Vibro-acoustic behavior of a plane radiator in the case of impact excitation

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1. Introduction

In order to understand and reduce impact generated noise, the acoustic radiation due to the impact of a sphere on a plane, semi-complex structure (plate with general boundaries where point masses and stiffeners can be added) has been modelled. First, the force generated during impact is obtained with a time domain approach because of the non linearity of the problem. Second, a variational approach in the frequency domain allows the impact response and sound radiation from the structure to be calculated. The theoretical formulation is given in section 2. The experimental validation of the developed model is presented in section 3. Then, a first application case to a plastic granulator is given in section 4: the theoretical model enables to design a special impact reduction structure (thin street metal + elastic layer) and a noise reduction of 8 dB(A) was obtained.

2. Theoretical formulation

This structural acoustic radiation case involves coupling between excitation source (sphere impact) and receiving structure (planar radiator). The radiation problem is solved in two steps.

The first step is the calculation of the force input into the structure. The elastic deformation d(t), the structural impact displacement w(t) and then the impact force f(t) are obtained through a numerical resolution of the following system of equations [1]:

- Hertz law for the elastic deformation during impact:

$$F(t) = k\left(d(t)\right)^{3/2} \qquad (1)$$

- Newton law for the movement (w(t) + d(t)) of the projectile of mass m:

$$\frac{d^2}{dt^2}\left(w(t) + d(t)\right) = -\frac{F(t)}{m} \qquad (2)$$

- Movement of the structure at impact point obtained with the structure impulse response M(t):

$$w(t) = \int_0^t M(t-\tau) \cdot F(t)\, d\tau \qquad (3)$$

The second step enables to obtain sound radiation from the structure with the input force. A variational approach [2] in the frequency domain is used in order to consider a semi-complex structure.

3. Experimental validation

Because the structural radiation problem for a semi-complex structure has been already validated [2], the validation concerns the computation of the force generated during the impact. Two cases of receiving structure are considered: a semi-infinite structure and a clamped rectangular plate.

3.1 Case of a semi-infinite receiving structure

This experience serves to validate the hertz contact law. A steel sphere is dropped directly on a force transducer attached to a heavy steel structure. The results are shown in Figure 1. There is good agreement between theory and experiment. The continuing oscillation of the impact force observed in the experience is due to the transducer resonance.

3.2 Case of a clamped rectangular plate

This experiment serves to validate the complete force calculation model in a case where coupling effects between excitation source and receiving structure can't be neglected. A steel sphere is dropped onto a clamped rectangular plate whose motion is measured with a laser vibrometer. A laser vibrometer was used in order to measure the very high frequencies in structure velocity generated by the impact and to avoid mechanical coupling problems between the structure and the vibration transducer. Figure 2 gives the experimental results. There is good agreement between theory and experiments.

4. Application to a plastic granulator

The developed model was used to reduce the noise generated by plastic parts projections on the inside wall of a plastic granulator. A special impact reduction structure (thin sheet metal + elastic layer) was designed to cover the inside of the granulator (see Figure 3). An interesting result from the computation was that the important parameter for impact force reduction was the thickness of the thin sheet metal (the thinner the better) and the characteristics of the elastic layer did not matter much. Figure 4 shows the obtained noise reduction of 8 dB(A). This solution has several advantages over classical enclosure type solutions: it is low cost and does not interfere with production and maintenance operations.

5. Bibliography

[1] W. Goldsmith, Impact, London: Edward Arnold, 1960.

[2] A. Berry et al., J.A.S.A., 88(6), 1990.

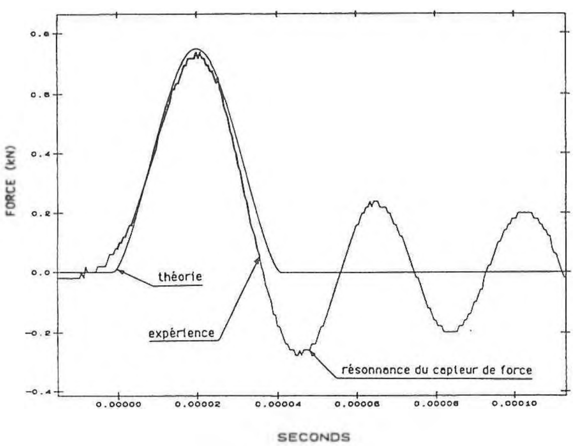

Figure 1: Impact force generated in the case of a semi-infinite receiving structure

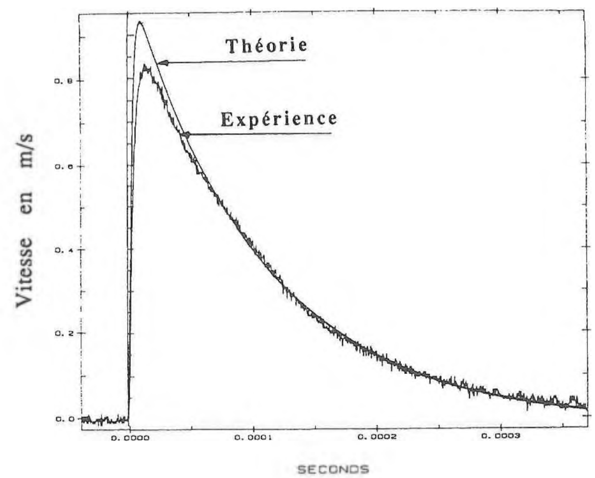

Figure 2: Structure velocity for a clamped rectangular plate

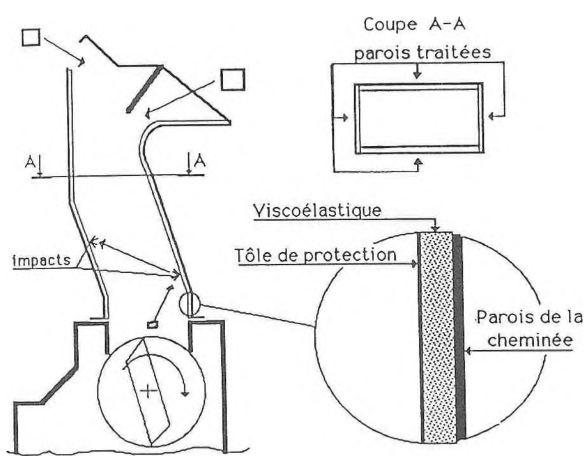

Figure 3: Special impact reduction structure for a plastic granulator

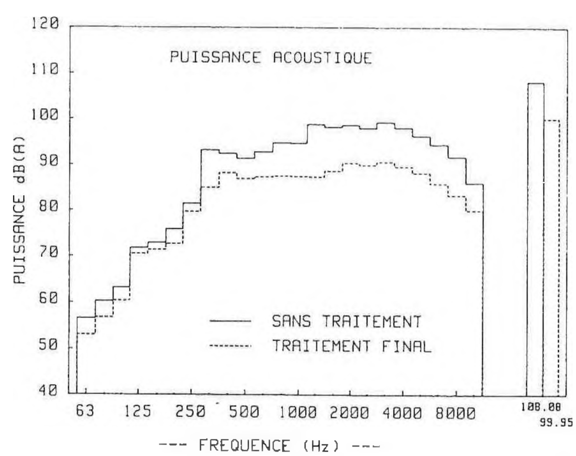

Figure 4: Noise reduction of 8 dB(A) obtained with the special impact reduction structure installed on the plastic granulator