Nonlinear Vibrations

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Abstract:

Investigation of nonlinear vibration phenomena with a goal to develop understanding of the rich behaviors unique to such systems. The objective is to build skills in mathematical solution methods, physical understanding, and intuitive reasoning for the dynamic behavior of nonlinear vibratory systems. The methods and concepts covered are the foundation for applied nonlinear vibration analysis in practical applications and engineering research.

List of topics:

a) **Mathematical Foundation for Linear Vibration**: To understand nonlinear vibrations of both discrete (i.e., matrix) and continuous (e.g., strings, beams) systems, it is useful to introduce mathematical tools that unify the analysis of linear vibrations of discrete and continuous systems. Separate from its use in nonlinear vibration, this mature understanding of linear vibration is valuable for those working in the field of vibration.

b) **Phase Plane Analysis**: Much qualitative information about system behavior can be obtained with phase plane analysis for the usual case when closed-form solutions of the nonlinear vibration equations are not possible. The analysis will focus on the case of nonlinear single degree of freedom mechanical systems (undamped and damped).

c) **Perturbation Methods**: The inability to solve most nonlinear equations necessitates the use of approximate methods such as perturbation and averaging. These are most useful for weakly nonlinear systems, that is, those that differ only slightly from a linear system whose solution we can find completely. Many practical systems fall in this category, so this is one of the most directly useful topics of the course.

d) **Forced Oscillations**: Many of the behaviors unique to nonlinear systems, and the cases of most practical importance, appear when external sinusoidal excitations act on the system. Examples include jump phenomena, sub- and super-harmonic resonance, internal resonance, etc. A core part of the class is to develop methods to analyze forced vibration and understand the behaviors that can differ dramatically from what is possible in linear systems.

e) **Time-Varying Systems**: Time-varying systems where the system parameters (e.g., stiffness) fluctuate with time arise naturally in many physical applications. Such systems are known as parametrically excited systems, and they can lead to resonant-like response called parametric instabilities. Floquet theory is crucial to examine these systems. Perturbation methods used for nonlinear systems (see above) will be applied to these time-varying systems to identify conditions where resonant-like parametric instabilities occur.

Time Table:

June 4: from 14:00 to 16:00 – Room 13B
June 5: from 14:00 to 16:00 – Room 17
June 6: from 9:00 to 11:00 – Room 8D
June 7: from 9:00 to 11:00 – Room 8D

June 18: from 14:00 to 16:00 – Room 17
June 19: from 14:00 to 16:00 – Room 17
June 20: from 9:00 to 11:00 – Room 17
June 21: from 9:00 to 11:00 – Room 17

June 25: from 14:00 to 16:00 – Room 9S
June 26: from 14:00 to 16:00 – Room 17
June 27: from 9:00 to 11:00 – Room 19
June 28: from 9:00 to 11:00 – Room 5B

July 2: from 14:00 to 16:00 – Room 17
July 4: from 9:00 to 11:00 – Room 17
June 5: from 9:00 to 11:00 – Room 17

Professional Biography

Prof. Parker is the L. S. Randolph Professor in Mechanical Engineering at Virginia Tech. Previously he was a University Distinguished Professor and the Executive Dean at the University of Michigan-Shanghai Jiao Tong University Joint Institute. He served 13 years on the faculty at Ohio State University. He received M.S. and Ph.D. degrees from the University of California, Berkeley.

Prof. Parker's research examines the vibration and stability of high-speed mechanical systems. One focus has been gear vibration. He is especially interested in high-speed, gyroscopic, nonlinear, and cyclically symmetric systems where analytical modeling can explain fundamental behaviors.

Prof. Parker is a Fellow of the American Society of Mechanical Engineers and the American Association for the Advancement of Science (publishers of Science). He received the 2015 ASME Myklestad Award for "major innovation in vibration research and engineering." The Chinese government selected him as an inaugural awardee for its 1000 Person Plan. He received the Presidential Early Career Award for Scientists and Engineers (presented at the White House) and National Science Foundation CAREER awards, as well as the ASME Gustus Larson, Ford Chief Engineer, French government Poste Rouge, SAE Ralph Teetor, and ASEE Global Engineering Educator and Outstanding Faculty Awards. He sits on the Editorial Board for the J. of Sound and Vibration.

Prof. Parker has been a Visiting Researcher at Politecnico di Torino, Risoe National Lab (Denmark), University of New South Wales, Sydney University, Tokyo University, NASA Glenn Research Center, and INSA Lyon.