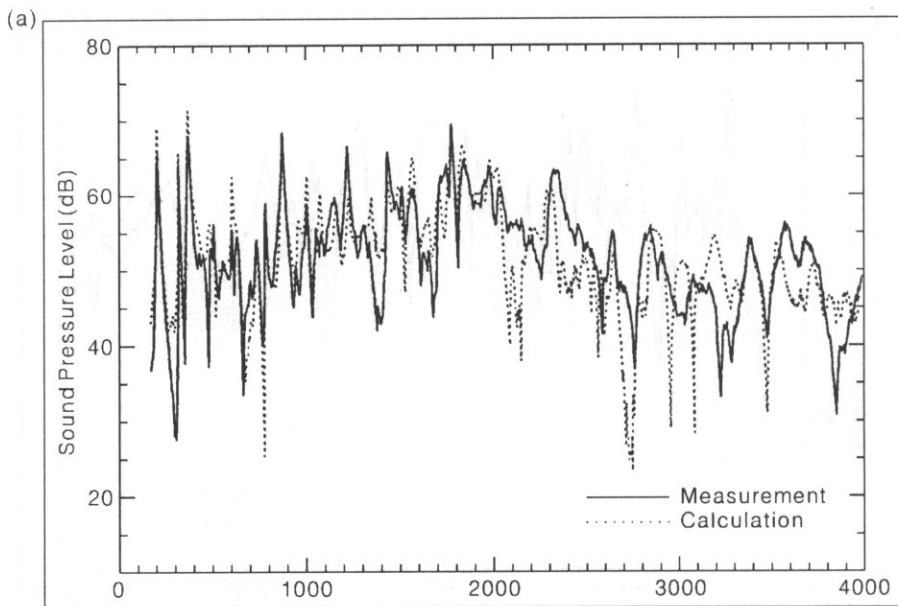(b) — Sound Pressure Level (dB) vs Frequency (Hz): Measurement (solid), Calculation (dotted)

Fig. 2. Measured and calculated pressure radiated by the upper plate, (a) at point P1, (b) at point P2, and radiated by the vertical plate (c) at point P1, (d) at point P2.
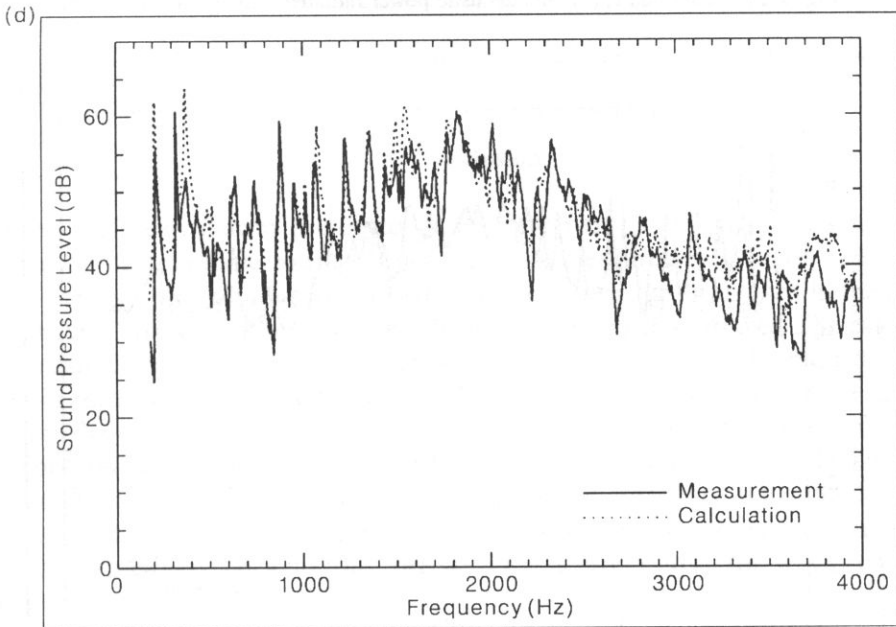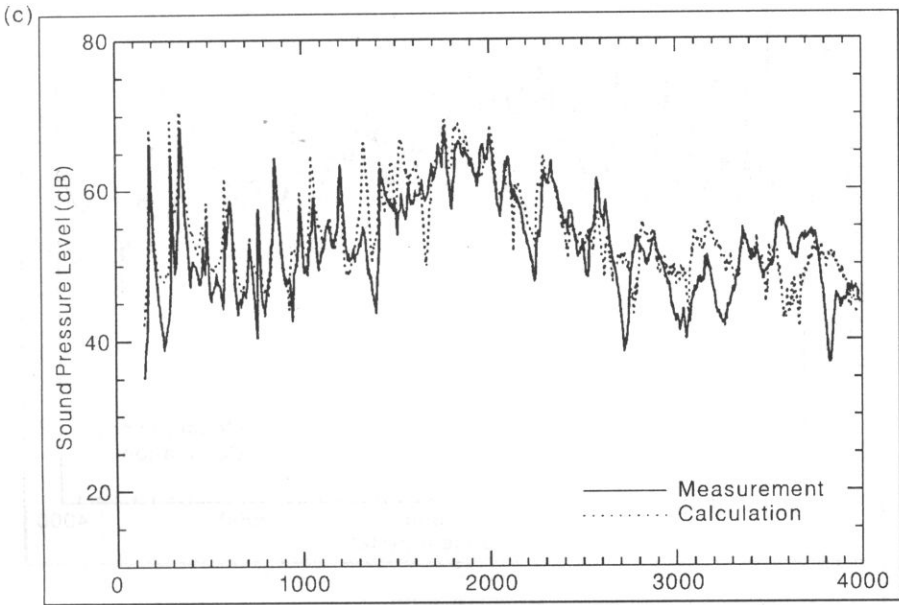
(a)

(b)

Fig. 3. Measured and calculated pressure radiated by 2 plates with coherent forces, (a) at point P1, (b) at point P2 and with non-coherent forces (c) at point P1, (d) at point P2.
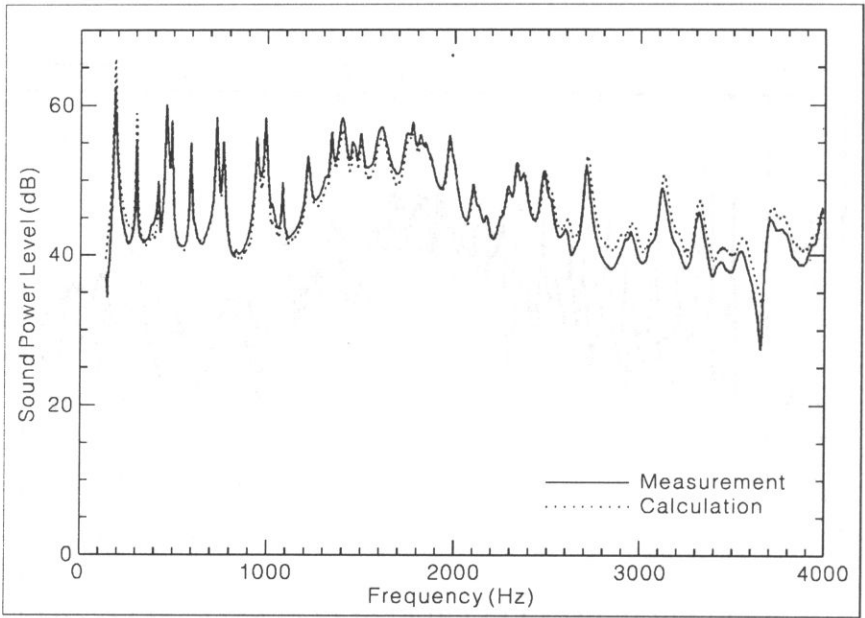
Fig. 4. Measured and calculated acoustic power radiated only by the upper plate.
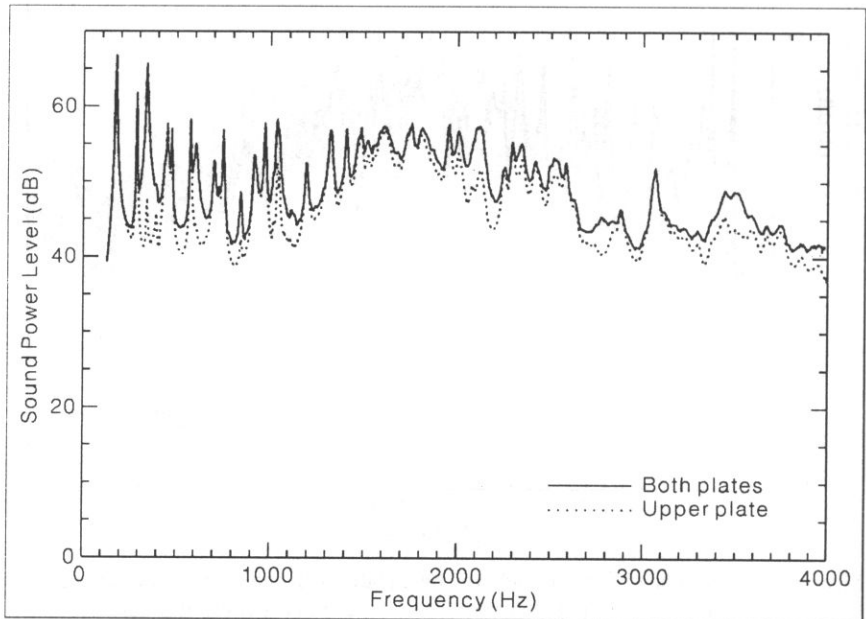

Fig. 5. Calculated acoustic power radiated by the upper plate alone and by the two plates.
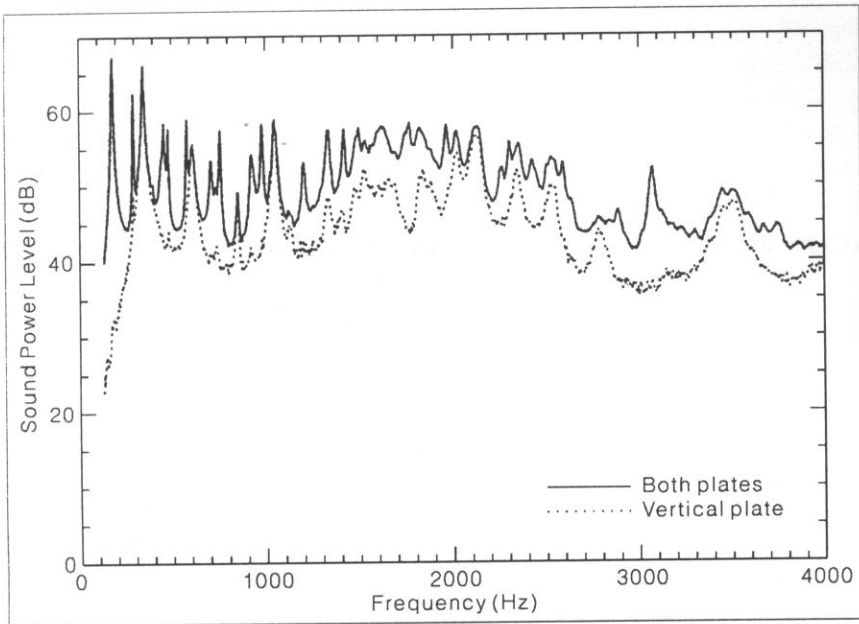
Fig. 6. Calculated acoustic power radiated by the vertical plate alone and by the two plates.

5. Conclusion

The simple calculation presented in the first part of the article, based on the distribution of monopole sources (only vibrating measurements) solely valid in the case of the aocustic radiation of baffled plane structure, has been used in the case of a rectangular box located on a rigid baffle with two vibrating surfaces. The calculated and measured pressure at a single point is similar in the $[0-3000]$ Hz frequency range except in some narrow frequency ranges. The calculated acoustic power, a smoothy quantity, does not present this kind of problem and gives very good results on all the frequency range of analysis $[0-4000]$ Hz. One can then obtain by calculation the total acoustic power and partial acoustic power of each face allowing to put in obviousness the each face contribution to the total acoustic radiation. The simple calculation used becomes in this precise case a good tool for a vibroacoustic diagnostic.