CHALMERS

Chalmers University of Technology, Sweden

Department of Mechanics and Maritime Sciences

Course PM
TME146 "Structural Dynamics Control"
Study period 2, 2019-2020 Acad. Year

Course code and name: TME146 "Structural Dynamics Control"
Credits: 7.5 Higher education credits (hec)
Institution: Department of Mechanics and Maritime Sciences
Instructor in total charge, lecturer and examiner: Prof. Viktor Berbyuk
Teaching Language: English
Duration: **2019-11-04 – 2020-01-18**

COURSE AIM

The course aims at providing knowledge on modern methods and concepts of passive, semi-active and active vibration control, to cross the bridge between the structural dynamics and control engineering, while providing an overview of the potential of smart materials, (magnetorheological fluids, magnetostrictive materials, and piezoceramics), for sensing and actuating purposes in active vibration control.

Vibration control applications appear in vehicle engineering, high precision machines and mechanisms, robotics, biomechanics and civil engineering. The focus of the project part of the course is on experimental validation of practical methods, i.e., methods that were found to actually work efficiently for passive and/or active vibration control. The course prepares students to use industry-leading data acquisition hardware and software tools for measurement, signal processing and vibration control.

PREREQUISITES

Basic knowledge in mechanics, in particular dynamics of particles and rigid body plane motion, some familiarity with state space models, vibrations and automatic control.

LEARNING OUTCOME

After completion of this course, the student should be able to:

-Derive the equations and solve vibration dynamics problems for controlled multibody systems with springs, dampers and bushings, as well as with active functional components like electromagnetomechanical dampers and actuators;
-Create mathematical and computational models suitable for structural dynamics control applications;

-Analyze vibration dynamics, dynamic responses of structural systems (response ratio, response spectra, etc.) for different damping concepts and external control;
-Explain in detail the basic principles on which the structural dynamics control methods rely and choose appropriate control strategy for particular applications;
-Formulate and solve passive, semi-active as well as active structural dynamics control problems for vibrating mechanical systems;
-Evaluate vibration control solutions experimentally by using LabVIEW, Matlab and test rigs with modern data acquisition hardware (CompactDAQ, CompactRIO);
-Understand, explain and apply the physics behind semi-active and active structural dynamics control solutions based on smart materials sensor and actuator technologies (magnetorheological fluids, magnetostrictive and piezoelectric materials);
-Carry out structural dynamics analysis and design vibration control strategies for vibrating systems having applications in automotive industry (chassis and powertrain suspensions), railway industry (high speed train bogie and car-body suspensions), wind power industry (turbine drive train systems), civil engineering;
-Understand that vibrations can be also used for advantage in some applications. Know the basic principles and the state of the art on vibration to electrical energy conversion by using smart materials (power harvesting technology);
-Show ability to work in project team and collaborate in groups with different compositions.

COURSE ORGANIZATION

The course comprises the following type of activities:

- Lectures (4 hours weekly)
- Exercises, (Problem Solving Sessions, 2 hours weekly)
- Matlab computer assignments in group of two students (4 hours weekly)
- Work with labprojects on validation of vibration control methods at the Vibrations and Smart Structures Lab in group of max 5 students (during weeks 49-51)
- Papers review project, *not compulsory*
- Reporting on computer assignments and labprojects
- Written exam.

COURSE CONTENT

Course content will comprise the following parts.

Introduction: Supplementary mathematics and mechanics for structural dynamics control. Vibration dynamics modelling and analysis. State space approach. Smart structures and active control of structural dynamics.

Passive control in structural dynamics: Vibration control by parameter optimization. Tuned mass damper technology. Vibration isolation. Dynamic vibration absorbers.

Feedback control and stability of structural dynamics: Review of different control strategies. Lyapunov stability of dynamical systems. Lyapunov equation. Routh-Hurwitz criterion.

Semi-active control in structural dynamics: Controllable stiffness/damping based semi-active vibration control. Continuous and on-off skyhook control strategies for semi-active structural control. Smart materials technology for active structures. Magneto-rheological fluid technology for semi-active structural dynamics control.

Active control in structural dynamics: The LQR optimization and active vibration control. The variational calculus for optimal structural dynamics control. The first integrals method and active vibration control. The Pontryagin maximum principle for optimal structural dynamics control.

Useful vibration: Magnetostrictive and piezoelectric materials technologies for vibration to electrical energy conversion (power harvesting from vibration). Models, simulations, experimental validation.

Applications: Vibration control in automotive engineering (vehicle suspensions, engine mounting systems, driveline vibration, vehicle comfort, motion stability and safety); Wind turbine drive train structural dynamics; Vibration control in rotor systems; Vibration control in high speed trains (primary and secondary car-body suspensions); Magnetostrictive sensors, actuators and electric generators for active structures, self-powered structural health monitoring systems, others.

Computer assignments and labproject: The topics will be closed related to the course lectures as well as to the ongoing research projects at the Division of Dynamics with industrial partners (AB Volvo, Scania, SKF, Swedish Wind Power Technological Centre, others).

COURSE SCHEDULE in brief

Mondays (November 4 – December 16):

- **weeks 45 – 51***,* 13:15-15:00 – **Lectures, Room ML2** (Hörsalsvägen 7 B, 2nd floor)
- **weeks 45 – 50,** 15:15-17:00 – **Computer assignments** in PC-room MT11 and MT12
- **weeks 49 – 51,** 15:15-17:00 – **Labprojects** in Vibrations and Smart Structures Lab

Thursdays (November 7 – December 19):

- **weeks 45 – 46***,* 08:00-09:45 – **Lectures, Room ML2** (Hörsalsvägen 7 B, 2nd floor)
- **weeks 47 -** *,* 08:00-09:45 – **Lectures, Room MA** (Hörsalsvägen 5)
- **weeks 48 – 51***,* 08:00-09:45 – **Lectures, Room ML2** (Hörsalsvägen 7 B, 2nd floor)
- **weeks 45 – 50***,* 10:00-11:45 – **Computer assignments** in PC-room MT11 and MT12
- **weeks 49 – 51,** 10:00-11:45 – **Labprojects** in Vibrations and Smart Structures Lab

Fridays (November 8– December 20):

- **weeks 45 – 51***,* 15:15-17:00 **– Problem Solving Sessions,** Room ML2

Self-studies: December 23, 2019 -January 3, 2020; January 10, 2020.

Detailed schedule with lectures and assignments contents available via course home page in Canvas

IMPORTANT DATES

- Reporting on computer assignments(CAs) and labprojects:
  - CAs Part 1 – at the latest November 18, 2019
  - CAs Part 2 – at the latest December 9, 2019
  - Lab 1 & Lab 2 – at the latest December 20, 2019
- Papers review project report (*not compulsory*) – at the latest January 12, 2020

Written exam: January 14, 2020, at 08:30-12:30. Place: To be given.

COURSE LITERATURE

Berbyuk V., *Structural Dynamics and Control,* Lecture Notes, *Second Edition,* Department of Applied Mechanics, Chalmers University of Technology, Göteborg, (*available at CREMONA before course start)*.
Hands-On for Computer Assignments and Labprojects, Department of Mechanics and Maritime Sciences, Chalmers University of Technology, 2018.
Introduction to LabVIEW and Computer-Based Measurements, National Instruments.

EXAMINATION

Computer Assignments and Labprojects work must be approved PRIOR to written exam and will give 3,0 hec. The written exam consists of *four* problems of the type solved on the problem solving sessions and during the lectures. Each problem on the exam can give maximum 5 points. The papers review project *(not compulsory)* can give maximum 3 points additionally. The total course mark will be based on results of the reporting of Computer Assignments & Labprojects work, the results of written exam and papers review project bonus points. The grades are: 9-13 points give **"3",** 14-17 points give **"4",** and 18 or more points give **"5"**. Bonus points are valid for the current course. A student can thus be credited with the bonus points at the ordinary exam and at the two re-examinations of the course.

Aids during the examination

Students are allowed to bring to the exam **any books** including textbook "*Structural Dynamics Control"* by Viktor Berbyuk. Any electronic calculator is allowed but not laptop.

COURSE EVALUATION

There will be course evaluation as is described in Chalmers policy.

COURSE PERSONNEL

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