VIBROACOUSTIC PERFORMANCES OF AN ACOUSTIC BOX THROUGH HYBRID FE-SEA METHOD

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ABSTRACT

A numerical FE-SEA model of a box-shaped test article has been made in order to compare numerical with experimental results and to mark the improvement due to the addiction of local details with respect to pure SEA. The hybrid FE-SEA method is computationally efficient to investigate the behavior of the structure and the acoustic performances of the fluid volume inside the box, especially in the mid frequency range. The subsystems with long wavelength behavior are modeled deterministically with FE, while the subsystems with short wavelength behavior are modeled statistically with SEA. Although this method provides results as ensemble average response for each subsystem subject to small variations in terms of mass and geometrical properties, the numerical results shows a good level of agreement with the experimental ones.

1 INTRODUCTION

The dynamic behavior of a structure is strictly linked to the frequency range of interest. Typically, at low frequencies it is characterized by global modes and relatively long wavelength behavior, conversely at high frequencies it shows local mode shapes and short wavelength behavior. For this reason, at low frequencies finite element method (FEM) is widely used. When the frequency arises, FEM computational cost increases until it becomes unaffordable. Hence, at high frequencies statistical energy analysis (SEA) is mostly used, also because this approach is well suited when local modes are predominant. Nevertheless, there are some cases in which, in a certain frequency range, some components of the structure show a long wavelength behavior while other ones have a short wavelength behavior.

The hybrid FE-SEA method is especially useful in this kind of situations. In fact, the former components are modelled with FEM and the latter with SEA.

In this paper the hybrid FE-SEA method is used in order to obtain numerical results comparable with experimental ones. The use of hybrid method enables the introduction of FE details into a standard SEA analysis [1].

In particular, in this paper a box-shaped test article (Figure 1) has been analyzed in order to become familiar with this method. It is made up of a set of six panels which are pinned on a stiffer trapezoidal frame. Mechanical properties of the structure are listed in Table 1. The frequency range of interest is 200-4000 Hz.

2 EXPERIMENTAL SETUP

The boundary condition of the structure is free, so in laboratory it was simulated by suspending the system with four ropes. For each panel a series of accelerometers (both triaxial and monoaxial) provided the acquisition of the vibrational level. A pair of microphones was set inside the box to measure the SPL of the cavity. The load was given by a shaker and the generated signal was a white noise in the range of interest.

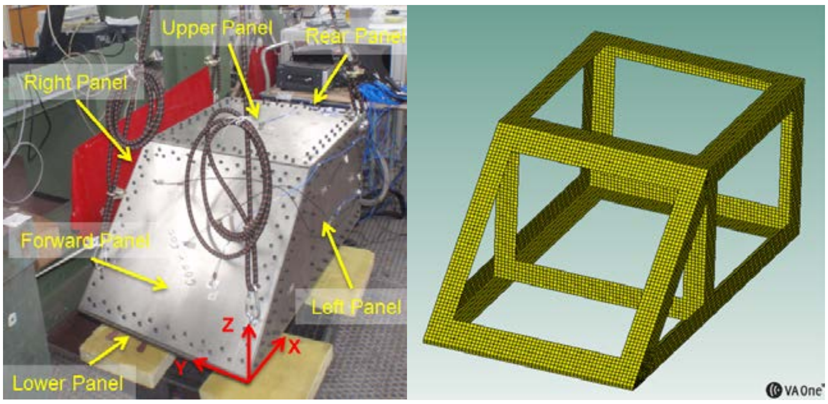

Figure 1- On the left: experimental setup of the box with specification of the panels name. On the right: internal frame modeled with VA ONE software.

	FRAME	PANELS
MATERIAL	Steel	Aluminum
t [mm]	8.3	1.0
E [GPa]	190	73
ν	0.30	0.30
ρ [kg/m^3]	7852	2780
DLF	1%	1%

Table 1- Material and mechanical properties of the system components.

3 MODELING

Two numerical models have been made: a pure SEA and a hybrid FE-SEA. The first thing to do in an FE-SEA model is establish which components are best modeled with FEM or SEA. In order to do so, it is important to analyze the modal density of each subsystem [2]. The frame is sufficiently stiff such that it has only 271 modes in the frequency range of interest and, so, it has been modeled with FEM, in particular, CQUAD4 elements with plate properties. For the six panels the flexural wavefield has been modeled through SEA plates, while the extensional and shear wavefields has been described with FEM, in particular CTRIA3 elements with membrane properties [3].

In order to decrease the level of uncertainty introduced by the SEA subsystems, FE punctual junctions between FE membranes and the FE frame have been taken into account and added in proper positions inside the virtual model. Hybrid line junctions have been provided on the edges of the box. They establish the coupling among adjacent SEA plates and FE membranes on each of their boundary. In fact, on each edge, the energy flows in the following manners:

- between an SEA plate and the correspondent FE membrane;
- between two SEA plates;
- between two FE membranes.

The acoustic part has been concerned introducing an SEA acoustic cavity with 1% absorption and some SIFs linked to the SEA panels. SEA area junctions have been used to allow energy flowing between the flexural wavefield and the cavity, while hybrid area junctions have simulated the energy exchange between the extensional wavefield and the cavity [4].

In the pure SEA model, every subsystem has a statistical formulation and information about punctual connections between frame and panels can’t be taken into account.
The software used for the analyses is VA One [5], which provides the possibility to combine in one work environment the SEA and FEM, in order to take advantage of both using the hybrid method.

4 RESULTS

In order to compare experimental and numerical results, the measured accelerations for each panel have been averaged such that a subsystem could be described by a single level of acceleration, that is the same result coming from SEA or hybrid FE-SEA method.

The numerical simulation shows that the numerical results are in good agreement with the experimental ones (Figure 2-3). SEA modeling brings to an overestimation of rear and upper panels acceleration level, but for the remaining panels it is near to the mean response starting from 800 Hz. This observation can be also successful extended to the acoustic noise transfer function (NTF), evaluated starting from the SPL of the SEA cavity.

Referencing to the hybrid FE-SEA results, it can be observed that panels acceleration levels and acoustic cavity SPL are very similar to the experimental ones starting in the whole analyzed range, both in terms of amplitude and peaks/valley behavior.

5 CONCLUSIONS

In this example the hybrid FE-SEA method reveals how much the SEA formulation can be improved by adding deterministic details and, on the other side, how much it can be beneficial to decrease the computational cost introducing an SEA formulation for appropriate subsystems.

The numerical discrepancies in terms of natural frequencies and amplitude could be due to the lack of information about the effective DLF spectra (the assumption of constant 1% is suggested by literature) and to an unvalidated model of the frame.

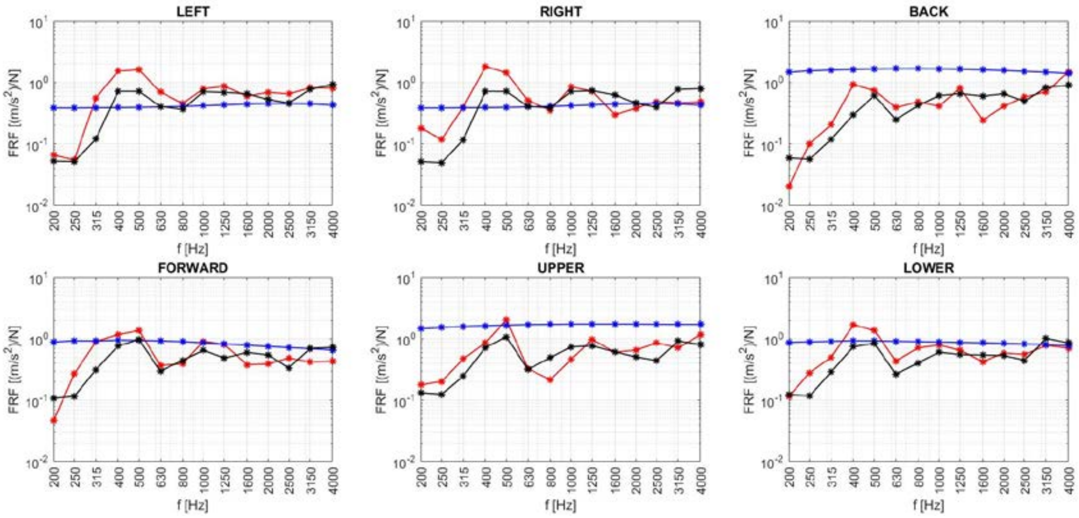

Figure 2- Comparison between experimental (red line), pure SEA (blue line) and hybrid FE-SEA (black line) results in terms of mean flexural acceleration FRF of the structure panels.

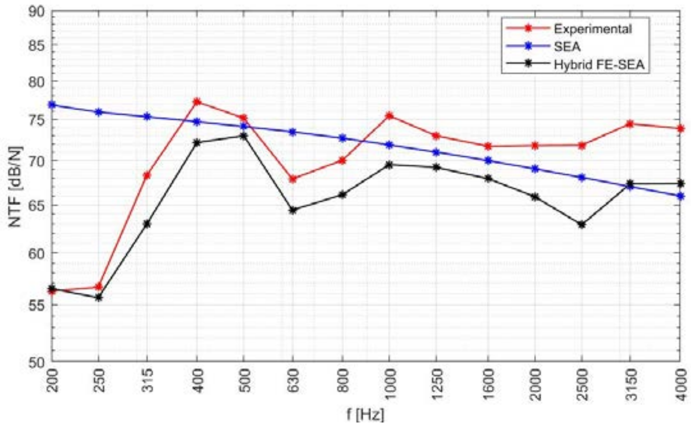

Figure 3- Comparison between experimental, pure SEA and hybrid FE-SEA results in terms of acoustic NTF for the cavity inside the analyzed box.

6 ACKNOWLEDGEMENT

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