Applied Dynamics

Activities of the "Applied Dynamics" team 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:

- Develop *theoretical methods*, *computer tools* and *experimental techniques*, to solve structural problems in *nuclear power station* components;
- 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 were solved, such as nonlinear vibrations in steam-generators, flow-induced vibrations of nuclear fuel, as well as stability problems in rotating machinery.

The second objective has been pursued by starting in 1990 a series of projects with (and for) the portuguese power supplier "Electricidade de Portugal (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 heat-exchangers, as well as structural identification problems.

There are no nuclear power stations in Portugal. However, past experience proved beyond doubt that our group is useful both as an active contributor for international science and as a problem-solver for domestic industrial partners. Therefore, the previously stated objectives remain our driving force and motivation.

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 and system identification.* As a spin-off from our research activities, teaching has been actively pursued on *structural dynamics* and *acoustics* — ranging from university level curses in Portugal (Coimbra, Lisbon) to several post-graduation short curses abroad (Paris, Dublin). Also, student training and university thesis (Graduation, MSc and PhD) have been successfully supervised, for both portuguese and foreign students.

Among the above-mentioned scientific fields one should stress those features which give our group a distinct profile from others working in structural dynamics in Portugal. Those features are:

- A proven expertise and output in *flow-excited systems* and *nonlinear vibrations*;
- A complementary theoretical/experimental approach for *every* problem.

During 1999, several research projects were pursued — namely "Remote impact identification", "Simulation and identification of complex systems", "Experimental modal identification" and "Nonlinear modelling and dynamics". In the context of these projects, a MSc was completed and a PhD thesis was pursued. We also started four new projects on "Analysis of structures subject to flow-induced vibrations", "Optimisation of rotor balancing", "Identification of machinery under working conditions" and "Modelling of vibration-generated droplets". As a major infra-structural improvement of our experimental facilities (the "Applied Dynamics Laboratory-ADL"), we designed and built a small-size wind tunnel, which is currently under completion. Our projects are almost entirely founded by external partners and institutions. Research results have been published in wide-audience journals and international meetings.

Remote impact identification*

José Antunes, Martins Paulino[1], Patrick Izquierdo[2], Thierry Grunenwald[2]

Objectives

To develop methods for the identification of impact phenomena inside critical components through signal processing of vibratory measurements from transducers at remote locations. The aim is to avoid placing force transducers under severe environmental conditions (space, temperature, radiation). This study is of particular significance for condition-monitoring of wear-prone components, such as heat-exchangers, and also as a tool for the analysis of ageing industrial facilities. The later aspect is of particular relevance for nuclear power facilities.

Results

This is a very difficult problem, because the interesting signals are often immersed in high noise contamination from many sources. In the previous year we developed a new method for the remote identification of impulsive forces using the information carried by the travelling waves generated by the impacts. We later extended our method to deal with multiple simultaneous impacts, a major improvement. A MSc thesis has been completed with success, based on these developments.

Recently we got interested in the so-called "blind" identification methods. These methods were originally developed in very different fields (geophysics and communications) to enable the identification of impulsive signals *without any information on the dynamics of the propagation path*. Therefore, blind deconvolution techniques seem extremely interesting for the problem of impact identification, because they avoid any explicit modelling of the system.

We recently started a systematic study of a number of blind deconvolution methods, in order to assert their robustness to noise effects and their effectiveness. All these techniques use higher-order statistics of the data in order to enable the identification of the impulsive sources. We also recently extended a blind identification algorithm (the minimum entropy method), in order to enable the effective use of multiple response measurements. Our published results are very encouraging, and we definitely intent to further pursue this work.

References

1. Paulino, M., Remote Identification of Impact Forces in Gap-Supported Structures, MSc. thesis, Universidade Nova de Lisboa, July1999.
2. Paulino, M., Antunes, J., Izquierdo, P., Remote Identification of Impact Forces on Loosely Supported Tubes: Analysis of Multi-Supported Systems, *ASME Journal of Pressure Vessel Technology*, **Vol. 121** (1999) 61-70.
3. Antunes, J., Izquierdo, P., Grunenwald, T., Blind Impact Force Identification of Gap-supported Vibrating Systems, Structural Mechanics in Reactor Technology, SMIRT-15 Conference, Seoul, August 15-20, 1999 (Paper J1-A1-PT).
4. Antunes, J., Paulino, M., Izquierdo, P. , Identification des Forces d'Impact à l'Aide de Méthodes Aveugles, Report CEA, December 1999.

Further work

Our next moves on this topic will be to try to blindly identify multiple simultaneous impacts. But also, suitable methods must be devised to properly scale the identified forces (a problem with all blind identification methods). These are major issues.

* Funding: Contract with Commissariat à l'Energie Atomique, Saclay, France. 9×10^6 PTE for three years.
[1] Instituto Superior de Engenharia de Lisboa.
[2] Commissariat à l'Energie Atomique, Saclay, France.

Simulation and identification of complex systems

José Antunes, Miguel Moreira[1], Heitor Pina[2]

Objectives

Complex dynamical systems, which present high-order dynamics and/or a nonlinear behaviour still present considerable challenges for both simulation and identification purposes. Nature-inspired computation methods, such as simulated annealing or genetic methods show considerable promises to deal with such problems.

The aim of this project is to apply such stochastic optimisation methods to dynamical problems of interest to industrial components. As a test problem, we chose to work on rotor-flow coupled vibrations, which is a problem with strong nonlinear effects. Also, our group has considerable experience in this problem.

Results

During 1999 we concentrated on improving the physical modelling of the above-mentioned system, both for the original nonlinear formulation and also for the linearised one. Also, new experiments were performed to assert the validity of our new improved formulations. The success of this work is attested by a number of publications.

References

1. Antunes, J., Mendes, J., Moreira, M., Grunenwald, T., A Theoretical Model for the Nonlinear Planar Motions of Rotors Under Fluid Confinement, *Journal of Fluids and Structures* **13** (1999) 103-126.
2. Moreira, M., Antunes, J., Pina, H. , A Theoretical Model for Nonlinear Orbital Motions of Rotors under Fluid Confinement, ASME Pressure Vessel and Piping Symposium on Flow-Induced Vibrations, Boston 1999. *Accepted for publication in Journal of Fluids and Structures.*
3. Moreira, M., Tissot, A., Antunes, J. , Experimental Validation of Theoretical Models for the Linear and Nonlinear Vibrations of Immersed Rotors, Accepted for presentation at the *8th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery (ISROMAC-8),* Honolulu, USA, March 2000.
4. Moreira, M., Antunes, J., Pina, H. , An Improved Model for Rotors Subject to Annular Dissipative Flows, Accepted for presentation at the Symposium on Flow-Induced Vibrations, Lucerne, Switzerland, June 2000.

Further work

In the near future we will concentrate in using the theoretical results of the rotor-flow system, obtained during 1999, as a test system to benchmark dimension-reduction techniques and/or flow computation schemes based on stochastic techniques.

[1] Instituto Politécnico de Setúbal.
[2] Instituto Superior Técnico de Lisboa.

Experimental modal identification*

José Antunes, João Soares[1], Paulo de Araújo[2]

Objectives

An essential step in the diagnosis of most vibratory problems is the modal analysis of the vibrating structures or machine components. Very often, theoretical methods (such as the finite element method) must be complemented — or even replaced — by the experimental identification of the system modes. This is a common problem, because important structural data or end-conditions, which are essential for analysis, are unknown or ill-defined. Hence, specific methods and software must be developed to cope with the need for experimental modes.

We have been developing a PC-based programme under contract for the portuguese power supplier EDP/CPPE for the past few years. Our aim when developing Version 2 of program ALADIN is, based on field experience, to develop a more robust and effective tool.

Results

Version 2 of programme ALADIN has been developed, which is better designed, more robust and with better identification performances. Documentation has just been completed and final tests are being conducted before the industrial version is issued to EDP/CPPE. As a practical application of ALADIN, a modal identification of RPI secondary pipe system has been performed, in order to fix a vibratory problem.

References

1. Araújo, P., Antunes, J. , Program ALADIN – Version 2: Operators Manual, ITN/ADL Report, December 1999.

Further work

ALADIN has become a mature programme. Therefore it will constitute a very good support for the development of new modal identification algorithms. Also, modules for prediction of structural modifications and forced responses will be developed if we (or our partners) feel the need for such developments.

* Funding: Contract with Electricidade de Portugal (EDP/CPPE). 6×10^6 PTE – 1997-2000.

[1] Electricidade de Portugal (EDP/CPPE).
[2] Université Technologique de Compiègne, France.

Nonlinear modelling and dynamics

José Antunes, Luís Henrique[1], Laurent Borsoi[2], Vincent Gibiat[3]

Objectives

Music acoustics is a field with great potential for the development of effective simulation and identification techniques. Indeed, control and understanding of self-excited regimes are the main objectives when musical instruments are addressed. In contrast, one is only happy to avoid vibratory and acoustic instabilities in industrial problems. Therefore, the level of physical understanding demanded by sound production instruments is usually higher than in typical industrial problems. Also, from our experience, techniques developed in music acoustics can be (and have been) adapted with success to stop vibrations in industrial facilities. Therefore, we maintain a modest activity in this field, as a source of interesting ideas and international contacts.

Results

During 1999 we improved our small test-model of the bowed string. We developed an effective technique to simulate the friction-induced vibrations of this very difficult system. Also, we developed a novel technique for the identification of the frictional interaction bow/string force from the string vibratory response.

References

1. Antunes, J., Tafasca, M., Borsoi, L. , Simulation et Identification des Régimes Vibratoires Non-Linéaires d'une Corde Vibrante, Accepted for presentation at *Colloque sur l'Analyse Modale Non-Linéaire,* Paris, Janvier 2000.
2. Tafasca, M., Antunes, J. , Etude du Comportement Vibratoire d'une Corde de Violon Excitée par Frottement, ITN/ADL Report, February 1999.

Further work

Future work will include the experimental validation of the above-mentioned techniques for system simulation and identification. Also we intend to develop similar techniques for wind instruments.

[1] Instituto Politécnico do Porto.
[2] Commissariat à l'Energie Atomique, Saclay, France.
[3] Ecole Nationale Supérieure de Physique et Chimie de Paris.

Analysis of structures subject to flow-induced vibrations

José Antunes, Philippe Piteau[1], François Axisa[2], John Fitzpatrick[3], Craig Meskell[3]

Objectives

Most serious problems in nuclear power stations and other industrial facilities are connected to flow-structure coupled vibrations. Typical examples include heat-exchanger tubes and fuel bundles. Our aim is to develop simplified flow models, which can lead to very fast computations of the flow-structure coupled dynamics.

Results

During 1999 we focused on the problem of large-amplitude motions of fuel bundles. We developed a new theoretical model for the vibrations of plane structures subject to axial flow, which can be applied to these components. The results obtained are very interesting and will be published soon.

References

1. Antunes, J., Piteau, P. , Analyse Théorique du Pincement d'une Lame Fluide sous Écoulement Axial, Report CEA, December 1999.

Further work

If founding is available in the near future, the main priority will be to experimentally validate our theoretical findings.

[1] Commissariat à l'Energie Atomique, Saclay, France.
[2] Ecole Nationale Supérieure des Techniques Avancées, Paris, France.
[3] Trinity College, Dublin, Ireland.

Optimisation of rotor balancing*

José Antunes, João Soares[1], Martins Paulino[2]

Objectives

Balancing is one the most common and important operations currently performed on all rotating machinery. Because the traditional way of rotor balancing (using influence coefficients and many test masses) is very time-consuming and costly, our aim is to optimise these operations. Therefore, we depart from standard procedures and intent to develop a new method which will enable balancing of flexible rotors at a fraction of the cost and time.

Results

As a preliminary work to convince the portuguese power supplier EDP/CPPE that better methods should be attempted, we developed a novel approach which seems to work very well, at least with numerically simulated dynamics. If this approach works in practice, it will prove invaluable.

References

1. Antunes, J. , Fast Balancing of Flexible Rotors: Preliminary Analysis of Balancing From a Single Vibratory Test, ITN/ADL Report, June1999.

Further work

The contract work for the next couple of years will consist in improving and experimentally validate our current ideas.

* Funding: Contract with Electricidade de Portugal (EDP/CPPE). 8×10^6 PTE, from Dec. 99 to Dec. 2001.

[1] Electricidade de Portugal (EDP/CPPE).
[2] Instituto Superior de Engenharia de Lisboa.

Identification of machinery under working conditions*

Carlos Martins[1], José Antunes, Moisés Piedade[1], Edgar Ataíde[2], Rui Sampaio[3]

Objectives

Modal identification of machinery is usually performed by testing the equipments under controlled conditions. Therefore, measurement of the test forces and vibratory responses are usually achieved when the plant is not working. If vibratory problems arise, production must be stopped in order to diagnose what is going wrong. Because this is obviously very costly, the aim of this project is to develop new methods of modal testing without the need to stop the machinery. Because a working plant is an extremelly noisy environment, this is a very difficult problem.

Results

This project was started very recently. At the present time we designed and built a laboratory test model, which will enable validation of the various identification methods developed by the partners in this project. Preliminary tests are currently being performed.

Further work

Most of the future work will concern algorithm development and testing. Then the best ones will be further tested under field conditions.

* Funding: Praxis XXI . $2{,}8 \times 10^6$ PTE – 1999-2001.

[1] INESC, Lisboa.
[2] Dep. Electrónica, INETI, Lisboa.
[3] Escola Nautica Infante D. Henrique, Lisboa.

Modelling of vibration-generated droplets*

José Antunes, Maria de Fátima[1], Miguel Moreira[2], Rui Sampaio[3]

Objectives

A new technique for producing encapsulated products for wine fermentation uses vibrations as the method for controlling droplet size and properties. At the current time, Portugal is among the very few countries who master this sophisticated technology. Because the portuguese supplier wants to improve the quality of their products, ITN/ADL was asked to provide a better know-how on the physical processes involved in the vibratory-generated droplet formation.

Results

This is a recent project. We started by developing a new vibratory-shaker concept, which will enable high-frequency and high-amplitude vibrations at a much lower power and at a fraction of the cost of conventional approaches. At the present time, two shaker prototypes were built and are being tested.

Further work

Most of our theoretical and experimental work on this project will concern droplet modelling and understanding the dynamics of this difficult problem.

* Funding: Contract with PROENOL. $1{,}5 \times 10^6$ PTE, for two years.

[1] PROENOL.
[2] Instituto Politécnico de Setúbal.
[3] Escola Nautica Infante D. Henrique, Lisboa.