PREDICTABILITY OF THE VIBROACOUSTIC RESPONSE OF SEMI-COMPLEX STRUCTURES

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1. INTRODUCTION

The prediction of the vibro-acoustic response of structures has been and is still a very important subject for which many approaches are proposed, mainly semi analytical, numerical and statistical. Great progress has been accomplished in the formulation and understanding of the vibration and acoustic radiation of basic structures such as beams, plates and shells. However, the number of formulations is so important that several researchers and engineers become skeptical about their rightness. At this juncture, some may question about the validity of those predictions. Two great types of validations may be performed (i) undertake systematic comparisons of theoretical models on given precise academic cases as undertaken by the Commission de Validation de la Société Française d'Acoustique or; (ii) test the validation of theoretical models versus experimental data. This will be the purpose of this paper.

The work presented here are the results of a team effort on the part of the Groupe d'Acoustique et Vibrations de l'Université de Sherbrooke. The predictability of actual situations has been analyzed in recent years for two types of basic structures, plates and shells.

The main idea lies in the fact that to evaluate the precision margin of our theoretical predictions, we have decided to start with basic academic structures and then, add degrees of complexity up to an actual situation. In this paper, we will address the case of shell-type structures, and due to lack of space, only some of the results will be presented.
2. THEORETICAL APPROACHES

Interestingly enough, it has been decided from the beginning to develop two different theoretical formulations, one is based on so-called semi-analytical methods while the other is based on numerical (F.E.M., B.E.M. methods). We have not enough space here to describe these formulations. Details are given in references [1,2,3,4,5]. The two types of formulations have been developed in order to predict cases with various degrees of complexity:

a) Small semi complex shell:
   - A simply supported cylindrical shell;
   - Same shell plus added stiffeners or stringers;
   - Same shell plus added partial damping;
   - Same shell, closed at both ends, defining a cylindrical cavity.

b) Actual shell:
   The actual shell is the 1/3 scaled-down Canadair's R.J.'s fuselage shown in figure 5. The dimensions are $L=4.84$ m; $\phi=0.449$ m; $t=6.34\times10^{-2}$ m. It includes 50 stiffeners, 39 stringers, the floor, the bulkhead and all this assembled by about 40 000 rivets. In that case, only the numerical formulation has been used for comparison purposes.

3. EXPERIMENTAL SET UP

The experimental setup is described in figure 1. The shell is made from a steel plate welded on a longitudinal line. The dimensions are $\phi = 0.36$ m, $L=1.01$ m, $h=1.2$ mm. The key feature lies in the realization of simply supported boundary conditions. It consists of a circular plate which insures no translation at the end of the circular shell. Also, this plate has been perforated sufficiently to allow rotation. All the instrumentation, transducers, shakers and computer analysis is classical. Great care has been given to the repeatability and validity of F.R.F. measurements as well as the modal analysis.

4. PREDICTABILITY : THEORY VERSUS EXPERIMENTS

- **Bare cylindrical shell**: (Fig. 2)
  The quadratic velocity has been obtained with 360 measurement points referred to the excitation force. The comparison is made against the analytical and the numerical models. The agreement is quite excellent except for mode (2,1) which is very sensitive to the boundary conditions and to the dissymmetry induced by the welded seam.

- **Cylindrical shell plus three stringers**: (Fig. 3)
  The results are quite interesting; two important trends have been identified. Firstly, the analytical model starts to deviate from the numerical model. We have found that this is due to a difficulty in the convergence of the Ritz approach when modes are strongly coupled.
Secondly, experimental data starts to deviate more than in the bare cylindrical shell case.

- **Cylindrical cavity**: (Fig. 4)
  
  The quadratic pressure inside the cylindrical cavity (cylindrical shell with two rigid end caps) has been measured. A very important phenomena can be pointed out: the spatial coupling with higher order acoustic modes and low order structural modes is quite important. Specifically, this means that acoustic modes up to 2500 Hz have to be included even though the response up to 350 Hz only is desired.

- **Actual structure**: 1/3 scaled down model of an airplane fuselage
  
  The 1/3 scaled-down model is shown in figure 5. A finite element numerical model has been built which includes stiffeners, stringers, bulkhead and the floor. The experimental quadratic velocity response of the fuselage is compared to the numerical simulation as shown in figure 6. Although the tendencies are there, discrepancies are significant. (Note that an in-depth modal analysis has been performed where orthogonality, MAC coefficients, mass control as been verified). The conclusions are the same for the acoustic response (Fig. 7).

5. **CONCLUSIONS**

A systematic study of the predictability of theoretical models has been performed for cylindrical shells. In the academic case (bare shell), analytical, numerical and experimental data show excellent agreement. When progressively adding degrees of complexity, several interesting conclusions may be drawn: structural inhomogeneities, defects, and non linearities cause discrepancies the more the structure resembles an actual one.
Figure 2. Small shell

Figure 3. Small shell + 3 stringers

Figure 4. Cylindrical cavity
Figure 5  
1/3 scaled-down R.J. fuselage

Figure 6  
1/3 scaled-down RJ fuselage : vibration response

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<th>Frequency (Hz)</th>
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References
Periodicals:

Others: