THE UNIVERSITY OF WESTERN ONTARIO - FACULTY OF ENGINEERING SCIENCE

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

CEE 9603a – Application of Random Vibration, Course Outline (Sept. to Dec. 2011)

Vibrations of engineering systems are analysed using random vibration theory considering the excitation as stochastic process. The course is focused on practical engineering problems and is designed to develop the students' appreciation for application of peak responses that often govern the design. Specifically, students will learn what are the ergodic processes and temporal statistics; how to model the wind and earthquake excitations as stochastic excitations; how to evaluate the parameters of the probability distribution for the upcrossing and first passage problems; how to assess the peak response of single- and multi-degree-of-freedom systems and their incorporation in design code; The students will also learn simple techniques to assess nonstationary responses and nonlinear random vibrations. The general topics are

- Stochastic processes: definition, interpretation, representation in frequency domain and power spectra density function;
- Modeling of wind and earthquake excitations: characteristics of commonly used power spectral density functions for wind and earthquake;
- Peak response of single-degree-of-freedom linear elastic system: time domain versus frequency domain approach, power spectral density of the response, introduction to upcrossing problem and first passage problem, assessment of peak response;
- Peak response of multi-degree-of-freedom linear elastic system: power spectra density function of the response; peak response, practical combination rules;
- Codification and peak responses: discuss how the peak responses and combination rules are implemented or used in design codes;
- Nonstationary and/or nonlinear responses: an introduction to the priestly's representation of nonstationary processes, assessment of probability distribution of peak responses with uncertain structural properties, use of stochastic Newmark's method and stochastic central difference method in solving structural vibration problem.

Prerequisites:

Equivalent knowledge of CEE458b, and CEE490.

Note: It is the **student's responsibility** to ensure that all Prerequisite and/or Corequisite conditions are met or that special permission to waive these requirements has been granted by the Faculty. It is also **student's responsibility** to ensure that they have not taken course listed as an Antirequisite. The student may be dropped from the course or not given credit for the course towards their degree if they violate the Prerequisite, Corequisite or Antirequisite conditions.

Antirequisites:

None

Contact Hours:

2 lecture hours per week **(Tentatively, Tuesday 8:30 to 10:30)**

Instructor:

Dr. H. P. Hong ESB3028; e-mail: hongh@eng.uwo.ca; *Secretary*: Room 3005

Textbooks and References:

- Lin, Y. K. Probabilistic theory of structural Dynamics, MacGraw-Hill, 1967.

- Simiu, E. and Scanlan, R.H. Wind effects on structures, John Wiley & Sons, New York, 1996
- Yang, C.Y. Random vibration of structures, John Wiley & Sons, New York, 1986
- About 23 journal papers to be assigned in the classes

Units:

SI units will be used in lectures and examinations

Evaluation:

The final course mark will be determined as follows:

Assignments, project and class participation	50%
Final Examination	50%
Total	100%

Note:

Students must pass the final examination to pass this course. Students who fail the final examination will be assigned the aggregated mark as determined above, or 48%, whichever is less.

Examination:

A final examination will be held on all work covered during the course. The date of exam will be announced in the class at least two weeks prior to the exam.

Assignments and Project:

a) There will be four assignments. Each student must turn in one solution before the end of two weeks after the assignment is given.

b) Each student must turn in one written report on a project dealing with an engineering problem considering application of random vibration. The report should not exceed 25 pages in double space including references, figures and tables. The format of the report should follow the instruction to authors for the *Canadian Journal of Civil Engineering*.

Use of English:

In accordance with Senate and Faculty Policy, students may be penalised up to 10% of the marks on all assignments, tests, and examinations for the improper use of English. Additionally, poorly written work with the exception of the final examination may be returned without grading. If resubmission of the work is permitted, it may be graded with marks deducted for poor English and/or late submission.

Cheating:

University policy states that cheating is a scholastic offence. The commission of a scholastic offence is attended by academic penalties that might include expulsion from the program. If you are caught cheating, there will be no second warning.

Attendance:

Any student who, in the opinion of the instructor, is absent too frequently from class, laboratory, or tutorial periods will be reported to the Dean (after due warning has been given). On the recommendation of the Department concerned, and with the permission of the Dean, the student will be debarred from taking the regular final examination in the course.

Conduct:

Students are expected to arrive at lecture on time, and to conduct themselves during class in a professional and respectful manner that is not disruptive to others.

Sickness and Other Problems:

Students should immediately consult with the Instructor of Department have any problem that could affect their performance in the course. Where appropriate, the problems should be documented (see attached). The student should seek advice from the Instructor or Department Chair regarding how best to deal with the problem. Failure to notify the Instructor or Department Chair immediately (or as soon as possible thereafter) will have a negative effect on any appeal.

Notice:

Students are responsible for regularly checking their e-mail and notices posted outside the Civil and Environmental Engineering Department Office.

The attached document "INSTRUCTIONS FOR STUDENTS UNABLE TO WRITE TESTS OR EXAMINATIONS OR SUBMIT ASSIGNMENTS AS SCHEDULED" is part of this course outline.

List of References to Be Read and Summarized by Students, & Discussed in Class Room

For Application of Random Vibration (ES603)

Distribution of peak responses

Cartwright, D. E. and Longuet-Higgins, M. S. 1956. The statistical distribution of the maxima of a random function, Pro. Royal Soc. London, A237, 212-223.

Davenport, A. 1964. Note on the distribution of the largest value of a random function with application to gust loading, Proceedings Institute of Civil Engineering, 28, pp. 187-196.

Vanmarcke, E. 1976. Structural response to earthquakes, in Seismic risk and engineering decision, (Eds. Lomnitz C. and Rosenblueth, E.) Elsevier, Amsterdam, pp. 287-337.

(Focus on the distribution of the peaks)

Representation of nonstationary processes

Priestly, M. B. 1965. Evolutionary spectra and non-stationary process, J. R. Statis. Soc. B27, 204-237.

Huang N. E. et al. 1998. The empirical mode decomposition and the Hilbert spectrum for nonlinear and non-stationary time series analysis, Proc. R. Soc. London, 454, pp. 903-995.

(Focus on the representation of non-stationary process)

Numerical simulation of Gaussian and non-gaussian processes

Shinozuka, M. 1972. Monte Carlo solution of structural dynamics, Computers & Structures, Vol. 2, pp. 855-874

Samaras, E., Shinozuka, M., Tsurui,, A. ARMA Representation of Random Processes Journal of Engineering Mechanics, Vol. 111, No. 3, March 1985, pp. 449-461

Li, Y. and Kareem, 1995. Stochastic decomposition and application to probabilistic dynamics, Journal of Engineering Mechanics, Vol. 121, No. 1, pp. 162-173.

Grigoriu, M. 1998. Simulation of stationary non-Gaussian translation processes, Journal of Engineering Mechanics, Vol. 124, No. 2, 121-126.

Paola, M. 1998. Digital simulation of wind field velocity, Journal of wind engineering and industry aerodynamics, 74-76, pp. 91-109.

(Focus on the simulation of stochastic processes)

Hysteresis and dynamic systems under random excitations

Wen, Y. K. 1976. Method for random vibration of hysteretic systems, Jouranl of Eng. Mech. Div., ASCE, Vol. 102, No. EM2, pp. 249263.

Baber, T.T. and Wen, Y. K. 1981. Random vibration of hysteretic degrading systems, Journal of Eng. Mech. Vol. 107, No. EM6, pp. 1069-1087.

Ang, A. H-S. 1987. Seismic damage analysis of reinforced concrete buildings, in Stochastic method in structural dynamics, Martinus Nijhoff Publishers, pp. 172-199.

Wen Y. K. 1989. Method of random vibration for inelastic structures, Appl. Mech. Rev. ASME, vol. 42, No. 2., pp. 39-52.

Ma, F., Zhang, H., Bockstedte, A., Foliente, G. C. and Paevere, P. [2004] “Parameter analysis of the differential model of hysteresis,” *Transactions of the ASME* **71**(3), 342-349.

Wen, Y. K. 1980. Equivalent linerization for hysteretic system under random excitation, Transaction, ASME, vol. 47, pp. 150-154.

Casciati, F. 1987. Approximate method in nonlinear stochastic dynamics, in Stochastic method in structural dynamics, Martinus Nijhoff Publishers, pp. 154-171

To, C.W.S. 1992. A stochastic version of the Newamrk Family of algorithms for discretized dynamic systems, Computers and Structures, Vol. 44, No.3, pp. 667-673.

Zhang, L., Zu, J. W. and Zheng, Z. 1999. The stochastic Newmark algorithm for random analysis of multi-degree-of-freedom nonlinear systems, Computers & Structures, Vol. 70, pp. 557-568.

(Focus on the approximate solution to nonlinear dynamic systems under stochastic random excitation)

Fractiles and peak responses of multi-degree-of-freedom system

Rosenblueth, E. and Elorduy J. 1969. Responses of linear system to certain transient disturbances, Fourth World Conference on Earthquake Engineering, Santiago, Chile, I, A-1, 185-196.

Vanmarcke, E. 1976. Structural response to earthquakes, in Seismic risk and engineering decision, (Eds. Lomnitz C. and Rosenblueth, E.) Elsevier, Amsterdam, pp. 287-337.

Der Kiureghian, A. 1981. A response spectrum method for random vibration analysis of MDF systems, *Earthquake Engineering and Structural dynamics,* Vol. 9, No. 5, pp. 419-435.

Li, C. C. and Der Kiureghian, A. 1997. Large mean out crossing of nonlinear response to stochastic input, in Engineering Probabilistic design and maintenance for flood protection, Eds. Cook, R. et al. Kluwer Academic Publishers, pp. 141-160.

Hong, H.P. and Wang, S.S. 2002. Probabilistic analysis of peak response with uncertain PSD function, *Earthquake Engineering and Structural dynamics*., Vol. 31, pp. 1719-1733.

(Focus on the fractiles of the peak response of MDOF systems)