

COURSE 104: THEORETICAL & EXPERIMENTAL MODAL ANALYSIS OF NONLINEAR MECHANICAL SYSTEMS

Sunday, January 29, 2012

Course Description

Because nonlinearity is a frequent occurrence in real-life applications, there is a need for efficient theoretical and experimental nonlinear modal analysis. In this context, nonlinear normal modes (NNMs) offer a solid theoretical and mathematical tool for interpreting a wide class of nonlinear dynamical phenomena, yet they have a clear and simple conceptual relation to the classical linear normal mode, with which practicing structural engineers are familiar. However, most structural engineers still view NNMs as a concept that is foreign to them, and they do not yet consider these nonlinear modes as a practical nonlinear analog of the LNMs. The objective of this course is to introduce the concept of NNMs and to illustrate in a simple manner their fundamental properties. The application of NNMs to theoretical and experimental modal analysis of nonlinear vibrating structures is then discussed extensively and illustrated using academic and real-life examples. Specifically, the NNMs of a full-scale aircraft are analyzed. Finally, the constructive utilization of nonlinearity through passive targeted energy transfer is proposed, and the resulting dynamical phenomena are analyzed using the NNM theory.

Who should attend

Graduate students and researchers who need to learn how to extend modal analysis to nonlinear vibrating structures. Practicing engineers who need to account for nonlinear behavior in their applications instead of overlooking it, as is the common practice.

Course Outline

This short course is organized into eight one-hour lectures. A hardcopy of the course notes will be provided, together with a CD-ROM that includes the lectures and bibliographical references.

Lecture 1: From Linear to Nonlinear Modal Analysis

- State-of-the-art of theoretical and experimental linear modal analysis
- Real-life applications
- Limitations of linear modal analysis
- Practical examples of nonlinearity
- Introduction to nonlinear system identification

Lecture 2: Definition and Fundamental Properties of Nonlinear Normal Modes

- Two definitions: undamped and damped nonlinear normal modes
- Frequency-energy dependence
- Modal interactions and mode bifurcations
- Graphical depiction of nonlinear normal modes: frequency-energy representation
- Analytic computation of nonlinear normal modes
- Matlab examples

Lecture 3: Basic Computational Methods

- Concept of periodic solution
- Computation of periodic solutions using shooting methods
- Sequential continuation
- Matlab examples

Instructors

The instructors for this short course are: Gaëtan Kerschen (University of Liège) and Alexander Vakakis (University of Illinois at Urbana-Champaign). The instructors have extensive experience in nonlinear structural dynamics, from analytical and numerical modeling to the interpretation and exploitation of experimental measurements.



Gaëtan Kerschen



Alexander Vakakis

Course Fee

The *regular* course fee for *Theoretical & Experimental Modal Analysis of Nonlinear Mechanical Systems* is \$350, and the *student* course fee is \$175. Course fee includes lunch, course handout material, and refreshment breaks. Lodging and additional food or materials are not included.

Lecture 4: Advanced Computational Methods

- Pseudo-arclength continuation
- Optimization of the algorithm
- Matlab examples including a full-scale aircraft
- Comparison of analytic and computational methods

Lecture 5: Experimental Modal Analysis of Nonlinear Systems

- Nonlinear phase resonance technique, nonlinear force appropriation, nonlinear mode indicator function
- Time-frequency analysis: wavelet transform
- Experimental demonstration

Lecture 6: A Global/Local Approach to Nonlinear System Identification

- Slow and fast dynamics, empirical mode decomposition.
- Nonlinear modal interactions, intrinsic modal oscillators.
- Nonlinear system identification of the dynamics of aeroelastic instability suppression.

Lecture 7: Constructive Utilization of Nonlinearity

- Passive targeted energy transfer in vibrating systems
- Interpretation using nonlinear normal modes
- Practical application: suppression of aeroelastic instability

Lecture 8: Closure and Group Discussion

- Brief summary of the short course and concluding remarks
- Challenges ahead including structural health monitoring and finite element model updating
- Feedback from attendees, questions and final survey

Attendees are strongly encouraged to bring their own laptop computers.
There will be no computers made available.

