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VIBROACOUSTIC BEHAVIOUR OF COMPLEX AND HETEROGENEOUS PLATES COUPLED WITH A CAVITY AND EXCITED AERODYNAMICALLY: CASE OF LARGE STRUCTURES

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1. INTRODUCTION

The noise transmission through moving structures is of high interest for aeronautical, automotive and railway industries : the structures are then generally large and contain many inclusions like picture windows.

The purpose is here to define, for that kind of problems, an alternative approach of discretization methods for preliminary draft studies at low frequency ranges (below few hundred Hertz). The guiding principle is to highlight the main physical phenomena which produce high internal sound levels.

Our approach is based both on an analytical modal description of the different parts of the system and on experimental investigations for acquiring some data we cannot actually compute (aerodynamic excitation data for instance).

We apply this technique to a parallelipipedic structure made up of thin orthotropic plates containing inclusions and excited with a turbulent boundary layer (T.B.L. : random excitation) and a vortex shedding (V.S.) generated by the interaction between the flow and an obstacle (harmonic excitation) : *Cf. figure 1*.

2. THEORETICAL FORMULATION

The first step consists in splitting the entire vibroacoustic problem into elementary ones which are easier to analyse, by applying a superposition law : we have then to treat a system made up of an heterogeneous plate (composed by a support structure and one or several inclusions) excited aerodynamically and coupled with a hard-walled cavity (*Cf. figure 2*). The different types of aerodynamic excitations are supposed to be decorrelated. The turbulent boundary layer is modelled using the cross spectral density of pressure defined in 1963 by G.M. CORCOS [1]. The vortex shedding is taken into account by a wall pressure distribution map which is determined using a mixed analytical-numerical and experimental method developed by M. MASSENZIO [2] & [3]. This method is built on an analogy between aeroacoustic sources created by the V.S. and a distribution of monopoles at the interface flow-obstacle. External acoustic medium respects Sommerfeld condition. The cavity can hold internal absorbent elements and can have absorbent upholstering. The inhomogeneous plate is thin, plane and baffled. Its modal scheme for transverse flexural vibrations is obtained with a Rayleigh-Ritz approximation while the internal acoustic pressure is deduced from an integral formulation.

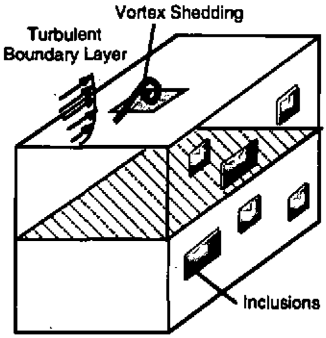

Figure 1

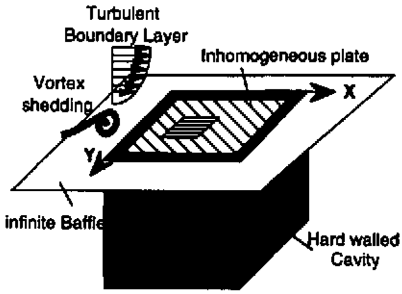

Figure 2

3. NUMERICAL RESULTS

In an earlier paper [4], we have investigated on an elementary system with quite small dimensions ($\approx$1 m^3) the effects of the orthotropy of the support plate, of the type of excitation and of the disturbances induced by the inclusions. Our purpose is here to have a better understanding of the vibroacoustic behaviour of large structures ($\approx$100 m^3).

We first compare computations with measurements realised in a double deck high speed train carriage at 220 km/h. In this case, the vortex shedding is generated in the gap existing between two carriages. Dimensions of the carriage are : width = 2,5m ; height = 4,0m ; length = 18,0m. For the computations, only the roof, the lateral faces and the middle floor are considered as vibrating surfaces and twenty two picture windows are modelled as inclusions. The coupling between hard walled cavity modes induced by the passenger seats and upholstering is neglected. We just consider the absorption effect with an equivalent acoustical damping coefficient (determined with a reverberation time measure). Results are provided *figure 3*.

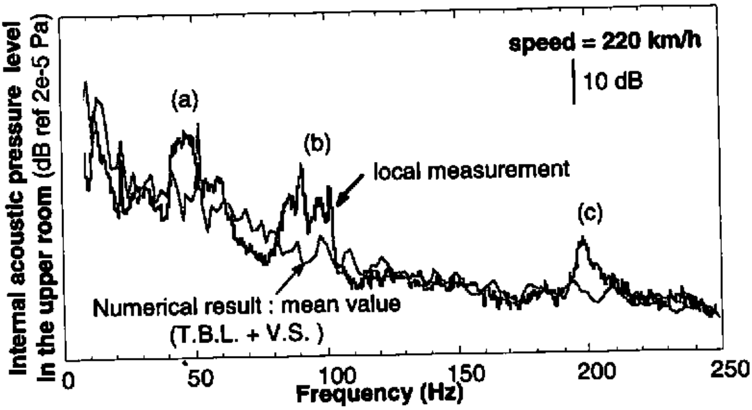

Figure 3

The experimental curve contains a continuous background level due to the T.B.L, on which appear three peaks marked (a), (b) and (c) generated by the V.S. We observe that the numerical result is conformable with the measurement except for the last two peaks (b) and (c). We have identified that this is just a consequence of a lack of harmonic components in the frequency spectrum of our V.S. model. We can then consider our vibroacoustic model validated in the case of a large and complex structure excited aerodynamically.

The second result concerns the effect of the orthotropy of the support plate when dimensions of the structure are very different in X and Y directions.

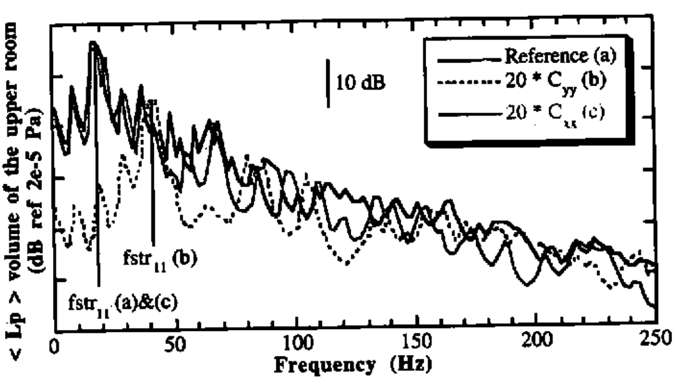

Figure 4

The studied system is composed of a lateral face of a double deck high speed train carriage (Ly / Lx = 0.1 , 5 picture windows) excited with a T.B.L. at 220 km/h and coupled with the internal volume of the upper room of the carriage. In *figure 4* a reference curve is compared to curves in which we have increased 20 times the Cxx and Cyy coefficients of the support plate's rigidity matrix [Cij].
It shows that the slender of large systems leads to a very high sensitivity of the rigidity matrix coefficients on the internal sound levels. Parameters in the transversal direction Y are the more sensitive ones because they have a great effect on the first structural eigenfrequency ($fstr_{11}$). And as it locates behind the first acoustic eigenfrequency of our system, modifying $fstr_{11}$ can strongly perturb the internal pressure levels.

4. CONCLUSIONS

The different results we have presented you lead to two main conclusions :

- on one hand, our simplified approach of the vibroacoustic behaviour of large and complex systems excited aerodynamically seems to be very accurate in the frequency range studied.
- on the other hand, numerical and experimental studies on scale models (volume ≈ 1 m^3) may be not representative of the principal acoustic phenomena occurring on the real object. So, when the total similarity does not exist, prototype tests remain necessary.

The main limits of our model concern :

- very low frequency range where structural coupling between the different faces of the parallelipipedic system is strong.
- frequency ranges where interface conditions between inclusions and support structure disturb strongly the internal acoustic levels.

We are now working on the possibility to have a multilayered support structure and inclusions of double windows type including elastic and dissipative limits with the main structure.

5. ACKNOWLEDGEMENTS

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