Course 104: Theoretical & Experimental Modal Analysis of Nonlinear Mechanical Systems

Sunday, January 31, 2010, 8:00 AM - 6:00 PM

Instructors

Dr. Gaëtan Kerschen, University of Liège
Prof. Maxime Peeters, University of Liège
Prof. Alexander Vakakis, University of Illinois at Urbana-Champaign

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. 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
- Frequency-energy dependence
- Modal interactions
- Mode bifurcations
- Frequency-energy representation
- Matlab examples

Lecture 3: Analytic computation of nonlinear normal modes
- Literature overview
- Asymptotic methods
- Harmonic balance method
- Examples

Lecture 4: Basic computational methods
- Concept of periodic solution
- Computation of periodic solutions using shooting methods
- Sequential continuation
- Matlab examples

Lecture 5: Advanced computational methods
- Pseudo-arclength continuation
- Optimization of the algorithm
- Matlab examples
- Comparison of analytic and computational methods

Lecture 6: Experimental modal analysis of nonlinear systems
- Wavelet transform
- Nonlinear normal mode invariance
- Nonlinear force appropriation and phase resonance
- Experimental example

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

Instructors


Gaëtan Kerschen


Maxime Peeters


Alexander Vakakis

The instructors for this short course are: **Gaëtan Kerschen**, University of Liège; **Maxime Peeters**, 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.

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 box lunch, course handout material, and refreshment breaks. Lodging and additional food or materials are not included

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