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 FCT 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, Cargèse). Also, student and post-doc training, as well as 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 researchers from CEA and ITN/ADL was internationally published during 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 scientific 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 both industry and academic research contracts. Research activities at ADL were internationally recognized by two prizes from the American Association of Mechanical Engineers (ASME).

Research Team

Researchers

J. ANTUNES, Princ. Researcher

Post-doc researcher

V. DEBUT

Students

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Collaborators

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M. PAULINO (15%), MSc, Inv. Professor (3)
R. SAMPAIO (10%), PhD, Adj. Professor (4)
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Optimization of the Noise Reduction in Tubular Heat Exchangers

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

Objectives

The objectives of this three years project, funded by a FCT/POCTI grant, is to increase our understanding of the relevant physical mechanisms of aero-acoustic instabilities, and to develop techniques for optimizing the acoustic baffle configurations.

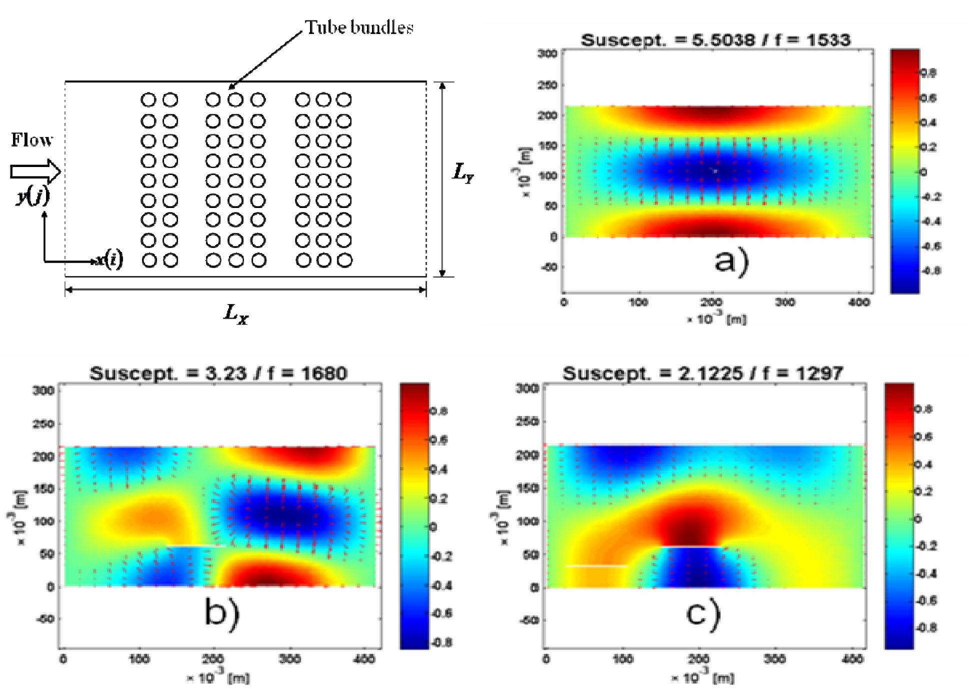
Results

The interaction between a gaseous flow and the tube banks of heat exchangers can lead to the self-excitation of acoustic resonances. 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. 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.

A simplified numerical model of the vortex-excited acoustic field has been coupled with two efficient global optimization methods (simulated annealing and genetic techniques) for the optimal configuration of a given number of acoustic baffles. Wind-tunnel experiments are currently being prepared in order to validate our theoretical results. Furthermore, analytical and experimental work has been developed on a closely related problem – acoustic self-excitation of corrugated pipes under axial flow – implying delicate and time-consuming tests. A paper has already been published on the mentioned results and a number of other papers will be published in the near future.

Published work

M. Moreira, J. Antunes, M. Paulino, V. Debut, H. Pina, Optimization of baffle configurations to prevent aeroacoustic instabilities in heat exchangers: A preliminary study, *Internoise 2006*, 3rd – 6th December 2006, Honolulu, EUA.



Laboratory model and acoustic modeshapes of the modes with largest susceptibility to instability, respectively with no baffles (a), 1 optimized baffle (b) and 2 optimized baffles.

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Flow-Induced Vibrations of Tubular Nuclear Components

J. Antunes, X. Delaune[1], P. Piteau[1],L. Borsoi[1]

Turbulence-induced vibration is a well-known source of structural vibrations, often leading to failures due to fatigue or wear problems. In the context of nuclear facilities, such problems are addressed with a particular care, for obvious safety reasons, but also due to the increased difficulties of problem-fixing in a radiation-active environment. At ITN/ADL, in close cooperation with CEA-Saclay, we gained a significant expertise in this area, both theoretically and experimentally.

During 2006, under contract, a new research project has been started with CEA, in order to develop an up-to-date computer program to predict the flow-induced vibrations of nuclear components such as fuel rods or steam-generator tubes, namely due to the turbulence of both axial and transverse flows. Most important, nonlinear vibro-impact and rubbing phenomena between the tubular components and their supports (accounting for gaps and pre-charges) must be incorporated in the nonlinear time-domain computational model, in order to enable realistic predictions. Then, computations supply the dynamical row data necessary for designing the multi-supported rods and tubes, with respect to wear and fatigue.

The first version of our program has been developed at ADL during 2006, as intended, and the software is currently being numerically validated at CEA. During 2007 – and possibly the following years – this project will continue, in order to refine several aspects of the modelling techniques. In particular, an improved model of the turbulence field (random in both time and space) will be developed.

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Dynamical modelling of nonlinear vibratory and acoustical systems

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

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. In previous years we developed efficient numerical techniques to predict the nonlinear dynamics and interaction forces of friction self-excited systems. Such detailed computations have been complemented in 2006 by a strong focus on the linearized analytical models of friction-excited systems. More specifically, we addressed the case of friction-excited bars and derived the single relevant parameter which controls self-excitation, as a function of the contact normal force, sliding velocity and the Coulomb friction law. We then performed extensive parametric analysis from fast eigenvalue computations of the linearized model, leading to results which enable a more clear understanding of nonlinear limit-cycle regimes.

We recently extended these techniques to the case of bowed strings – with results to be published during 2007 – and plan to also study the case of friction-excited shells, which is particularly relevant for the understanding of brake squeal phenomena. During 2006 five papers have been published, with results from our recent work in this field. A PhD thesis encompassing our findings of the last years is to be presented at Southampton University shortly.

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