NONLINEAR VIBRATION

PROF. S. K. DWIVEDY
Department of Mechanical Engineering
IIT Guwahati

INTENDED AUDIENCE : Senior under graduate or post graduate and PhD students in Mechanical Engineering can take this course under Advanced Dynamics domain

INDUSTRIES APPLICABLE TO : All the industry dealing with manufacturing, automobile, aerospace etc. will require nonlinear vibration analysis to improve their productivity

COURSE OUTLINE :
Most of the vibrating structure are nonlinear in nature. But for simplification of the analysis they have been considered to be linear. Hence, to actually know the response of the system one should study the nonlinear behavior of the system. Here one may encounter multiple equilibrium points or solutions which may be stable or unstable. The response may be periodic, quasiperiodic or chaotic. The present course is a simulation based course where one can visualize the response of different mechanical systems for different resonance conditions. Out of 9 modules, first 8 modules are on developing the equations of motion, solution procedure of these equations and application of them to general single and multi-degree of freedom systems. The last modules which will be covered in 3 weeks taking 3 different applications of current interest are project based and it will give a very good practical exposure. The course will be very useful for undergraduate, post graduate and PhD students in Academic institutions and also practicing engineers in Industry.

ABOUT INSTRUCTOR :
Prof. S. K. Dwivedy has started working in the field of nonlinear Vibration during his PhD program at IIT Kharagur. He is teaching the Nonlinear Vibration Course for the last 20 years at IIT Guwahati. He has developed the web and video courses on Nonlinear Vibration in NPTEL. He has guided 10 PhD students and more than 40 M. Tech students and published more than 150 papers in the International Journals and Conferences in the field of nonlinear vibration. These works have been in diverse areas such as structural applications, energy harvester, robotic manipulators, metallic ion polymer composites, pneumatic artificial muscles, vibration absorbers in biomedical applications.

COURSE PLAN :

Week 1: Module 1: Introduction to Nonlinear Mechanical Systems

Introduction to mechanical systems, Superposition rule, familiar nonlinear equations: Duffing equation, van der Pol's equation, Mathieu-Hill's equation, Lorentz system, Equilibrium points: potential function

Week 2: Module 2: Development of Nonlinear Equation of Motion using Symbolic Software

Force and moment based Approach, Lagrange Principle, Extended Hamilton's principle, use of scaling and book-keeping parameter for ordering

Week 3: Module 3: Solution of Nonlinear Equation of Motion

Numerical solution, Analytical solutions: Harmonic Balance method, Straight forward expansion and Lindstd-Poincare' method

Week 4: Method of Averaging, Method of multiple scales, Method of 3 generalized Harmonic Balance method

Week 5: Module 4: Analysis of Nonlinear SDOF system with weak excitation

Free vibration of undamped and damped SDOF systems with quadratic and cubic nonlinearity, and forced vibration with simple resonance

Week 6: Analysis of Nonlinear SDOF system with hard excitation

Nonlinear system with hard excitations, super and sub harmonic resonance conditions, Bifurcation analysis of fixed-point response

Week 7: Vibration Analysis of Parametrically Excited system

Principal and combination parametric resonance conditions, Floquet theory, frequency and forced response of nonlinear parametrically excited system.

Week 8: Analysis of Periodic, quasiperiodic and Chaotic System

Stability and bifurcation analysis of periodic response, analysis of quasi-periodic system, analysis of chaotic System

Week 9: Numerical Methods for Nonlinear system Analysis

Solutions of a set of nonlinear equations, Numerical Solution of ODE and DDE equations, Time response, phase portraits, frequency response, Poincare section, FFT, Lyapunov exponent

Week 10: Practical Application 1: Nonlinear Vibration Absorber

Equation of motion, Solution of EOM: Use of Harmonic Balance method, Program to obtain time and frequency response

Week 11: Practical Application 2: Nonlinear Energy Harvester

Development of Equation of motion: symbolic software, Solution of EOM: Use of method of Multiple Scales, Program to obtain time and frequency response

Week 12: Practical Application 3: Analysis of electro-mechanical system

Development of Equation of motion and its solution, Use of Floquet theory, Parametric instability regions, Study of periodic, quasiperiodic and chaotic response