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Structural Dynamics

Instructor

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Department: Civil Engineering

Course Time: MWF 2-3

Lecture venue: STLH, Department of Civil Engineering

Detailed Course Page: http://civil.iisc.ac.in/~manohar/about_the_course.doc

Announcements

Brief description of the course

This is a core course for students of M Tech (Civil Engineering) who major in Structural Engineering. The course has three strands: (a) basic issues in modelling vibrating systems in time and frequency domains, (b) applications in earthquake and bridge engineering, and (c) exact and approximate methods for analysing structural response.The course would consist of lectures, tutorials, laboratory demonstrations, home assignments, class tests and final examination.

Prerequisites

No formal requirements. Exposure to solution of ODE-s and matrix algebra is assumed.

Syllabus

Equations of motion. Degrees of freedom. Dâ€™ Alembert principle. SDOF approximation to vibrating systems. Energy storage elements: mass, stiffness and damper. Undamped free vibration. Natural frequency. Damped free vibration. Critical damping. Forced response under periodic and aperiodic excitations. Support motions. Resonance. Impulse response and complex frequency response functions. Duhamel integral. Vibration isolation: FTR and DTR. Multi-DOF systems. Normal modes and natural frequencies.

Orthogonality of normal modes. Natural coordinates. Uncoupling of equations of motion. Repeated natural frequencies. Proportional and non proportional damping. Damped normal modes. Principle of vibration absorber. Continuous systems. Vibration of beams. Forced response analysis by eigenfunction expansion. Moving loads and support motions. Effect of axial loads. Approximate methods for vibration analysis. Rayleighâ€™s quotient. Rayleigh-Ritz method. Method of weighted residual. Method of collocation. Galerkinâ€™s method.

Course outcomes

1. To learn how to formulate and solve the equations of motion governing linear dynamical systems subjected to periodic and aperiodic excitations.

2. To understand the notions of frequency and time domain analyses, discrete and continuous systems, generalized coordinates, normal modes and orthogonality properties, and uncoupling of equations of motion.

3. To learn how to model structural dynamic behavior of structures subjected to wind, earthquake and moving loads.

4. To introduce approximate methods for free and forced vibration analysis of linear systems.

5. To witness laboratory demonstration of various dynamical phenomena such as resonance, normal modes, vibration under dynamic support motions, seismic wave amplification, sloshing in liquid storage tanks, vibration absorption and isolation and rocking of rigid objects.

6. To witness the working of a multi-axes earthquake simulator.

Grading policy

Three class tests: 30 marks

Four assignments: 20 marks

Final examination: 50 marks

These weights are approximate and the instructor may make minor changes later.

Assignments

After about every 6-8 classes, one assignment would be assigned.

1. The assignments should be submitted before 12:00 hours of the last date announced for submission. Late submissions carry penalty of 10% of marks per day. Assignments that are submitted after five days of the last date would be assigned zero marks.

2. Work should be well organized and done neatly. All assumptions made must be clearly stated with adequate justifications. The pages should be numbered and stapled securely. All graphs must bear axes labels, legends and captions. Equations of motion should be derived based on clearly drawn free body diagrams. All numerical results should be reported with appropriate number of significant digits and must bear the correct units.

3. Problems requiring numerical work could be done on the Matlab platform. In this event, the Matlab code should be included in the document to be submitted along with suitable printouts of the numerical results and graphs.

Resources

Recommended books for the course

1. L Meirovich, 1984, Elements of vibration analysis, McGraw-Hill, NY
2. R W Clough and J Penzien, 1993, Dynamics of structures, McGraw-Hill, NY
3. S S Rao, 2004, Mechanical Vibrations, 4th Edition, Pearson Education, New Delhi.

Additional List of references

I Theory of vibrations

1. L Meirovich, 1997, Principles and techniques of vibrations, Prentice Hall, NJ.
2. L Meirovich, 1967, Analytical methods in vibrations, Macmillan, NY.
3. W T Thompson, 1983, Theory of vibrations, Prentice hall, New Delhi
4. G B Warburton, 1976, The dynamical behavior of structures, Pergamon Press, Oxford.
5. F S Tse, I Morse and R T Hinkle, 1983, Mechanical vibrations, CBS Publishers, New Delhi
6. W W Seto, 1964, Mechanical vibrations, Schaum outline series, McGraw-Hill, Singapore.
7. M Paz, 1984, Structural dynamics, CBS Publishers, New Delhi.
8. J M Biggs, 1964, Introduction to structural dynamics, McGraw-Hill, NY
9. R E D Bishop and D C Johnson, 1960, The mechanics of vibrations, Cambridge University Press,

Cambridge.
10. S P Timoshenko and J L Weaver, 1974, Vibration problems in engineering, John Wiley, New York.
11. C W de Silva, 1999, Vibration: fundamentals and practice, CRC Press, Boca Raton.
12. B H Tongue, 1996, Principles of vibrations, Oxford University Press, Oxford.
13. F Y Cheng, 2001, Matrix analysis of structural dynamics, Marcel and Dekker, NY.
14. A K Chopra, 1995, Dynamics of structures, Prentice Hall India, New Delhi
15. P L Gatti, 2014, Applied structural and mechanical vibrations, CRC Press, Boca Raton.
16. S S Rao, 2007,Vibration of continuous systems, John Wiley, New York.

II Applications

1. L Fryba, 1999, Vibration of solids and structures under moving loads, Thomas Telford, London.
2. E Simiu and R H Scanlan, 1977, Wind effects on structures, Wiley, NY
3. N M Newmark and E Rosenblueth, 1971, Fundamentals of earthquake engineering, Prentice Hall, NJ.
4. R D Blevins, 1990, Flow induced vibrations, Van Nostrand, NY.
5. A Major, 1980, Dynamics in Civil Engineering, Vol I-IV, Akademiai, Budapest.
6. J P Den Hartog, 1956, Mechanical Vibrations, McGraw-Hill, NY.
7. M Y H Bangash, 1993, Impact and explosions: analysis and design, Blackwell, Oxford.
8. R A Ibrahim, 2005, Liquid sloshing dynamics, Cambridge University Press, Cambridge.

III Computational methods

1. M Petyt, 1998, Introduction to finite element vibration analysis, Cambridge University Press, Cambridge.
2. W Weaver and P R Johnston, 1987, Structural dynamics by finite elements, Prentice Hall, NJ
3. K J Bathe, 1996, Finite element procedures, Prentice Hall, India, New Delhi
4. R R Craig, 1981, Structural dynamics: an introduction to computer methods, Wiley, NY.

IV Sources of Useful information

1. R D Blevins, 1979, Formulas for natural frequency and mode shapes, Van Nostrand, NY.
2. H Bachmann et al., 1995, Vibration problems in structures, Birkhauser Verlag, Basel.
3. C M Harris and C E Crede, 1995, Shock and Vibration handbook, McGraw-Hill, NY.
4. W F Chen and C Scawthorn, 2003, Earthquake engineering handbook, CRC Press, Boca Raton.
5. C W de Silva, 2005, Vibration and shock handbook, CRC Press, Boca Raton.

6. D G Jones, 2001, Handbook of Viscoelastic vibration damping, John Wiley, Chichester.