CHALMERS
Chalmers University of Technology, Sweden

Department of Applied Mechanics

Course PM
TME145 "Vibration Control"
Quarter 2, 2010

Course code and name: TME145 "Vibration Control"
Credits: 7.5 Higher education credits (hec)
Institution: Department of Applied Mechanics
Instructor in total charge, lecturer and examiner: Prof. Viktor Berbyuk
Teaching Language: English
Course home page:
http://www.student.chalmers.se/sp/course?course_code=TME145
Duration: **2010-10-26 – 2010-12-19**

COURSE AIM

The course aims at providing knowledge on modern methods, concepts and algorithms 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 hardware and software tools for measurement, signal processing and vibration control, (CompactDAQ, CompactRIO, LabVIEW from National Instruments Corporation, others).

PREREQUISITES

Basic knowledge in dynamics, vibration theory and motion control.

LEARNING OUTCOME

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

1. Derive equations of motion and solve vibration dynamics problems for mechanical systems with conventional springs, dampers and bushings, as well as active functional components like electromagnetomechanical dampers and actuators. Create computational models of vibration mechanical systems by using LabVIEW and/or Matlab/Simulink.
2. Validate the vibration system models, analyze vibration dynamics of the system for different damping concepts, choose appropriate vibration control concept and design optimal vibration control for particular applications by using created computational models together with experimental set up and modern data acquisition hardware (CompactDAQ, CompactRIO).
3. Understand the physics behind semi-active and active vibration control solutions based on smart material sensor and actuator technologies (magnetorheological fluids, magnetostrictive and piezoelectric materials).
4. Formulate and solve passive, semi-active as well as active vibration control problems for some structural vibration systems. Evaluate vibration control solutions experimentally.
5. Carry out vibration dynamics analysis and design vibration control solutions for vibration systems having applications in automotive industry like chassis and powertrain suspensions, high speed train suspensions, suspension of unbalanced rotors, etc.
6. Understand that vibrations can also be used for advantage in some applications. Know the basic principles on vibration to electrical energy conversion by using smart material based power harvesting technology.
7. Show ability to work in teams and collaborate in groups with different compositions.

COURSE ORGANIZATION

The course will be organized in a way to implement an integrated teaching approach consisting of *Theory, Virtual Instrumentation and Graphical System Design, and Experiment,* supporting high outcome of learning of vibration dynamics and control theory.

The course will comprise the following type of activities:

- Lectures (4 hours weekly)
- Exercises, (Problem Solving Sessions, 2 hours weekly)
- LabVIEW / CompactDAQ / CompactRIO tutorials and computer assignments in group of two students (4 hours weekly, during the first 3 weeks)
- Reporting on computer assignments
- Team-work with labprojects (4 hours weekly, during the last 4 weeks)
- Reporting on labprojects
- Papers review project, *not compulsory,* (during 7 weeks)
- Written exam.

COURSE CONTENT

Course content will comprise the following parts.

1. *Introduction.* Supplementary mathematics for vibration dynamics and control. Vibration dynamics of multibody systems (MBS). State space approach. Mathematical and computational models of vibration dynamics of MBS. Validation and verification of mathematical and computational models. Optimization of

vibration dynamics of MBS. LabVIEW, CompactDAQ, and CompactRIO from National Instruments Corporation.

2. *Passive vibration control* (PVC). Free and forced vibration of mechanical systems. Review of methods for PVC. Vibration isolation. Conventional mounts and mounting systems. Dynamic vibration absorbers. Tuned mass dampers. Design of optimal dynamic absorbers and tuned mass dampers.
3. *Semi-active vibration control.* Smart material technology for vibration control. Magnetorheological fluid based technology for semi-active vibration control. Magnetorheological tuned mass damper for vibration control. Algorithms for semi-active vibration control.
4. *Active vibration control.* Feedback control system. Controllability. Observability. Stability. LQR optimization. Variational calculus and optimal vibration control. First integrals method for active vibration control. Hybrid control.
5. *Useful vibration.* Magnetostrictive and piezoelectric material based technology for vibration to electrical energy conversion (power harvesting from vibration). Modelling, simulation, experimental validation.
6. **Applications:** *Vibration control in automotive engineering* (vehicle suspensions, engine mounting systems, vehicle comfort, motion stability and safety); *Vibration control in rotor dynamical systems* (suspension systems of washing machines); *Vibration control in high speed trains* (primary and secondary bogie suspensions); *Power harvesting from vibration* (magnetostrictive electric sensors and electric generators, smart material based self-powered structural health monitoring systems).

Computer assignments and labproject topics will be related to the ongoing research projects at the Division of Dynamics with industrial partners (Volvo Truck Corporation, National Instruments Corporation, Asko Appliances AB, CHARMEC, others).

COURSE SCHEDULE in brief

Tuesday (October 26 – December 7):

- **weeks 43 – 49**, 13:15-15:00, lecture room ML4 – **Lecture**
- **weeks 43 – 45**, 15:15-17:00, PC-room MT0 – **Computer assignments**
- **weeks 46 – 49,** 15:15-17:00, Vibration and Smart Structure Lab – **Labprojects**

Wednesday (October 27 – December 08):

- **weeks 43 – 49**, 10:00-11:45, lecture room ML4 **– Problem Solving Session**

Friday (October 29 – December 10):

- **weeks 43 – 49**, 08:00-09:45, lecture room ML4 – **Lecture**
- **weeks 43 – 45**, 10:00-11:45, PC-room MT0 – **Computer assignments**
- **weeks 46 – 49,** 10:00-11:45, Vibration and Smart Structure Lab – **Labprojects**

Detailed schedule with lectures and assignments contents will be available via course home page.

IMPORTANT DATES

Reporting on VC2010 project

- Part 1 – (Online report) at the latest 5/11/2010;
- Part 2 – written report at the latest 19/11/2010;

- Part 3 – written report at the latest 3/12/2010;
- Part 4 – written report together with answers on all assistants' comments obtained on Part 2- Part 3 reports (if any) – at the latest December 14, 2010.
- Papers review project (*not compulsory*) – at the latest December 14, 2010.

Written exam: December 16, 2010, 14:00-18:00, M-building.

COURSE LITERATURE

1. Berbyuk V., *Vibration Dynamics and Control,* Lecture Notes, Department of Applied Mechanics, Chalmers University of Technology, Göteborg, 2010.
2. *LabProject in Vibration Control, Hands-On*, Department of Applied Mechanics, Chalmers University of Technology, Göteborg, 2010.
3. *Introduction to LabVIEW and Computer-Based Measurements,* National Instruments, 2007.

All course literature will be available before course start for the reasonable student price.

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"**.

COURSE EVALUATION

There will be course evaluation as is described in Chalmers policy. For details, please visit: http://www.chalmers.se/en/sections/education/current_students/course-evaluation

COURSE PERSONNEL

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