MODELING ACOUSTIC RESPONSE OF STRUCTURALLY COMPLEX SHELL SYSTEMS

Jordi Rubio*, Serguei Iakovlev, Pedro Diez***
*Laboratori de Calcul Numeric, Departament de Matematica Aplicada III,
Universitat Politecnica de Catalunya, Barcelona, Spain
**Department of Engineering Mathematics and Internetworking, Dalhousie University, Halifax, Canada

1. INTRODUCTION

One possible approach to modeling non-stationary acoustic radiation by cylindrical shells is to employ the classical analytical methodology of mathematical physics (e.g. [1-4]). The resulting methodology (which we will refer to as the "response-functions-based methodology") is very robust and computationally efficient, but, unfortunately, it has a very substantial shortcoming of not being able to handle geometries different from the simplest classical ones (e.g. spherical and cylindrical). In order to overcome this lack of versatility, an idea was proposed to combine the response-functions-based approach with FEM, thus producing a methodology that would combine the computational efficiency of the former with the geometrical versatility of the latter.

2 Problem formulation and solution methodology

The fluid domain is assumed to be governed by the wave equation, which is solved using a combination of the separation of variables and Laplace transform (spatial and temporal variables, respectively). The methodology has been discussed in detail in our earlier work [1-6], and we do not reproduce the respective discussion here, but summarize that the approach produces the acoustic components (diffracted and radiated one) in the form of a Fourier series with time-dependent coefficients which, for the radiated pressure, also depend on the normal displacements of the outer surface of the shell.

The structural part is approached using a 2D plane strain model discretized with the finite element methodology, with the normal displacements of the structural surface passed to the fluid solver at each time step and the total acoustic pressure received from the fluid solver, also at each time step, thus the coupling between the two solvers is accomplished.

3 RESULTS AND DISCUSSION

In order to test the capabilities of the methodology, we considered several structural configurations, and present the results for one of them here. But first, we remark that the model has been extensively tested using several benchmark problems, and a very good agreement with experimental data was observed for thin shells without any structural enhancements.

One of the most typical scenarios of industrial relevance is a shell with two attached masses of dimensions that are comparable with the thickness of the shell, Figure 1.

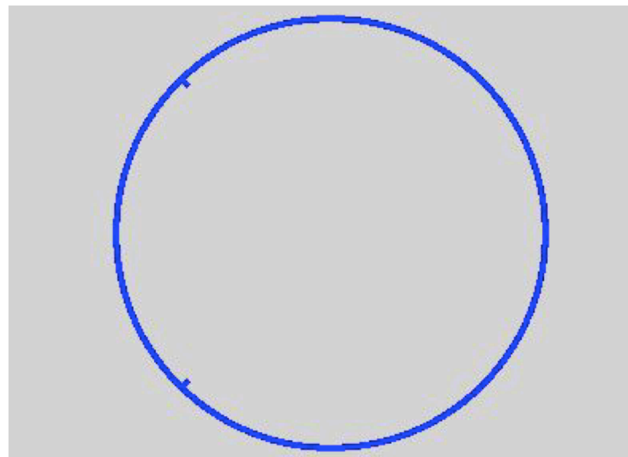

Figure 1. Shell with two "light" attached masses.

For such a configuration, the attached masses were observed to act in a "source-like" manner when the structure (a steel shell with the thickness-to-radius ratio of 0.03 submerged into water) was subjected to a single acoustic pulse, Figure 2. This behavior is a very characteristic feature that was observed in similar systems in experimental studies that offer acoustic field images [7], and having demonstrated that this behavior indeed takes place provides additional confidence in the physical adequacy of the developed model.

We note that the respective wave pattern is rather complex, and appears to have several different components to it. This is also consistent with the experimental results [7] where several different types of radiated waves were seen to emerge, in particular the symmetric Lamb wave S_0, the antisymmetric (or pseudo-Rayleigh) wave A_0, and the Scholte-Stoneley wave A. Thus, the present approach appears to be quite adequate for accurate modeling of the complete structure of the radiated field since the fluid solver has been demonstrated to produce very good results for simple shells in that it accurately reproduces all known types of radiated waves [8].

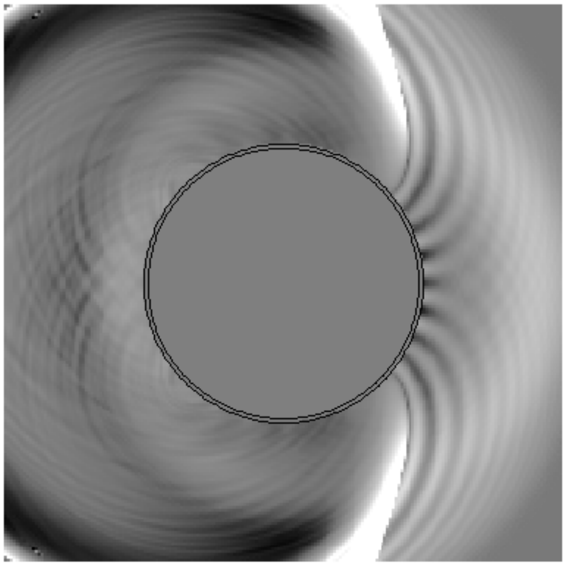

Figure 2. The "source-like" behavior of the attached mass.

6 CONCLUSIONS

Judging from a number of studies that we carried out for some of the most typical structural configurations of industrial relevance, we can conclude that the proposed methodology appears to be a very efficient tool for modeling the acoustic response of cylindrically shaped, structurally complex submerged structures.

The methodology appears to be particularly attractive for the use at the pre-design stage where it is often necessary to carry out extensive parametric studies, and where higher computational efficiency is a considerable asset.

ACKNOWLEDGEMENTS

S.I. gratefully acknowledges the support of the Natural Sciences and Engineering Research Council (NSERC) of Canada. The mobility grant for scholars provided by the Erasmus Mundus program in the framework of the Master of Science in Computational Mechanics (FPA 2013-0220 2014 Erasmus+) is also acknowledged.

REFERENCES

1. Iakovlev, S. (2006) External shock loading on a submerged fluid-filled cylindrical shell, Journal of Fluids and Structures 22, 997-1028.
2. Iakovlev, S. (2007) Submerged fluid-filled cylindrical shell subjected to a shock wave: Fluid-structure interaction effects, Journal of Fluids and Structures 23 (1), 117-142.
3. Iakovlev, S. (2008) Interaction between a submerged evacuated cylindrical shell and a shock wave. Part I: Diffraction-radiation analysis, Journal of Fluids and Structures 24, 1077-1097.
4. Iakovlev, S. (2008) Interaction between a submerged evacuated cylindrical shell and a shock wave. Part II: Numerical aspects of the solution, Journal of Fluids and Structures 24 (7), 1098-1119.
5. Iakovlev, S., Gaudet, J., Dooley, G., MacDonald, B. (2010) Hydrodynamic fields induced by the shock response of a fluid-filled submerged cylindrical shell containing a rigid co-axial core, Journal of Sound and Vibration 329 (16), 3359-3381.
6. Iakovlev, S. (2009) Interaction between an external shock wave and a cylindrical shell filled with and submerged into different fluids, Journal of Sound and Vibration 322 (1-2), 401-437.
7. Derbesse, L., Pernod, P., Latard, V., Merlen, A., Decultot, D., Touraine, N., Maze, G. (2000) Acoustic scattering from complex elastic shells: visualization of S_0, A_0 and A waves, Ultrasonics 38, 860-863.
8. Iakovlev, S., Santos, H. A. F. A., Williston, K., Murray, R., Mitchell, M. (2013) Non-stationary radiation by a cylindrical shell: numerical modeling using the Reissner-Mindlin theory, Journal of Fluids and Structures 36, 50-69.