CE 49C VIBRATION BASED HEALTH MONITORING

Elective Course

Spring 2009

Instructor: *Name:* Pelin GÜNDEŞ

Course Data: Hours: WWW 678, Room: NH404

Course Description (Proposed Catalog):

CE49C.01 Vibration based health monitoring (3+0)

Single degree of freedom systems, multi degree of freedom systems, introduction to vibration based health monitoring, impulse response, frequency response function, vibration instrumentation, optimal sensor placement, probability and stochastic processes, random vibrations, signal processing, Fourier series expansion, Discrete Fourier Transforms, Fast Fourier Transform, Stochastic system identification

Prerequisite: CE49C Vibration based health monitoring

Course Objectives:

To develop an understanding of and appreciation for basic concepts in structural dynamics such as single degree of freedom systems, multi-degree of freedom systems, dynamic equilibrium, mode shapes, eigenfrequencies, damping and their relation to damage.

To help the students develop an intuitive feeling about dynamic behavior and response of structures

To help students understand the dynamic behavior of structures in different domains

To discuss various tools used in the analysis of structures. To give the students an overview of all the steps involved in planning, executing and interpreting the results from vibration testing.

Textbook:

Heylen W., Lammens S. And Sas P., 'Modal Analysis Theory and Testing', Katholieke Universiteit Leuven, 1997.

Ewins D.J., 'Modal Testing, Theory, Practice, and Application' (Mechanical Engineering Research Studies Engineering Design Series), Research Studies Pre; 2 edition (August 2001)

Maia, N. M. M. and Silva, J. M. M.*Theoretical and Experimental Modal Analysis,* Research Studies Press Ltd, Hertfordshire, 1997, 488 pp.,ISBN 0863802087

Reference Books:

Rao S.S., 'Mechanical vibrations', Pearson, Prentice Hall, 2004; Inman D.J., 'Engineering Vibration', Prentice Hall, 1994; Juang, 'Applied system identification', Prentice Hall.

Curricular Context:

This course introduces the basic principles of the theory of vibrations with direct implications and applications to design of engineering structures.

Computer Usage: N/A

Class Policies:

Homework and Quizzes: Periodic quizzes to be held. 20% of the course grade.

Midterm projects: Three midterms, each 20% of the course grade.

Final project: Presentation of a case study on vibration monitoring or a related field, 20% of the course grade.

Contribution of the Course to Program Outcomes:

(a) An ability to apply knowledge of mathematics, science and engineering

(c) An ability to design and conduct experiments, as well as to analyze and interpret data.

(d) An ability to function on multidisciplinary terms

(e) An ability to identify, formulate and solve engineering problems

(k) An ability to use the techniques, skills and modern engineering tools necessary for engineering practice

Course Assessment:

Course will be assessed on the basis of the accomplishments regarding the course objectives and the contributions to the program outcomes. The evaluation will consist mainly of the responses from the students, who will provide their comments to various course related questions in the final week of the semester.

Week	Topics	Reading Assignment	Projects and Quizzes	Course Topics and Objectives
1	Single degree of freedom systems	Related chapters from the book of Rao and Ewins	-	Newton's laws, continuous systems, discrete systems, classification of vibration, mathematical background: ordinary differential equations, harmonic motion, free vibration of single degree of freedom systems, forced vibration, harmonic excitation
2	Single degree of freedom systems	Related chapters from the book of Rao and Ewins	-	Base excitation, electrical systems, analogy between electrical and mechanical systems, response of sdof systems to impulsive forces, response of sdof systems to arbitrary loading,frequency response function
3	Multi degree of freedom systems	Related chapters from the book of Rao and Ewins	-	Two degree of freedom systems, equations of motion for forced vibration, free vibration analysis of an undamped system
4	Multi degree of freedom systems	Related chapters from the book of Rao and Ewins	Quiz 1	Modeling of continuous systems as multi degree of freedom, eigenvalue problem, normalization of modes, rigid body motion, orthogonality of modes, modal equations of undamped systems
5	Introduction to vibration monitoring	Related chapters from Maia and Silva	Quiz 2	Introduction to vibration monitoring, time domain, frequency domain, modal space, system poles, natural frequencies, damping ratios, residues, frequency response function, impulse response function, mdof systems, transfer function, residues, Laplace domain,why do we instrument structures, steps in instrumenting structures, optimal sensor placement
6	Vibration instruments	Related chapters from McConnell	Project 1	Strong motion instrumentation, analog and digital accelerographs, types of exciters and transducers, electromagnetic shakers, hydraulic shakers, inertia shakers,piezoelectric sensors, force balance accelerometers, LVDTs, mounting of accelerometers, calibration, basic steps to acquire data
7	Fourier Series, DFT, Fast Fourier Transforms	Related chapters from Newland	Project 2	Fourier series expansion, Discrete Fourier Transform, Fast Fourier Transform of Cooley and Tukey
8	Signal processing	Related chapters from Heylen	Quiz 3	Types of signals, typical signal processing operations, sampling, analog to digital conversion, aliasing, leakage,windows
9	Signal processing	Related chapters from Heylen	-	Averaging, power spectral density, filtering, analogue filters, digital filters, high pass low pass filters, causal and acausal filters, types of excitation signals, processing of earthquake records, instrument correction, baseline adjustments,filtering,padding,tapers,
10	Probability and stochastic processes	Related chapters from Newland, Papoulis	Project 3	Probability density function, Gaussian distribution, calculation of averages, probability distribution function, joint probability distribution, ensemble averages, second order averages, conditional probability, ensemble averaging, correlation, autopcorrelation, cross correlation,
11	Random vibrations	Related chapters from Newland	-	Spectral density, narrow band and broad band processes,white noise, spectral density of a derived process, cross spectral density
12	Random vibrations	Related chapters from Newland	-	Transmission of random vibration, statistics of narrow band processes, crossing analysis, distribution of peaks, frequency of maxima, accuracy of measurements
13	Stochastic system identification	Related journal papers, Related chapters from Juang, Ljung	Final project	Dynamic models of vibrating systems: Finite element model, Stochastic state space model, ARMA model, frequency domain models. Stochastic system identification methods, peak picking, complex mode indication function, Instrumental variable method, covariance based and data driven stochastic subspace system identification methods