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A HYBRID TOOL FOR QUICK CHARACTERIZATION OF COMPOSITE PANELS EQUIVALENT PROPERTIES

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ABSTRACT
It is well established that to develop a quiet machine, the best way is to take into account its acoustic radiation properties at the early stage of the conception by optimizing its geometry and material properties using acoustic prediction tools. Usually, prediction is made using Finite Element Method (FEM) and in most cases, these FEM codes require input data that cannot be easily obtained. This is particularly true when the material is a "home made" composite material (glass fibers with polyester resin, etc.), in a procedure that cannot ensure a rigorous control on thickness, density, etc. Consequently, there is a need for a tool that allows to quickly and easily characterize the "equivalent properties" of unknown composite panels in order to get input data for FEM codes (or for itself). In this paper, a method is proposed which uses a simple experimental setup and a fast numerical code running on a personal computer. This allows to extract equivalent properties of composite panels in terms of "young modulus", "density" and "damping factor" versus frequency. The experimental setup allows to test small rectangular panels (225 mm by 285 mm) with a very easy installing procedure (clamped at the corners). A dedicated numerical code (based on hierarchical finite element method) is used to fit parameters in order to match measured and simulated data. It is shown that this method allows to quickly extract useful equivalent properties for composite materials.

1 - HIERARCHICAL FINITE ELEMENT FORMULATION
The simulation part of this hybrid method is based on the hierarchical finite element formulation [1,2] of a rectangular Love-Kirchoff plate. The normal displacement of the plate is given by:

$$\mathrm{w}\left(\xi,\eta\right)=\sum_{\mathrm{r}=1}^{\mathrm{p}}\sum_{\mathrm{s}=1}^{\mathrm{p}}\mathrm{q}_{\mathrm{rs}}\mathrm{Q}_{\mathrm{r}}\left(\xi\right)\mathrm{Q}_{\mathrm{s}}\left(\eta\right) \tag{1}$$

where ξ and η are defined such that $\mathrm{x}=\frac{(1+\xi)\,\mathrm{a}}{2}$ and $\mathrm{y}=\frac{(1+\eta)\,\mathrm{b}}{2}$.
a and b are the length and width of the plate. The Qr basis functions set is presented in fig. 1.
This basis functions set is built from polynomial functions [1] for the first four functions and from trigonometric functions [2] for the rest. This functions set allows to easily define cinematic boundary conditions (free, simply supported, clamped, rigid point) on each edge and on each corner of the plate, simply by removing appropriate functions from the complete set.

2 - VALIDATION OF THE FORMULATION
Validation of the formulation is obtained by comparing the developed code results to those of well known codes: **MNS/ADNR** (MNS/ADNR structural acoustics and vibration software, MECANUM INC, http://www.mecanum.com) and ***SDRC-IDEAS Vibroacoustics***. Figure 2 shows a comparison of the developed code and IDEAS results (mean quadratic velocity of a plate excited by a shaker) in the case of a "Four corners pin clamped" case (see figure 4) for a homogeneous steel plate. This figure shows that the boundary conditions are well mastered by the developed code. Figure 3 shows a comparison of the developed code and MNS/ADNR results in the case of a "simply supported plate" case for a

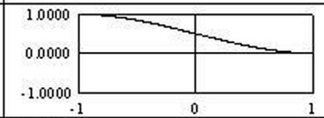
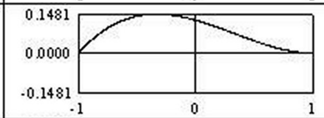
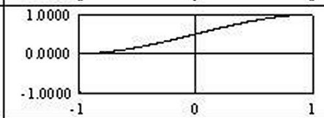
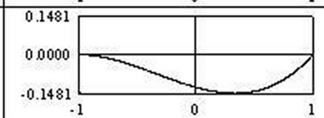
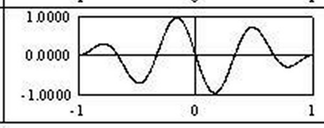
Function order	Equation	Hybrid set $Q_r(\xi)$
r=1	$Q_1(\xi) = \frac{1}{2} - \frac{3}{4}\xi + \frac{1}{4}\xi^3$	
r=2	$Q_2(\xi) = \frac{1}{8} - \frac{1}{8}\xi - \frac{1}{8}\xi^2 + \frac{1}{8}\xi^3$	
r=3	$Q_3(\xi) = \frac{1}{2} + \frac{3}{4}\xi - \frac{1}{4}\xi^3$	
r=4	$Q_4(\xi) = -\frac{1}{8} - \frac{1}{8}\xi + \frac{1}{8}\xi^2 + \frac{1}{8}\xi^3$	
r>4 For example here r =10	$Q_{10}(\xi) = \sin(3\pi\xi + 3\pi)\sin(5\pi\xi + 5\pi)$	

Figure 1: Hierarchical hybrid basis functions set.

viscoelastic plate (Young modulus and damping factor are frequency dependent). This figure shows that the developed code allows to efficiently simulate viscoelastic plates.

3 - EXPERIMENTAL SETUP

The measurement part of this hybrid method consist on a clamp fixture presented in figure 4 which allows to set "Four corners pin clamped" boundary conditions. This type of fixture have two advantages: (*i*) Easy mounting set-up (*ii*) Low vibration energy losses at the boundaries, allowing a better characterization of the intrinsic panel damping. The plate is excited by an electro-dynamic shaker and its mean quadratic velocity is measured using a scanning laser vibrometer coupled to a PC.

4 - VALIDATION OF THE EXPERIMENTAL SETUP

Figure 5 shows the comparison of experimental measurements versus theoretical prediction using the developed code. This result is the mean quadratic velocity of a steel plate excited by a shaker. Figure 4 shows that the experimental set-up allows actually to set "Four corners pin clamped" boundary conditions. Also, figure 6 presents a general view of the setup.

5 - EXPLOITATION OF THE METHOD

As example of exploitation of this hybrid method, figure 7 and table 1 represent respectively the "fitted" mean quadratic velocity and the extracted equivalent properties in terms of Young modulus and damping factor of an unknown composite panel made of Glass Fibers embedded in viscoelastic resin.

Frequency (Hz)	Young Modulus (GPa)	Damping factor
50	3.89	0.031
100	3.90	0.026
120	4.10	0.030
150	4.15	0.030
285	4.55	0.034
512	5.15	0.048
730	5.00	0.070

Table 1: Equivalent properties of the unknown composite panel obtained by curve fitting.

6 - CONCLUSION & PERSPECTIVES

This proposed hybrid method allows to quickly extract equivalent properties of unknown materials in

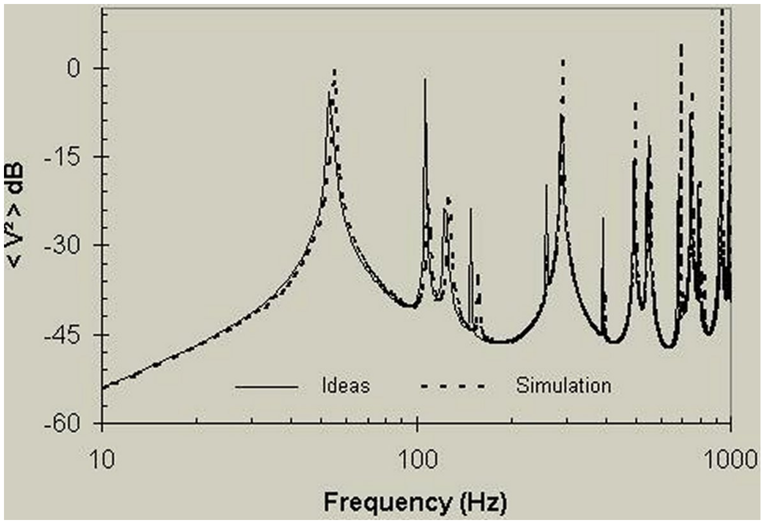


Figure 2: Comparison between Ideas and the developed code (steel plate).

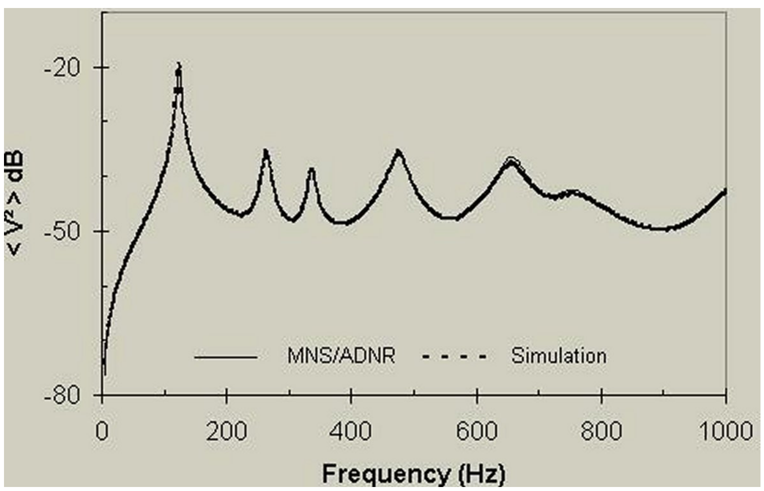


Figure 3: Comparison between MNS/ADNR and the developed code (viscoelastic plate).

order to obtain input data for finite element code and to help design. The fitted result presented in this paper has been manually fitted. The authors are presently studying an automatic fitting procedure.

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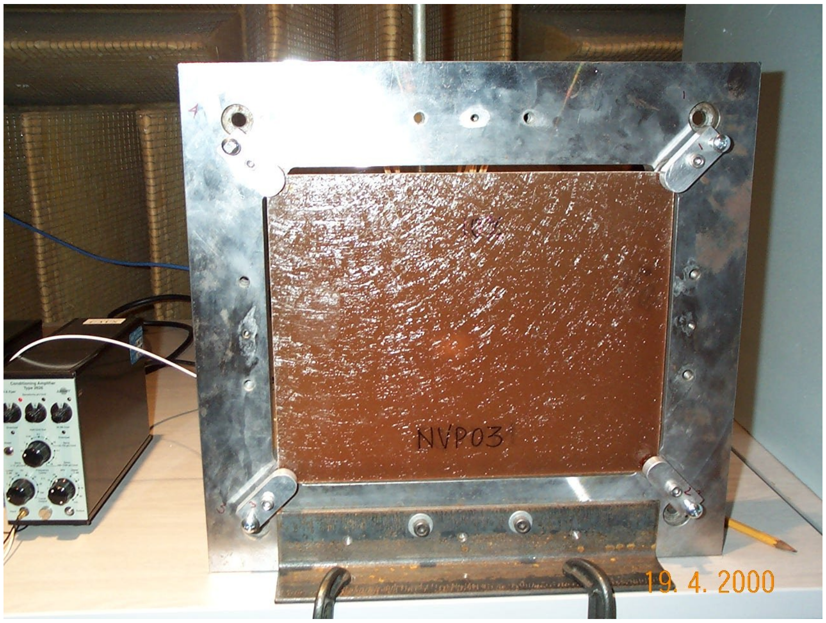

Figure 4: The plate fixture for experimental measurement.

Figure 5: Comparison of experimental result and simulation by the developed code.

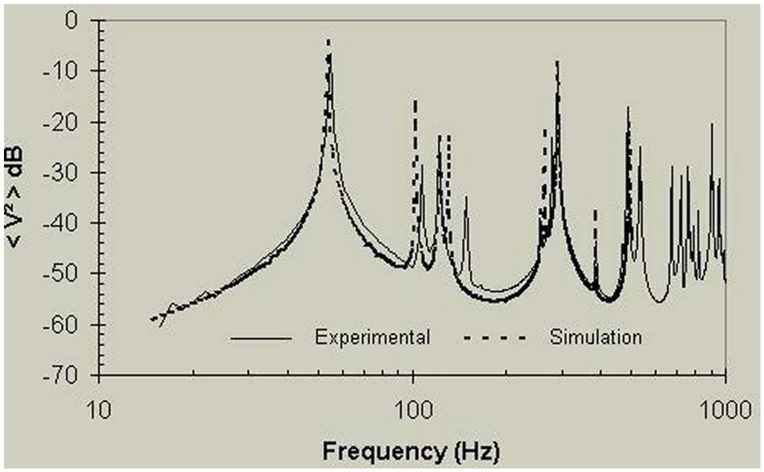

Figure 6: General view of the setup.

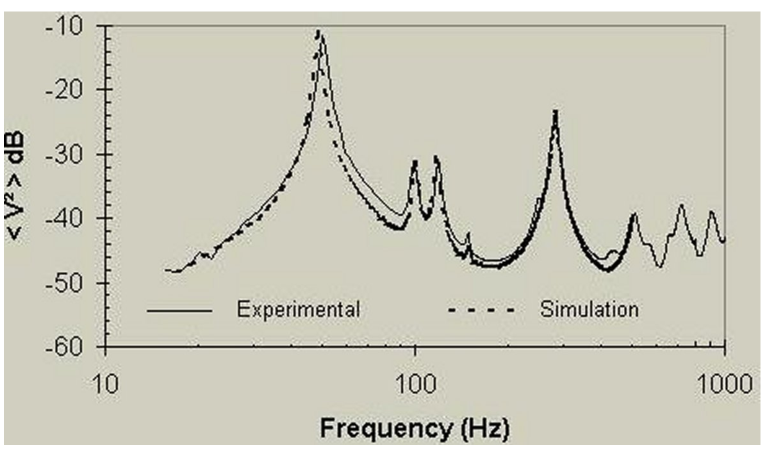

Figure 7: Example of characterization of an unknown composite panel.