

TIME TABLE

TIME	Monday September 13	Tuesday September 14	Wednesday September 15	Thursday September 16	Friday September 17
9.00 - 9.45	Registration	Shaw	Wagg	Brennan	Ribeiro
9.45 - 10.30	Virgin	Shaw	Wagg	Brennan	Ribeiro
11.00 - 11.45	Virgin	Shaw	Virgin	Ribeiro	Wagg
11.45 - 12.30	Virgin	Virgin	Virgin	Ribeiro	Wagg
14.30 - 15.15	Shaw	Virgin	Brennan	Ribeiro	
15.15 - 16.00	Shaw	Brennan	Brennan	Wagg	
16.30 - 17.15	Shaw	Brennan	Ribeiro	Wagg	
17.15 - 18.00	Shaw	Brennan	Ribeiro	Wagg	

ADMISSION AND ACCOMMODATION

Applicants must apply at least one month before the beginning of the course. Application forms should be sent on-line through our web site: <http://www.cism.it> or by post.

A message of confirmation will be sent to accepted participants. If you need assistance for registration please contact our secretariat.

The 700,00 Euro registration fee includes a complimentary bag, four fixed menu buffet lunches (Friday not included), hot beverages, on-line/downloadable lecture notes and wi-fi internet access.

A limited number of participants from universities and research centres who are not supported by their own institutions can be offered board and/or lodging in a reasonably priced hotel. Requests should be sent to CISM Secretariat by **July 13, 2010** along with the applicant's curriculum and a letter of recommendation by the head of the department or a supervisor confirming that the institute cannot provide funding. Preference will be given to applicants from countries that sponsor CISM.

The Deutscher Akademischer Austausch Dienst (DAAD) and the Deutsche Forschungsgemeinschaft (DFG) offer support to German students. Please contact:

DAAD, Kennedyallee 50, 53175 Bonn
tel. +49 (228) 882-0
e-mail: postmaster@daad.de
web site: <http://www.daad.de/de/kontakt.html>

DFG, Kennedyallee 40, 53175 Bonn
tel. +49 (228) 885 2655
e-mail: ing4@dfg.de
web site: <http://www.dfg.de>

Information about travel and accommodation is available on our web site, or can be mailed upon request.

Please note that the centre will be closed for summer vacation the first three weeks in August.

For further information please contact:

CISM
Palazzo del Torso - Piazza Garibaldi 18
33100 Udine (Italy)
tel. +39 0432 248511 (6 lines)
fax +39 0432 248550
e-mail: cism@cism.it

Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

ACADEMIC YEAR 2010
The Zienkiewicz Session



EXPLOITING NONLINEAR BEHAVIOUR IN STRUCTURAL DYNAMICS

Advanced School
coordinated by
Lawrie Virgin
Duke University, Durham
NC, USA
David Wagg
University of Bristol
UK

Udine, September 13 - 17, 2010

EXPLOITING NONLINEAR BEHAVIOUR IN STRUCTURAL DYNAMICS

In many cases there are clear advantages in deliberately including nonlinear effects into the design of a structure. An obvious example is structural dampers. The most effective dampers contain highly nonlinear processes such as friction, fluids and most recently magneto-rheological fluids. Understanding and modelling the behaviour of these nonlinear effects is not a trivial process. However, there has been a dramatic increase in our understanding of nonlinear systems in the past 20 years, which has led to the realisation that beyond just modelling nonlinear effects, engineers can also use them to their advantage.

There are many physical phenomena which lead to nonlinear vibration problems. In some cases nonlinearities either cannot be avoided, or add some

benefit, which leads to designing in the face of nonlinearity. For example, if minimal mass in a vibration absorber is required, then large amplitude responses would be expected, so designing in this case necessitates consideration of nonlinear behaviour. This important form of nonlinearity is called geometric nonlinearity. In addition to large deformations, this also includes the effects of combined stretching/compressing with vibration and nonlinear alignment of structural elements. Geometric nonlinearity can be used, for example, to design high performing spring elements such as bi-stable structures with snap-through behaviour.

Increasingly applications are found at the nano or micro scale. For example, for a typical nano-scale resonator at room temperature, the system dynamic

range requires that it be driven into nonlinear regimes in order to get the response above the thermal noise floor. In such situations one must deal with nonlinear behaviour, and can often utilize it to good effect. Nonlinearity can also be caused by external forces acting on a linear system, such as fluid or magnetic forces. Nonlinear behaviour can be induced from constraints in the system, such as freeplay, backlash, impact and friction. Friction in bolted structural joints can also be used as a source of increased damping for some structures.

Control forces can be added to a structural system in order to control the behaviour in some way and make it an adaptive structure. For example to reduce unwanted vibrations, detect damage, harvest energy or to shape change (morph)

the structure. However, to create adaptive structures, the structure needs to have some awareness of its condition and/or the environment it is in. This is achieved by having a series of measurement sensors mounted on (or integrated into) the structure. Information from the sensors is then used by the global control system. This is where the smart (or intelligent) behaviour is generated.

The course will focus on how nonlinear effects can be exploited by the geometric and material design of structures. Introducing actuators and sensors to the structure to create adaptive capability will also be studied. The course is addressed to doctoral and postdoctoral researchers in aerospace, civil and mechanical engineering, applied mathematics, academic and industrial researchers.

PRELIMINARY SUGGESTED READINGS

S. W. Shaw and B. Balachandran, A Review of Nonlinear Dynamics of Mechanical Systems in Year 2008, JSME Journal of System Design and Dynamics 2, 611-640, 2008.

Ribeiro P. & van der Heijden G.H.M. Elasto-plastic and geometrically nonlinear vibrations of beams by the p-version finite element method, Journal of Sound and Vibration, 2009, 325, 321-337.

Kovacic, I., Brennan, M.J. and Waters, T.P. A study of a non-linear vibration isolator with quasi-zero stiffness characteristic. Journal of Sound and Vibration, Vol. 315, Issue 3, (2008), 700-711.

Adaptive Structures: Engineering Applications by David Wagg, Ian Bond, Paul Weaver, and Michael Friswell. Wiley, 2007.

Vibration of Axially-Loaded Structures by Lawrence Virgin. Cambridge 2007.

INVITED LECTURERS

Michael Brennan - University of Southampton, UK

7 Lectures on:

Using non-linearity to good effect in structural dynamics. Active vibration isolation. Vibration isolators with quasi-zero-stiffness. The asymmetric Duffing oscillator. High-static-low-dynamic stiffness in vibration isolation.

Pedro Leal Ribeiro - Universidade do Porto, Portugal

7 lectures on:

Design of vibrating inelastic and geometrically non-linear structural elements. Geometrical nonlinear and inelastic models of structural elements. Elasto-plastic and geometrically non-linear forced oscillations: trajectories and stress fields. Free oscillations with plastic strains: the effect of plastic strains and large displacements on the mode shapes and natural frequencies.

Steve Shaw - Michigan State University, East Lansing, USA

7 lectures on:

Accounting for and exploiting nonlinearity in torsional vibration absorbers for rotating machinery, including automotive applications. Use of instabilities and bifurcations for sensing applications with micro- and nano-scale mechanical devices. The interplay of noise and nonlinearity and its importance in bifurcation detection.

Lawrie Virgin - Duke University, Durham, NC, USA

7 Lectures on:

Examining geometrical and other forms of nonlinearity in structural dynamics. Highly deformed structures typical of very lightweight systems. Postbuckling behaviour and associated dynamics. Transient dynamics in rigid body structures. Exploiting chaotic behaviour. Aspects of experimental nonlinear dynamics.

David Wagg - University of Bristol, UK

7 Lectures on:

Using non-linear effects in adaptive structures. Control of flexible structural elements. Modal control and adaptive control of structures. Using shell structures as morphing elements.

LECTURES

All lectures will be given in English. Lecture notes can be downloaded from CISM web site, instructions will be sent to accepted participants.

**EXPLOITING NONLINEAR BEHAVIOUR
IN STRUCTURAL DYNAMICS**

Udine, September 13 - 17, 2010

Application Form

(Please print or type)

Surname _____

Name _____

Affiliation _____

Address _____

E-mail _____

Phone _____ Fax _____

Method of payment upon receipt of confirmation (Please check the box)

The fee of Euro 700,00 includes IVA/VAT tax and excludes bank charges

I shall send a check of Euro _____

Payment will be made to CISM - Bank Account N° 094570210900,
VENETO BANCA - Udine (CAB 12300 - ABI 05418 - SWIFT AMBPIT2M - IBAN
CODE IT83Z 05418 12300 09457 0210900).

Copy of the receipt should be sent to the secretariat

I shall pay at the registration counter with check, cash or VISA
Credit Card (Mastercard/Eurocard, Visa, CartaSi)

IMPORTANT: CISM is obliged to present an invoice for the above sum. Please indicate to whom the invoice should be addressed.

Name _____

Address _____

C.F.* _____

VAT/IVA* No. _____

(*) Only for EU residents or foreigners with a permanent business activity in Italy.

Only for Italian Public Companies

I ask for IVA exemption (ex law n. 537/1993 - art. 14 comma 10).

Privacy policy: I understand that data received via this form will be used only to provide information about CISM and its activities, within the limits set by the Italian legislative decree no. 196/2003 and subsequent amendments.

Complete information on CISM's privacy policy is available at www.cism.it.

I have read the "Admission and Accommodation" terms and conditions and agree.

Date _____ Signature _____