Simulation and identification of complex dynamic systems (ROTDYN)

J. Antunes, M. Moreira[1], H. Pina[2], P. Piteau[3]

Objectives

The general objectives of this project are to develop analytical and numerical methods to solve difficult and important problems in fluid-structure interaction and in flow-induced vibrations, involving strong non-linear effects. The specific objective pursued in 2003 was modelling the flow-structure coupled dynamics of finite-length bearings and squeeze-film dampers, which are very common in industrial machinery.

Results

We developed a semi-analytical technique for solving the Reynolds lubrication equation in two dimensions (axial and azimuthal). This method, based on a double-Fourier series development of the flow pressure field, coupled to a Galerkin reducing technique, converges to the true solution when an adequate number of series terms is used. The number of terms needed is quite small, for low rotor eccentricities, but increases somewhat for large amplitude motions when non-linear flow effects become very significant. Currently, we are testing the computational efficiency of the series method, for a number of typical configurations, as compared to classical numerical techniques such as finite-differences. Two conference publications have been produced from the results obtained, a journal paper being currently prepared.

Published, accepted or in press work

1. M. Moreira, J. Antunes, H. Pina, An Improved Linear Model for Rotors Subject to Dissipative Annular Flows, *Journal of Fluids and Structures*, **17** (2003), 813-832.

2. J. Antunes, M. Moreira, P. Piteau, Finite length bearings and squeeze-film dampers: A two-dimensional dynamical solution (Invited Paper), *Proeedings of the CMEM 2003 Computational Methods and Experimental Measurements XI,* Halkidiki, Greece, May 2003, 425-434.

3. J. Antunes, M. Moreira, P. Piteau, A theoretical series solution for the dynamics for finite length bearings and squeeze-film dampers, *Proc. of the Proceedings of the ASME Pressure Vessels and Piping Conference*, Cleveland, USA, 20-24 July, 2003, **FIV-02G**.
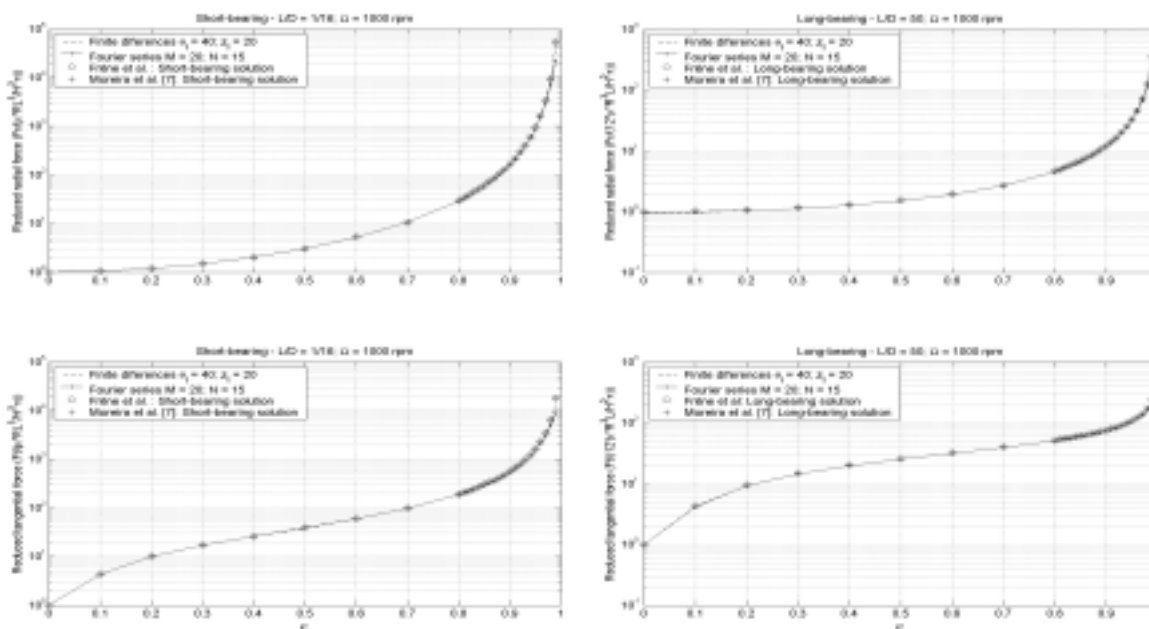
Comparison of analytically and numerically computed flow forces as a function of the rotor eccentricity (test-cases for short and long rotors).

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Dynamical modelling of nonlinear systems (EXCITE)

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Objectives

The project EXCITE has been, for a couple of years, an international cooperative effort to develop theoretical methods and numerical techniques to deal with strongly non-linear dynamical problems, such as involving impacts and friction phenomena. The main objective for 2003 was development of a modelling technique to predict the self-excited responses of shells subjected to moving loads, which is a very interesting physical problem with significant industrial applications (breaking devices, for instance).

Results

A non-linear model, based on a modal representation of the shell coupled with contact-friction shell/exciter interface, has been developed. This modelling technique proved to predict quite well the various self-excited regimes that may arise, as observed in our preliminary experiments. For the purpose of this study, a fascinating Tibetan instrument has been taken as specific subject for study. Therefore, apart from their interest in a more general context, our results also proved valuable in the field of music acoustics. A number of publications emerged from this study, also connected with a PhD thesis being prepared at ADL. One of them was recently distinguished as outstanding, after being presented at the Spanish Conference on Acoustics.

Published, accepted or in press work

4. O. Inacio, L. Henrique, J. Antunes, Simulation of the Oscillation Regimes of Bowed Bars: A Nonlinear Modal Approach, *Communications in Nonlinear Science and Numerical Simulation*, **8** (2003), 77-95.

5. O. Inacio, L. Henrique, J. Antunes, The Physics of Tibetan Singing Bowls, *Revista de Española de Acústica (in print).*

6. O. Inacio, L. Henrique, J. Antunes, Nonlinear Dynamics and Playability of Bowed Instruments: From the Bowed String to the Bowed Bar, *Proeedings of the CMEM 2003 Computational Methods and Experimental Measurements XI,* Halkidiki, Greece, May 2003, 391-400.

7. O. Inacio, L. Henrique, J. Antunes, The Physics of Tibetan Singing Bowls: 1 – Theoretical Model (Invited Paper), *Proceedings of the 34º Congreso Nacional de Acústica y Encuentro Ibérico de Acústica,* Bilbao, October 15-17, 2003 (CD-ROM).

8. O. Inacio, L. Henrique, J. Antunes, The Physics of Tibetan Singing Bowls: 2 – Numerical Simulations (Invited Paper), *Proceedings of the 34º Congreso Nacional de Acústica y Encuentro Ibérico de Acústica,* Bilbao, October 15-17, 2003 (CD-ROM).
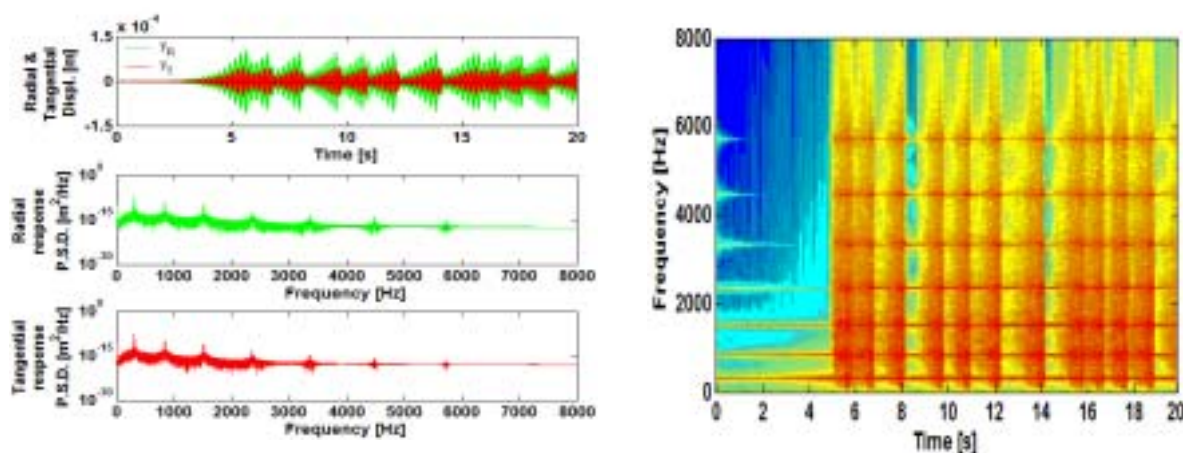
Time-domain,response, spectra and spectrogram of a self-excited unsteady vibratory regime in a shell excited by a moving load (Tibetan bowl).

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Dynamical modelling of geological inclusions (GEOMODELS 2)

F. Ornelas[1], R. Taborda[1], J. Antunes

Objectives

The general objective of this project is development of theoretical models to predict the motions of geological inclusions as a fonction of the shear motions of the enclosing matrix, which can be modelled as a fluid, and their confrontation with experiments (performed at FCL/LATEX). This problem is important for understanding geological structural patterns and their history. During 2003 our aim has been a detailed study of the confined shear-flow, modified by inclusions, both theoretically and experimentally.

Results

A numerical model of the flow subjected to moving boundary conditions, based on the finite-element method as applied to the Stokes formulation, was extended to deal with non-competent (e.g., sliding) matrix/inclusion interfaces. Extensive experiments and computations have been performed by the various partners of this project, in order to validate the numerical model. Insight has been gained on the controversial issue of "bow-tie-shaped" and "eye-shaped" flow configurations around inclusions. From these results two publications emerged, others being currently prepared.

Published, accepted or in press work

9. R. Taborda, J. Antunes, F. O. Marques, 2-D Rotation Behavior of a Rigid Ellipse in Confined Viscous Simple Shear: Numerical Experiments Esing FEM, *Tectonophysics (in print)*.

10. F. O. Marques, R. Taborda, S. Bose, J. Antunes, Can Matrix Rheology be Inferred From Flow Patterns Around a Rigid Circular Inclusion in Simple Shear? Insights From Modelling, Submitted to *Earth and Planetary ScienceLetters*
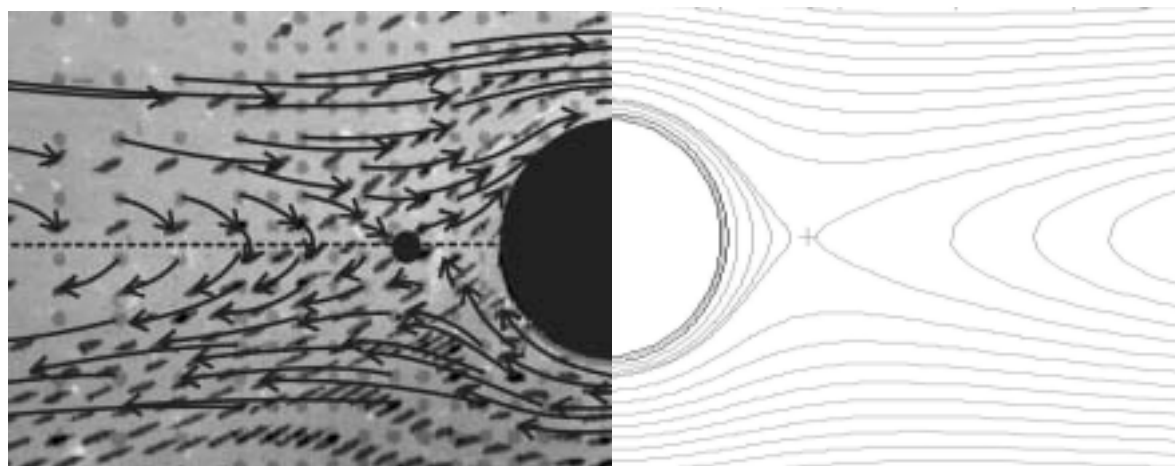
Detail of the velocity-field for constrained shear flow around a circular inclusion (experiment and computation).

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Shape optimization of vibratory and acoustic systems

J. Antunes, L. Henrique[1], J. S. Carvalho[2], C. Besnainou[3]

Objectives

Developing new methods for the optimization of dynamical systems, focusing on the problem of shape optimization, in order to obtain a target-set of resonance frequencies. Following our research of the previous year, our objectives for 2003 were to (1) achieve the simulation of the dynamical responses of optimized bars to various excitations, and (2) develop optimization programs for the shape-optimization of acoustic resonators.

Results

Our objectives were fully accomplished, in the context of a PhD thesis prepared in connection with this project. The techniques developed are now being adapted to be used by our French partner, in order to deal with a different – and more complex – dynamical system. Feedback of their experience will be very important for our future developments. Experiments will follow in 2004, to validate the results of this research. Also, we will strive to develop a technique for the simulation of the coupled vibro-acoustic system (bar and resonator).

Published, accepted or in press work

1. L. HENRIQUE, J. ANTUNES, Optimal Design and Physical Modelling of Mallet Percussion Instruments, *Acta Acustica*, **89** (2003), 948-963
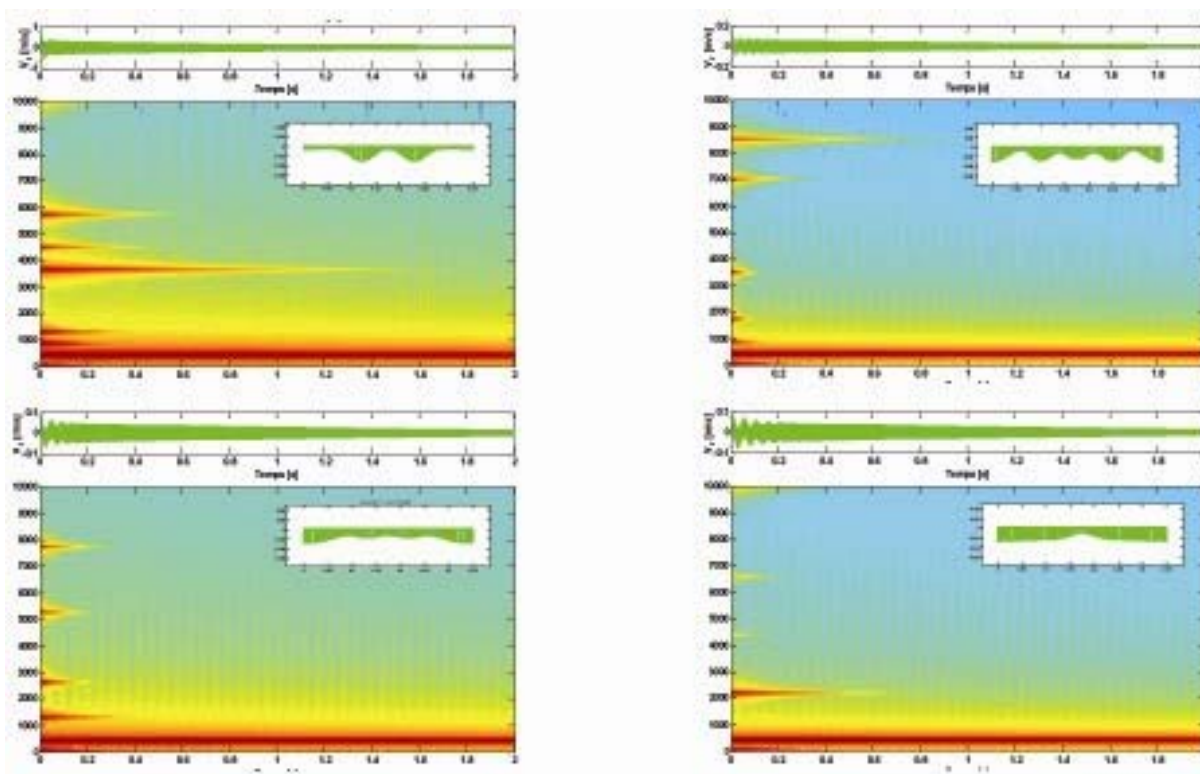
Spectrograms of the impact responses of four shape-optimized bars.

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