Applied Dynamics

José Antunes

The activities at Applied Dynamics Laboratory (ADL) are devoted to research in nuclear engineering, with an emphasis on 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 Portuguese Science Foundation (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, Trinity College Dublin 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 (M.Sc. and Ph.D.) 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 in 2006 and another volume on flow-induced vibrations is currently under completion, to be released in 2012.

Among the above-mentioned scientific fields one should stress those features which give this 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 both industry and academic research contracts. Research activities at ADL were internationally recognized by two prizes from the American Association of Mechanical Engineers (ASME).

A new researcher, Vincent Debut, joined the permanent staff of the Applied Dynamics group in 2008 under a five year contract, being involved since then in most of the research activities at ADL.

Research Team

Researchers

J. ANTUNES, Princ., Group Leader
V. DEBUT, Ass.

Students

M. CARVALHO, FCT grant

Collaborators

L. HENRIQUE, IPS, Adj. Professor
M. MOREIRA, IPS, Adj. Professor
O. INÁCIO, IPP,, Adj. Professor
M. MARQUES , IST, FCT grant

Simulation and experimental identification of flow-excited vibro-impact dynamics in nuclear components with support clearances

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

Objectives

In nuclear facilities, flow turbulence excitations and fluid-elastic phenomena may induce structural vibrations or instabilities, leading to fatigue failures and wear, which must be addressed with particular care for safety reasons. At ITN/ADL, in a long-term close collaboration with CEA-Saclay (contract TGV-ICE), we gained significant expertise in these areas. As in previous years, this project was aimed at the development at ITN/LDA of up-to-date computational and identification techniques to deal with turbulence-induced and fluid-elastically unstable vibrations of nuclear components, such as fuel rods or steam-generator tubes. Effective use of our remote identification techniques was made in connection with validating experiments performed by colleagues at the test-loops in CEA-Saclay, France.

Results

The experimental setup sketched and pictured in Figure 1 was used as a representative conceptual rig for steam-generator tubes. A flexible instrumented beam was excited by a shaker or by air flow, leading to vibro-impact responses. Figure 2 shows a detail of the instrumented clearance support.

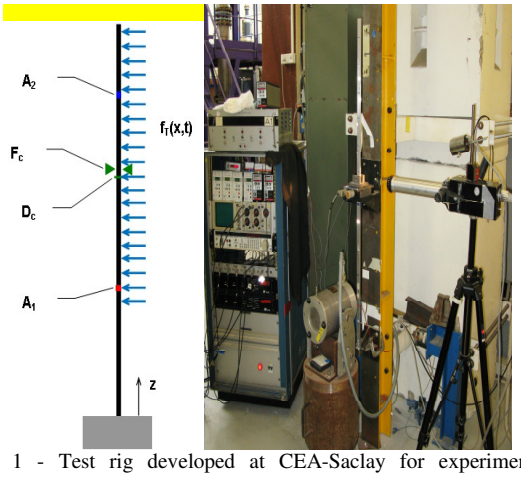


Fig. 1 - Test rig developed at CEA-Saclay for experimental validation of the impact force and response identification techniques developed at ITN/ADL.

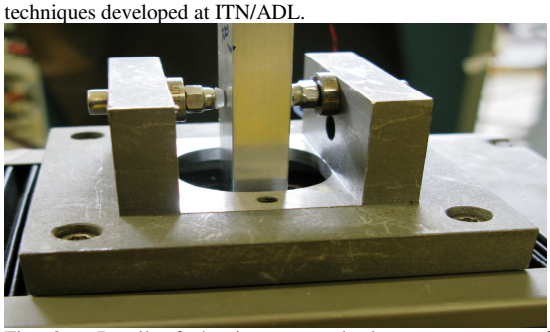


Fig. 2 - Detail of the instrumented clearance support of the experimental rig at CEA-Saclay.

Figure 3 illustrates one such experiment, showing the impulsive impact forces and the gap-limited tube vibrating motion, for a turbulence excited test. The experimental and remotely identified results obtained constitute a validation of our identification approach to deal with gap-supported tubes subjected to flow excitation, at least for a single clearance support. We are currently extending this work to multi-supported systems.

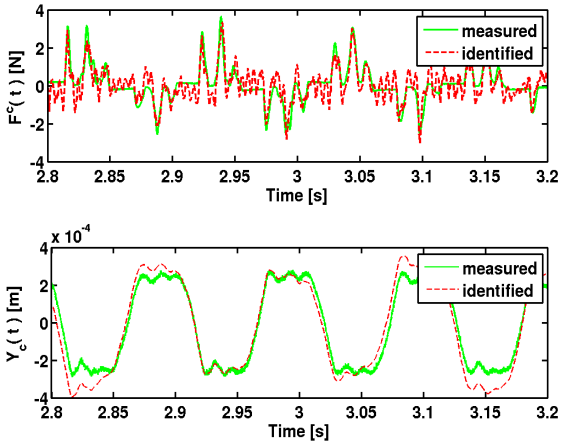


Fig. 3 - Measured and remotely identified impact force and tube displacement at the gap-support, under turbulence excitation of the vibrating beam.

Results connected with this research were published at several international conferences and journal papers, as next listed.

Publications

X. Delaune, P. Piteau, V. Debut, J. Antunes, "Experimental validation of inverse techniques for the remote identification of impact forces in gap-supported systems subjected to local and flow turbulence excitations", *ASME Journal of Pressure Vessel Technology*, Vol. 5, Paper 051301 (2011).

J. Antunes, X. Delaune, P. Piteau, "Time-domain simulation of the random vibrations of tubes subjected to turbulence-conveying flows", Paper 57162, *Proceedings of the ASME 2011 Pressure Vessels and Piping Conference (PVP 2011)*, July 17-21, 2011, Baltimore, USA.

X. Delaune, J. Antunes, P. Piteau, L. Borsoi, "Experiments and computations of a loosely supported tube under two-phase flow buffeting and fluid-elastic coupling forces", *21st International Conference on Structural Mechanics in Reactor Technology (SMIRT 21)*, 6-11 November 2011, New Delhi, India.

P. Piteau, X. Delaune, J. Antunes, L. Borsoi, "Experiments and computations of a loosely supported tube in a rigid bundle subjected to single-phase flow", *Jounal of Fluids and Structures* (in print).

1 Commissariat à l'Energie Atomique, DEN/DM2S/SEMT/DYN, CEN-Saclay, France

Dynamical analysis and tuning of carillon bells

J. Antunes, V. Debut, M. Carvalho, O. Inácio[1], J. Soeiro de Carvalho[2]

In the context of the FCT project PTDC/EAT-MMU/104255/2008, we have started a three-year project dealing on the physical and musicological aspects of the historical Mafra carillons, from the XVII century. After development of a specific modal identification software, well adapted to axi-symmetrical shells, which was validated by laboratory experiments performed on a contemporary bell, we started the identification field-work in the Mafra carillons, which will be pursued during 2012 in parallel with the development of tuning techniques.

Fig. 1 - Experimental identification of bell modes : laboratory bell (left), Mafra carillon (right).

[1] Instituto Politécnico do Porto, Escola Superior de Música e Artes do Espectáculo, Laboratory of Music Acoustics, Porto
[2] Universidade Nova de Lisboa, Faculdade de Ciências Sociais e Humanas, Lisbon

Analytical computation of shell modes subjected to fluid-structure coupling

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

Fluid-structure coupling problems are recurrent in nuclear power facilities (steam-generators, pipes, reactor vessels, pressurizing systems). In the context of a research project funded by CEA/Saclay (France) we have developed a theoretical model to predict the modes of cylindrical shells when subjected to coupling by an incompressible dense fluid. This theoretical model was validated against extensive finite-element computations using the CAST3M program, and then applied in the analysis of vibratory experiments performed at Saclay.

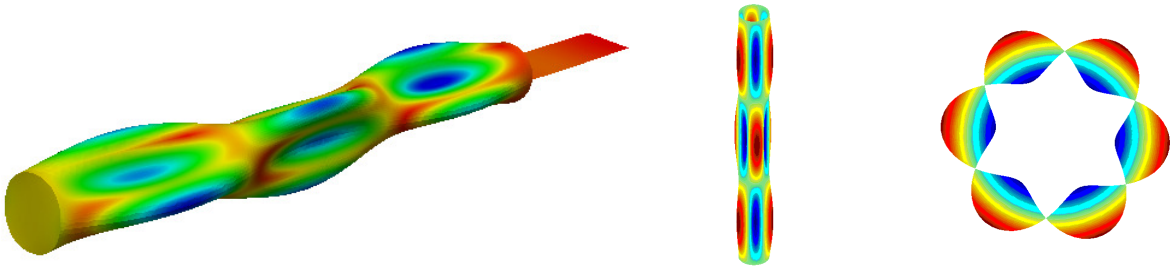


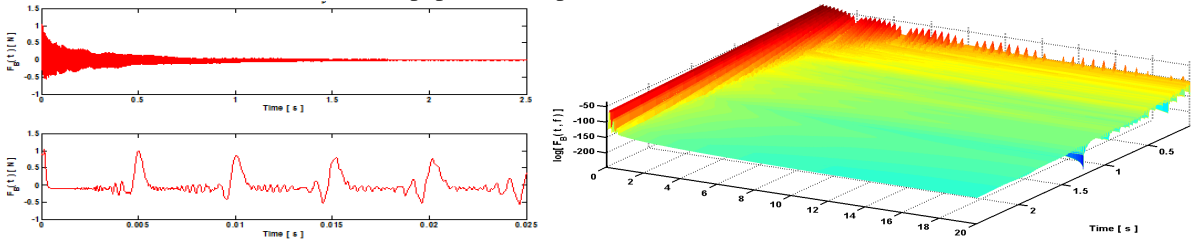
Fig. 1 - Comparison between a vibration shell mode computed using the CAST3M finite element code (left) and the corresponding results from the simplified analytical model (right).

[1] Commissariat à l'Energie Atomique, Laboratory of Dynamical Studies, Saclay, France

Dynamics and string/body coupling in the Portuguese guitar

J. Antunes, V. Debut, O. Inácio[1], M. Marques[2], A. Ribeiro[2], P. Serrão[2]

In the context of the FCT project PTDC/FIS/103306/2008, we started in 2011 a detailed analysis of the dynamics of worn strings, which display local mass-deposits and/or mass-voids at specific locations due to playing. We developed a detailed model for worn strings, capable of computing their distorted vibration modes and simulating their time-domain responses. A detailed statistical analysis of the dynamical changes due to the string wear was also achieved. A conference paper will be presented soon on this work.



Time-domain bridge excitation force from a plucked string (left) and the corresponding spectrogram (right).

[1] Instituto Politécnico do Porto, Laboratory of Music Acoustics, Porto; [2] Instituto Superior Técnico, Lisbon