Short Doctoral Course (12 h)

Active Control of Sound and Vibration with Practical Applications

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Summary

In this course, an overview of active vibration control will be presented. Both feedback and feedforward strategies will be introduced. In feedback control, receptance method will be introduced and implemented to assign the eigenvalues of the system. This problem is known as "pole placement". Experimental results will be shown on a T-plate, where the natural frequencies and damping ratios of the plate are modified as a result of feedback gains. Stability analysis using Nyquist criteria will be presented. The receptance method will also be extended to partial pole placement and robust control. Experimental results on an H-rig structure show how these techniques in active control work. An application of pole placement will be demonstrated on an Agusta-Westland W30 helicopter. Vibration suppression is achieved using both velocity and displacement feedback by assigning the poles of the helicopter to avoid blade passing frequency. In feedforward control, Least Mean Square (LMS) algorithm will be considered. A secondary signal will be generated to cancel the vibrations from primary (disturbance) source. Examples such as active noise control of a duct and active vibration control of an aircraft wing will be provided. The feedforward control will also be applied to nonlinear systems. The performance of linear with nonlinear control will be compared. The course also includes three tutorials. The first tutorial is to simulate a feedback control based on measured data. In the second tutorial, feedforward control using LMS algorithm will be practiced. In the third tutorial, active control in a duct will be considered.

Keywords: *Active Control, Pole Placement, Receptance Method, Stability Analysis, Nyquist Method, Feedback and Feedforward Control, Least Mean Squares.*

Prof. Maryam Ghandchi Tehrani is currently appointed as Lecturer in Active Control at the Institute of Sound and Vibration Research, University of Southampton, UK (October 2010). She has earned a B.Sc. in Mechanical Engineering at the Iran University of Science and Technology (2002), then a M.Sc. in Mechanical System Engineering (2004) and a Ph.D. on Passive Modification and Active Control for Structural Vibration Suppression at the University of Liverpool (2007). She has been already Visiting Professor at the Department of Engineering (Dalmine) within the Project "Italy®" in 2013. She has been awarded of several scholarships (B.Sc., Ph.D.) and grants (EPSRC, Visiting Grants), and published numerous articles in peer-reviewed international journals on Structural Dynamics and Vibration Control, with particular focus on Receptance Method, Pole Placement Method, Active Vibration Control of Parametrically-Excited Systems, Non-Linear Dynamics of Inertial Actuators, Energy Harvesting.

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Course Timetable

Monday 3 November 2014	09:30 - 10:30	Introduction to active control
	10:30 - 11:30	Feedback control and stability analysis
	11:30 - 12:30	Pole placement by the receptance method
	15:00 - 16:00	Application of feedback control on helicopters
	16:00 - 18:00	Computer Laboratory 1: Feedback control
Tuesday 4 November 2014	15:00 - 18:00	Computer Laboratory 2: Construction of FRF from measurements, LMS algorithm Computer Laboratory 3: Active noise control
Wednesday 5 November 2014	15:00 - 16:00	Digital control
	16:00 - 17:00	Feedforward control in a duct, nonlinear control
	17:00 - 18:00	Application of feedforward control on an aeroplane wing

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Short Course: Active Vibration Control

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Active Control

In this course, an overview of active vibration control will be presented. The objective of active vibration control is to modify the system response in a controllable way. Both feedback and feedforward strategies will be introduced.

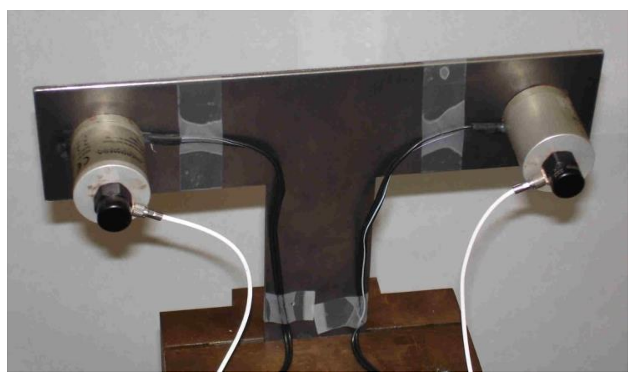
In feedback control, receptance method will be introduced and implemented to assign the eigenvalues of the system. Classical methods such as passive modification have some limitations in choosing the parameters of mass stiffness and damping. Modification can be assignment of poles or zeros (resonances or anti-resonances) to a structure using the velocity and displacement feedback. The measured receptances of the structure are replaced by the mathematical model of mass, stiffness and damping.

Experimental results will be shown on a T-plate, where the natural frequencies and damping ratios of the plate are modified as a result of feedback gains. Stability analysis using Nyquist criteria will be presented. The receptance method will also be extended to partial pole placement and robust control. Experimental results on an H-rig structure show how these techniques in active control work. An application of pole placement will be demonstrated on an Agusta-Westland W30 helicopter. Vibration suppression is achieved using both velocity and displacement feedback by assigning the poles of the helicopter to avoid blade passing frequency.

In feedforward control, Least Mean Square (LMS) algorithm will be considered. A secondary signal will be generated to cancel the vibrations from primary (disturbance) source. Examples such as active noise control of a duct and active vibration control of an aircraft wing will be provided. The feedforward control will also be applied to nonlinear systems. The performance of linear with nonlinear control will be compared.

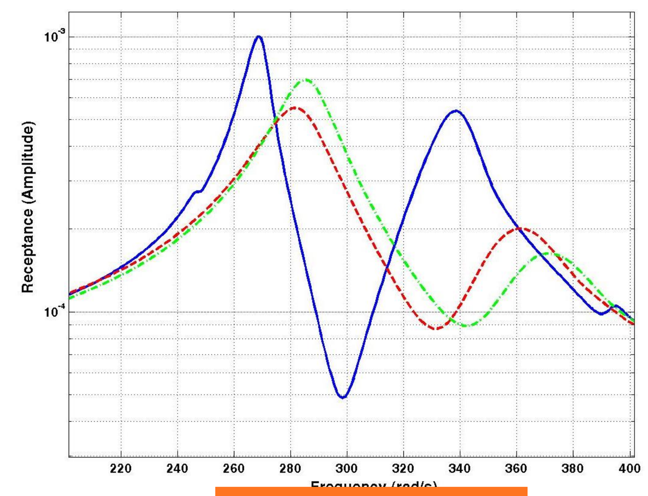
The course also includes three tutorials. The first tutorial is to simulate a feedback control based on measured data. In the second tutorial, feedforward control using LMS algorithm will be practiced. In the third tutorial, active control in a duct will be considered.

Output Feedback



T-shaped plate under control

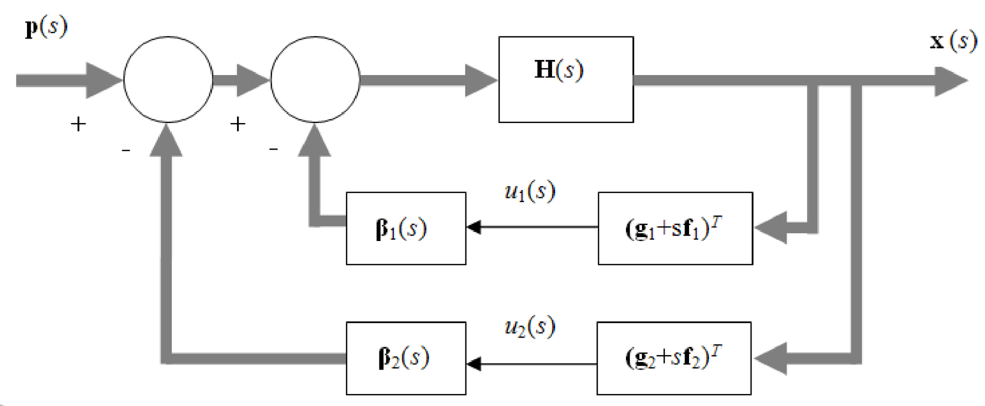
$$\mathbf{M}\ddot{\mathbf{x}}+\mathbf{C}\dot{\mathbf{x}}+\mathbf{K}\mathbf{x}=\mathbf{b}u(t)+\mathbf{p}(t)$$

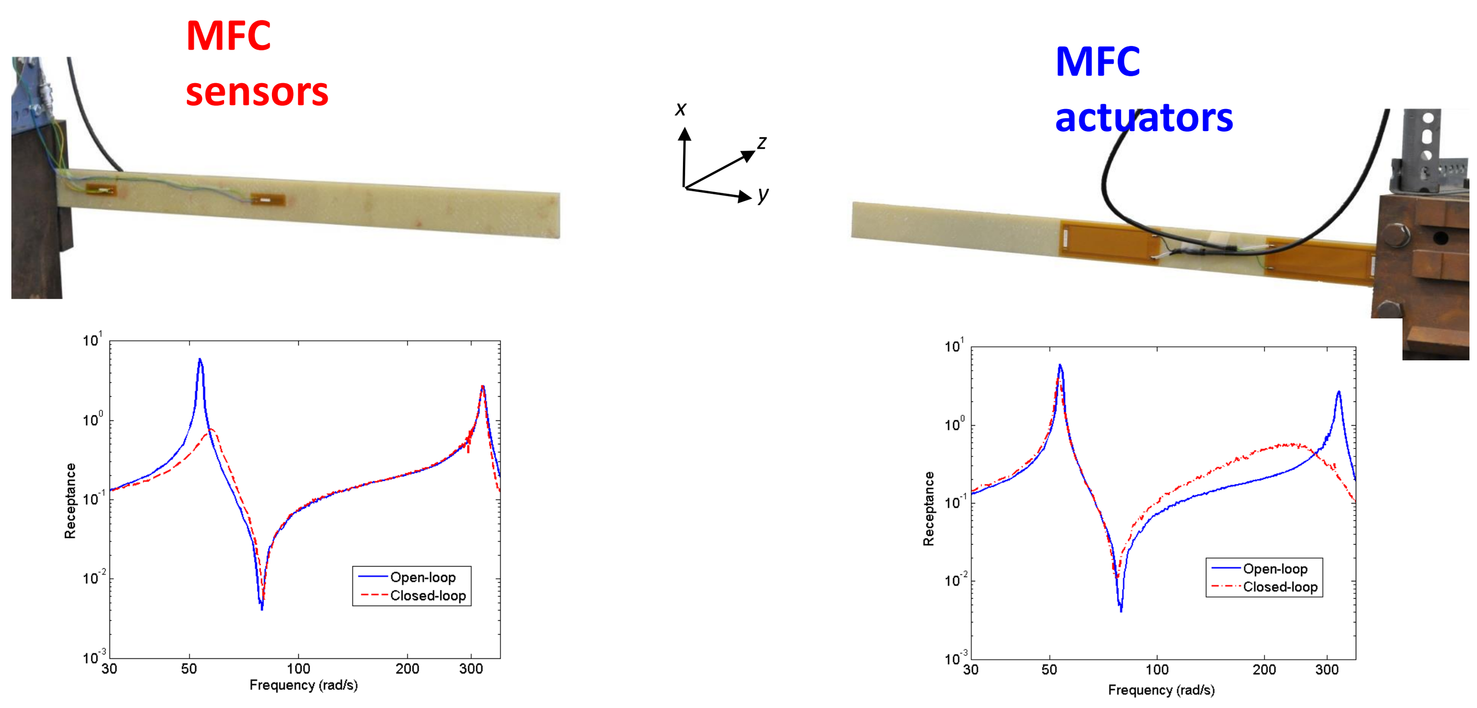


Pole placement

Robust Pole Placement

$$\hat{\mathbf{H}}(s)=\mathbf{H}(s)-\frac{\mathbf{H}(s)\mathbf{b}(\mathbf{g}+s\mathbf{f})^T\mathbf{H}(s)}{1+(\mathbf{g}+s\mathbf{f})^T\mathbf{H}(s)\mathbf{b}}\qquad u(t)=-\mathbf{f}^T\dot{\mathbf{x}}-\mathbf{g}^T\mathbf{x}$$

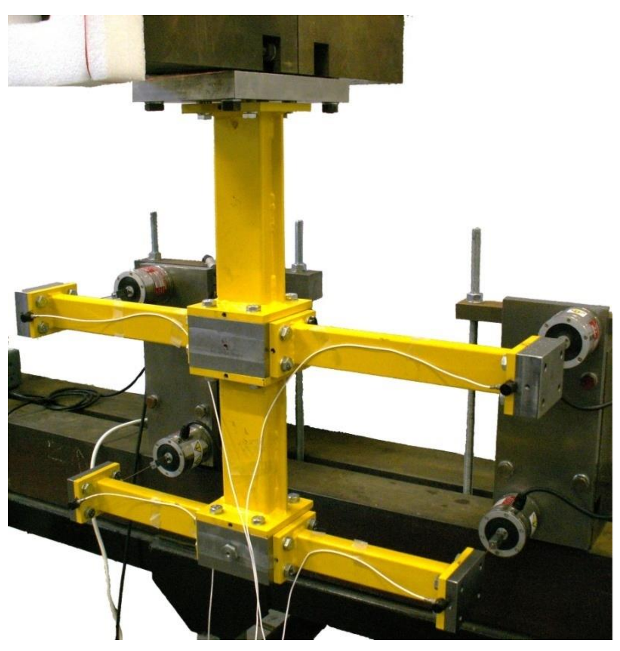




Piezo beam using state feedback

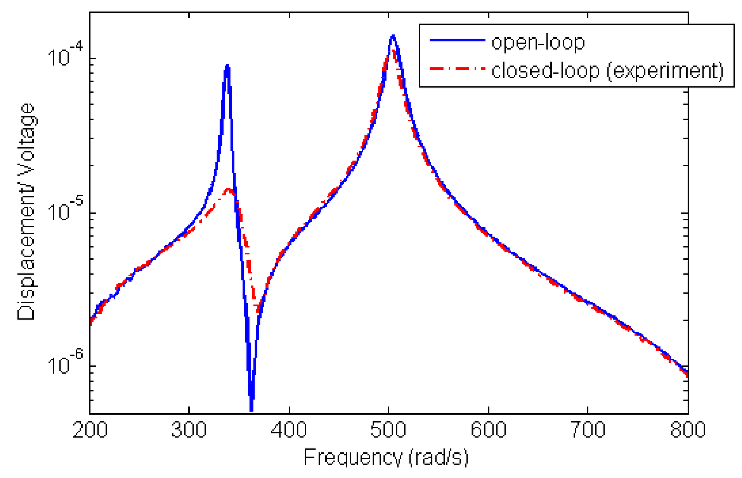
Partial Pole Placement

T-Configuration

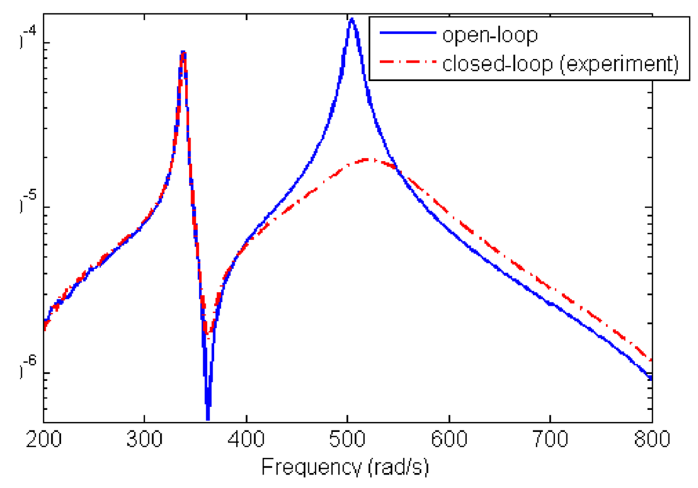


H-Configuration

T-configuration

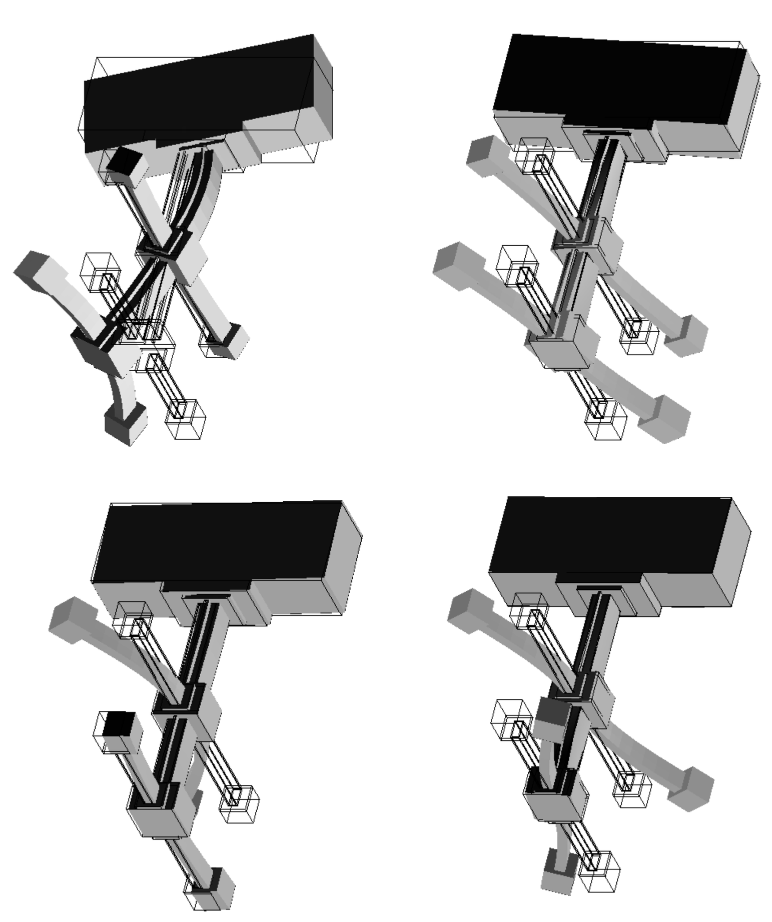


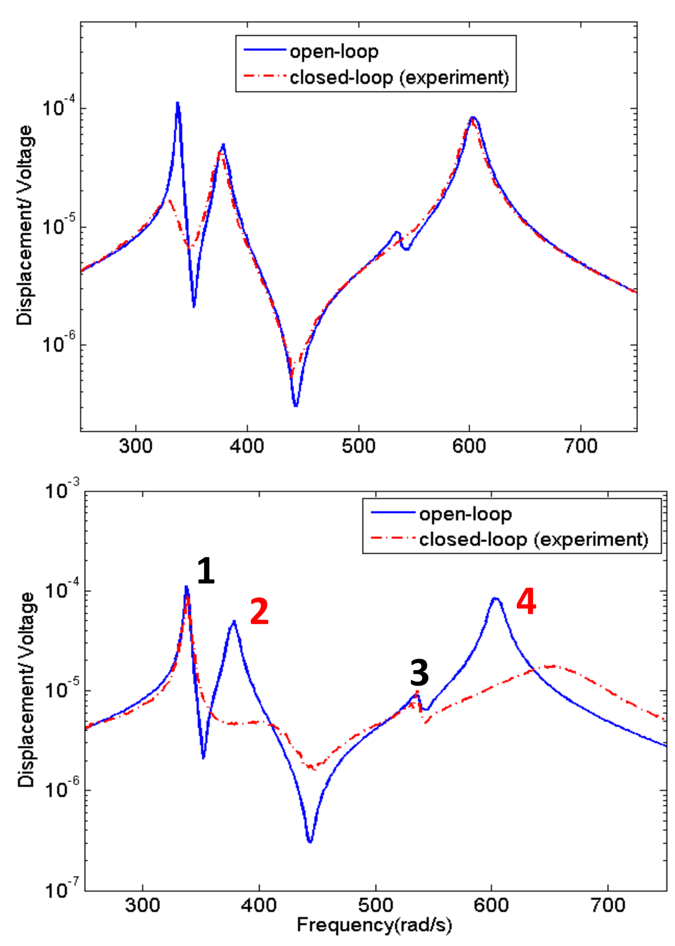
Assignment of bending mode



Assignment of Torsional mode

H-configuration





W30 Helicopter

Receptance method is developed and implemented to control the vibration modes of real structures.

Active vibration control on W30