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On the comparison of formulations for model reduction of harmonic frequency-dependent damped fluid-structure problems

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When dealing with FEM models of vibroacoustic problems including frequency-dependent devices like porous or viscous interfaces, some model reduction techniques are required to keep the computation time as low as possible, in particular for optimisation or uncertainties propagation purposes. In this context, several formulations [1, 2, 3] can be found in the literature, which generally differ from one to another by the choice of the variable used for the fluid description (typically, displacement, pressure, velocity potential or displacement potential are available). Each of these formulations has some characteristics which induce specificities in the numerical treatment of the problem, in particular in terms of size and symmetry of the final matrix system [1, 4].

In the context of model reduction, one of the classical approach consists in using Ritz bases constituted with shapes which are solution of the decoupled system, in which the acoustic domain has rigid boundaries while the structure vibrates in vacuo [5, 6, 7]. From the point of view of the structure, this is reasonable while the fluid is light (e.g. air), while even in this case, the fluid boundary condition do not correspond to those observed in the coupled system. This is the reason why if one wants a good estimation of the acoustic field, a very large number of modes should be included in the fluid basis. Some information about convergence rate properties of these formulations for modal analysis of coupled systems can be found in literature, and the purpose of this paper is to propose an equivalent work concerning convergence properties of decoupled bases for model reduction of vibroacoustic problem in the context of harmonic response when the problem includes poroelastic materials with frequency-dependent parameters in the fluid domain.

Two configurations are tested, a simple parallelepiped box closed by an elastic plate, and a more complex case exhibiting some curved panels. On both models, a porous layer is considered in the acoustic domain. The quantities of interest are the acoustic power in the cavity and the mean squared velocity of the vibrating structure, in harmonic response due to structural excitations.

The analysis is then focused on the number of fluid modes in the Ritz basis, for estimation of the damped harmonic response. The convergence rate properties of the considered formulations are given for the two configurations, and a particular attention is paid on the effect of inclusion of the so-called "static" mode in the fluid basis. This can be either included in the basis itself (indicated as p^s in the figures) or considered as added effect on the structural matrices due to the presence of fluid [5, 8] (indicated as p_0 in the figures).

Both examples exhibit the same trends: the static mode should be included for correct estimation of the response, and the presence of the coupling surface and the poroelastic media induce very slow convergence to the reference solution.

Some ways to improve convergence are finally suggested in order to improve the convergence of the procedures [9].

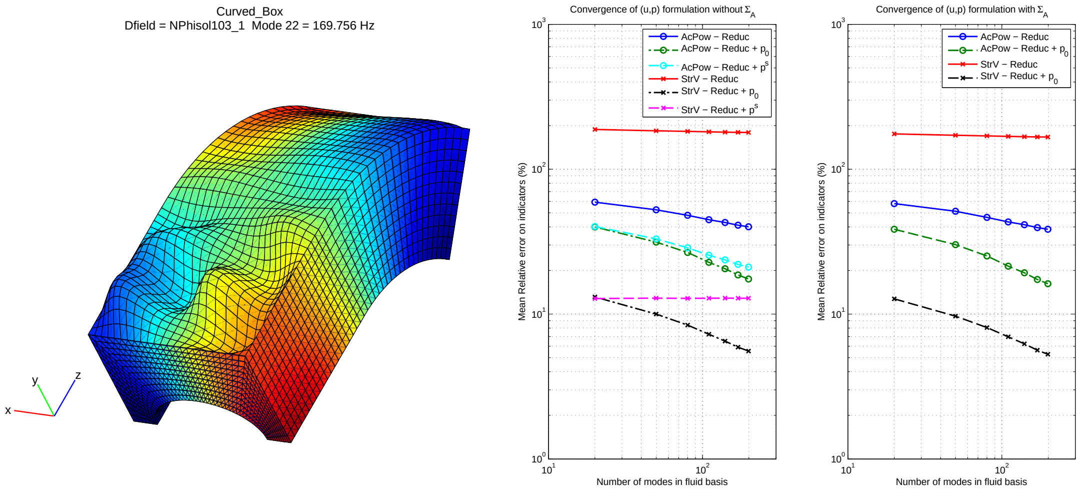

Figure 1: a) One of the modes of the "curved" box (color = acoustic pressure, shape = structural displacement); b) Convergence of harmonic response with/without porous material, in terms of acoustic power (AcPow) and quadratic structural velocity (StrV), when the projecting bases include or not the "static" terms p^s or p_0.

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