VIBRATORY MEASUREMENTS TO ESTIMATE MECHANICAL PROPERTIES OF COMPOSITE MATERIALS

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1- INTRODUCTION

In practice, engineers frequently work with materials of unknown mechanical properties. However, pratically every aspect of the acoustic domain require the knowlegde of the elastic modulii, density and structural damping of material. These properties are easy to quantify for classical materials such as steel and aluminium. On the other hand, when we have to deal with composite materials, they may be more difficult to estimate. The purpose of this paper is to demonstrate that it is possible to find the mechanical properties of a composite material with the help of vibratory measurements.

2- EXPERIMENTAL METHOD

We have chosen to run our experiment with a fiberglass/polyester composite material. The sample tested was handcrafted using a wet layup and a chopper process. The mechanical properties found in the literature generally concern glass/epoxy composite materials with a particuliar fiber orientation [1]. However, very few publications concern glass/polyester materials[2]. Moreover, it is a known fact that the properties of a composite material vary a lot with the fiber/resin ratio which is difficult to quantify.

To begin our experiment, we designed a 0.48 m x 0.42 m x 6.86 mm simply supported rectangular plate. Since the plate's thickness varied (6.35 mm to 7.87 mm), we considered the tickness mean for our simulations. A shaker located at 8 cm and 7 cm from a corner was used to produced a pseudo-random excitation. Using a force-transducer and laser vibrometer, which mesured the displacement for a precise point, it was possible to mesure the frequency response (H1) between the imposed force and the plate's displacement. The frequency response has been mesured for 361 points on the surface of the plate with a span of 0 to 2400 Hz. Using all the frequency responses and a simple algorithm, we calculated the mean square velocity of the plate. Figure 1 shows the setup used in the experimentation.

3- IMPULSE EXCITATION

Since the results could not be analysed directly on site, we made sure that our measurements were accurate. In this way, we made some impulse excitation tests to verify if the frequencies found by impulse excitation corresponded to the one obtained with the mean square velocity. Table 1 shows the first five modal frequencies of the plate (f_{mn}).

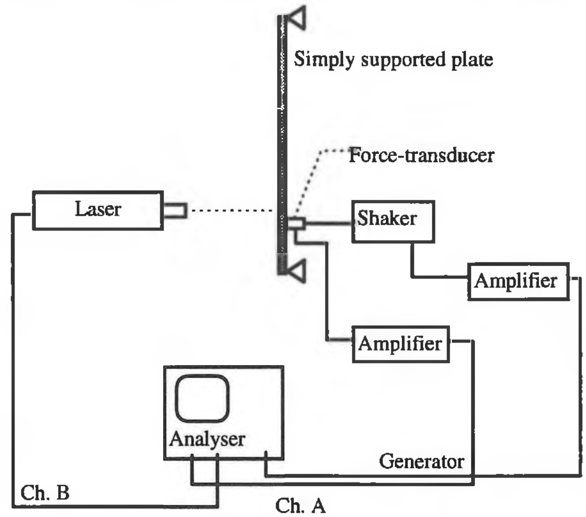

Figure 1: Schematic experimental setup.

Table 1

Comparison of the first five modal frequencies obtained by impulse excitation and mean square velocity

f_{mn} with impulse excitation (Hz)	f_{mn} with mean square velocity (Hz)
80.5	81.0
183.0	183.0
210.0	212.0
310.0	314.0
350.0	350.0

4- RESULTS

Knowing the frequency corresponding to the first experimental mode and the expression of the modal resonance frequencies of a simply supported isotropic panel (eq.1), it is possible to find a rough estimate for the elastic modulii.

$$\omega_{mn} = \sqrt{\frac{D}{\rho h}}\left[\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2\right] \text{ (rad / s)} \qquad (1)$$

where $D = \dfrac{Eh^3}{12\left(1-\nu^2\right)}$

a and b are the dimension of the plate
m,n = 1,2,3,...

With the use of a program called ADNR [3] developed at GAUS, which give us the opportunity to simulate the vibroacoustic behavior of a simply supported plate, we tried to obtained, by iteration, the same theorical mean square velocity as found in our experiment.

Figure 2 compares the experimental mean square velocity to the one simulated by ADNR. As can be seen, the vibratory levels and the position of the peaks are very similar. The properties used in ADNR to obtained this curve correspond to the real properties of the composite material or are very close.

Contrary to all expectations, the composite material used behaved like an isotropic material with the following properties:

E = 8.3 GPa	ρ = 1450 kg/m^3
ν = 0.26	$\mu = 10^{-2}$

If we look attentively at the experimental curve, we note a few irregularities in the mode definition. Those irregularities are mainly due to the fact that the plate is not perfectly homogeneous and has a small variation in thickness. This fact also introduces the same modeat two frequencies, therefore doubling the mode. This phenomenon can be seen at 530 Hz and 1400 Hz. In general, this method gives very good results.

4- CONCLUSION

We have presented a method that gives the opportunity to quantify the mechanical properties of materials by using vibratory measurements. This method consists in correlating the theorical mean square velocity of a simply supported plate to the one obtained experimentally. We applied this method to a composite fibreglass/polyester material and we obtained very good results. It is then possible to predict precisely the acoustic power radiated by such material.

5- ACKNOWLEDGMENTS

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6- REFERENCES

[1] LOUIS A. Roussos, C.A. Powel, F.W. Grosveld, and L.R. Koval, *"Noise transmission characteristics of advanced composite structural materials,"* J. Aircraft, **21** (7), july1984, p 528-535.

[2] E.O. Ayorinde, R.F. Gibson, *"Improved method for in-situ elastic constant of isotropic and orthotropic composite materials using plates modal data with trimodal and hexamodal Rayleigh formulations,"* Journal of Sound and Vibration and Acoustics, Transactions of the ASME, **117**,april 1995, p 62-69.

[3] O. Foin, *" Étude du comportement vibro-acoustique de plaques multicouches, "* M. Sc. A , Université de Sherbrooke, Québec, Canada, mars 1995.

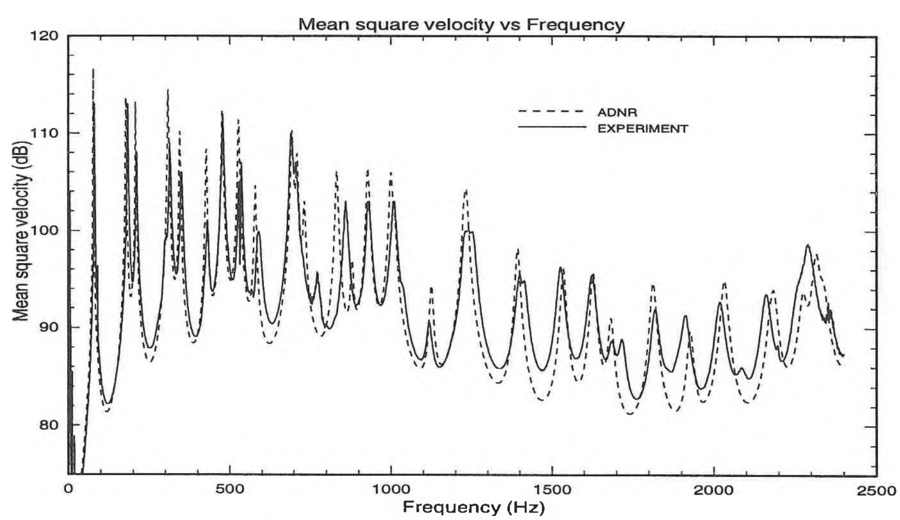

Figure 2 : Comparaison of the experimental and theorical mean square velocity.