Applied Dynamics

José Antunes

The activities at Applied Dynamics Laboratory (ADL) are devoted to research in nuclear engineering, with an emphasis in the vibratory and acoustic behaviour of mechanical components. Our group started in 1986, with the following objectives: (1) Develop theoretical methods, computer tools and experimental techniques, to solve structural problems in nuclear power station components; (2) Use this state-of-the-art know-how, in order to solve structural problems arising in Portuguese power plants and other industrial facilities.

The first objective has been pursued through extensive international collaboration with our main scientific partner - the French Commissariat à l'Energie Atomique (CEA) / Département de Mécanique et Technologie (DMT). More than one decade of fruitful collaboration is attested by a significant number of published results. Important problems have been solved, such as nonlinear vibrations in steam-generators, flow-induced vibrations of nuclear fuel and stability problems in rotating machinery. Furthermore, new identification techniques have been developed and applied with success to nonlinear dynamical systems.

The second objective has been pursued by starting in 1990 a series of projects with (and for) the Portuguese power supplier Electricidade de Portugal / Companhia Portuguesa de Produção de Electricidade (EDP/CPPE), stemming from actual structural problems in power plants (Sines, Setúbal): These projects enabled us to model and solve vibratory problems arising in rotating machinery, vibro-acoustical problems in boilers and heat-exchangers, as well as structural identification problems. Several computer codes have been developed in connection with these projects.

In recent years we also developed research projects of more fundamental nature, mainly funded through the Praxis XXI and POCTI research programmes. These projects have been developed in partnership with several Portuguese institutions (Faculdade de Ciências de Lisboa, Instituto Politécnico do Porto, Instituto Politécnico de Setúbal, Instituto Superior Técnico, Universidade Nova de Lisboa), as well as the Université de Paris and Southampton University. This work, developed in the context of fundamental physics – in particular addressing problems in music acoustics, optimization and structural geology – is centred in modelling nonlinear dynamics and flow-structure phenomena. The methods developed transcend the context of these projects and may be adapted to solve several aspects of industrial problems.

The Applied Dynamics team is mainly concerned with the following scientific fields: structural dynamics, flow¬induced vibrations, nonlinear dynamics, vibro-acoustics, experimental methods, signal processing, system identification, structural and acoustical optimization. As a spin-off from our research activities, teaching has been actively pursued on structural dynamics and acoustics - ranging from university level courses in Portugal (Coimbra, Lisbon) to several post¬graduation short courses abroad (Paris, Dublin). Also, student training and several university thesis (MSc and PhD) have been successfully supervised, for both Portuguese and foreign students. An extensive book on fluid-structure dynamics and acoustics, co-authored by two CEA and ADL researchers will be published early 2006.

Among the above-mentioned scientific fields one should stress those features which give our small group a distinct profile from others working in structural dynamics in Portugal. Those features are: (1) a proven expertise and output in flow-excited systems and nonlinear vibrations; (2) a complementary theoretical/experimental approach for every problem.

Most of the research projects pursued at ADL have been based on research contracts.

Research Team

Researchers

J. ANTUNES, Princ.

Students

O. INÁCIO (25%) PhD Student, Inv. Professor (1)

Technical Personnel

A. ANASTÁCIO

Collaborators

L. HENRIQUE (15%), PhD, Adj. Professor (1)
M. MOREIRA (30%), PhD, Adj. Professor (2)
M. PAULINO (20%), MSc, Inv. Professor (3)
R. SAMPAIO (10%), PhD, Adj. Professor (4)
(1) IPP, Porto
(2) IPS, Setúbal
(3) IPL, Lisboa
(4) ENIDH, Lisboa

Dynamical modelling and optimization of nonlinear vibratory and acoustical systems

J. Antunes, O. Inácio[1],L. Henrique[1], M. Wright[2]

Objectives

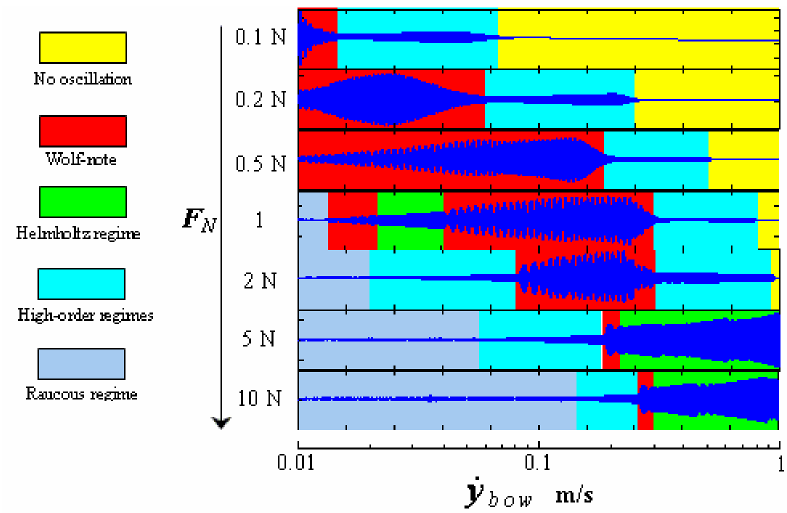
This research started a few years ago as a POCTI funded project, an international cooperative effort to develop theoretical methods and numerical techniques for dealing with strongly non-linear dynamical problems, such as involving impacts and friction phenomena. The main objective was the development of modeling techniques for nonlinear multi-modal structures. These techniques have been applied to a paradigmatic problem in nonlinear physics – bowed instruments – but can be easily adapted to industrial problems of the same nature. In recent years, coupling of vibratory and acoustical systems has also been addressed, namely through the point of view of dynamical optimization.

Results

Last year we extended our modal computational approach in order to address the dynamics of several complex vibratory sub-systems coupled by frictional phenomena. During 2005 these two computational interaction models have been explored in order to assert the merits and disadvantages of each approach. At the same time, the prototypical computed system has been explored, in order to highlight interesting dynamical features. Concerning dynamical optimization, we started to exploit a recently built experimental set-up, in order to obtain test data to substantiate a theoretical model for the vibroacoustics and radiation of vibrating bars or plates coupled to acoustical resonators. Both have been designed using optimisation techniques, which enabled us to tune their resonances at will. A significant number of papers emerged from this research, a PhD thesis anchored on the optimization results was concluded with success, and another PhD related to the nonlinear aspects of this project will be concluded early next year.

Published work or in press

1. O. Inácio, L. Henrique, J. Antunes, "The dynamics of tibetan singing bowls", Acta Acústica united with Acustica (in press).
2. O. Inácio, J. Antunes, "Simulation methods for the nonlinear string/body coupled dynamics of bowed musical instruments: A comparative analysis", *Proceedings of the Forum Acusticum,* Budapest, August 29-September 2, 2005.
3. O. Inácio, J. Antunes, "Dynamical regimes of bowed-string instruments with body-coupling", *Proceedings of the Twelfth International Congress on Sound and Vibration*, Lisboa, July 11-14, 2005.
4. L. Henrique, O. Inácio, J. Paulino, J. Antunes, "Optimization of vibratory and acoustical components of percussion instruments: Theoretical and experimental results" (Invited Paper), *Proceedings of the Forum Acusticum*, Budapest, August 29-September 2, 2005.
5. O. Inácio, L. Henrique, J. Antunes, "Optimized bass-trapping resonators for control rooms: A preliminary study", *Proceedings of the Internoise,* Rio de Janeiro, Brasil, August 7-10, 2005.
6. L. Henrique, J. Antunes, O. Inácio, J. Paulino, "Application of optimization techniques for acoustical resonators", *Proceedings of the Twelfth International Congress on Sound and Vibration,* Lisboa, July 11-14, 2005.



Coupled String/Body Computations for Increasing Normal Bow Force and Tangential Velocity

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Dynamical Modelling of Geological Inclusions

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

This has been a fruitful project, funded by a FCT/POCTI grant, developed in collaboration with the group of structural geology of FCL. The expertise of our colleagues in geologic experiments and field interpretation has been enriched by our experience in flow modelling, leading to a growing corpus of published theoretical and experimental results. Recently, 2-D finite element modelling was used to investigate the influence of a permanent low-viscosity layer between matrix and inclusion on matrix flow and inclusion rotation under viscous simple shear flow. Rigid inclusions of different shape (circle, square, ellipse, lozenge, rectangle and skewed rectangles) and aspect ratio (R) were used. The calculated matrix flow pattern is neither bow tie nor eye-shaped, the two classically accepted flow configurations. New results and interpretations on the inclusion rotations have also been obtained, showing that a low-viscosity layer (LVL) makes inclusions with R = 1 rotate synthetically, but the rotation rate depends upon shape (circle or square) and orientation. Therefore, shape matters in the slipping mode. The present numerical results closely agree with previous results of analogue experiments with a permanent low viscosity interface. On the other hand, analogue and numerical modelling was used to show that the flow of a Newtonian viscous fluid around a rigid body, in simple shear, depends strongly on the degree of confinement, i.e. the ratio between the shear zone width (H) and the rigid inclusion's least axis (e2) (S=H/e2). It also depends on how closely we look at the inclusion, which leads to the definition of an effective channel length and an effective flow pattern, compatible with micro-tectonics observations. If we consider a long channel, the flow pattern is bow tie-shaped, but tends to become eye-shaped as S approaches infinity. Therefore, special care must be taken when trying to infer rock rheology (e.g. viscous Newtonian or non-Newtonian) from geometrical patterns (e.g. geometry of a mantle and tails of recrystallized material around a rigid body), which are assumed to reflect the flow type. Finally, incompressible Navier–Stokes in 2D finite element modelling was used to investigate rigid inclusion rotation under confined bulk simple shear flow.

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Noise Reduction Optimization in Tubular Heat Exchangers

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

The interaction between a gaseous flow and the tube banks of heat exchangers can lead to the self-excitation of acoustic resonances, originating the formation of stationary acoustic waves in the fluid. These lead to high-amplitude pressure fluctuations inside the equipment, with the consequent vibratory excitation of structural elements. When the frequencies of the excited acoustic modes near-coincide with the modal frequencies of tubes, high vibratory levels can seriously affect the system integrity. It is worthwhile to point out that this problem only arises in gaseous heat exchangers, since the typical sound speed in liquids lead to acoustical frequencies typically beyond those of the structural component vibrations. To the present date, in spite of the industry concern by this problem, the physical mechanisms of sound excitation of by cross-flows within tubular banks are not yet fully understood, therefore the available criteria for predicting such flow-acoustic instabilities are not trustfully. Typically, this problem is solved by inserting plates inside the tubular banks (so-called acoustic baffles), in order to inhibit the acoustical instabilities by modifying the acoustic field. However the physical mechanism that renders a given baffle configuration effective or not is still insufficiently known and controversial. In this three years project, funded by a FCT/POCTI grant, we started by developing techniques for optimizing the acoustic baffle configurations. In particular, an efficient method for achieving fast acoustical computations of realistic baffled enclosures, based on a constrained approach of acoustical modal synthesis, has been developed. We expect this will enable us, in the next stage, to achieve baffle configuration optimization with computational savings of one to two orders of magnitude. Then, optimization algorithms will be coupled to suitable flow-acoustical interaction models, to be developed and experimentally validated by wind-tunnel experiments.

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