ME 7206 Dynamics of Rotating Machinery ("Rotor Dynamics")

What is this class about?

Rotating machinery encompass the gamut from tiny dentist drills to the mighty steam turbines and pervade our lives. Examples include pumps, compressors, aircraft engines, power generation equipment, centrifuges, motors, generators, crank shafts, drive shafts, etc. The source of most vibration encountered in almost all situations is very likely some kind of rotation upstream in the complex chain of machinery and structural elements.

This course is an introduction to the area of rotor dynamics. Numerous practical case studies will be explored. Rotating machinery exhibit fascinating dynamic phenomena, many of which have not been explained to this day. Also, the problems can be complex since they deal with interdisciplinary areas. This course peeks into this fascinating world.

The aspects of modeling such rotor-disk-bearing assemblies will be explored in detail. Since fluid-film bearings are in wide use, the effect of these bearings on the dynamics of rotors will be studied. Apart from detailed analysis of some simplified models, general methods of modeling and analysis such as the finite element method will be discussed. Practical issues such as balancing techniques and fault diagnostics will be explored. If time permits, active control using magnetic bearings will be discussed.

Who can take it?

Graduate students in Engineering; undergraduate senior students with permission.

Prerequisites

Knowledge of ODEs, matrix theory, computational ability (MATLAB), undergraduate vibration.

For more information please contact Dr. Nat at nataraj@villanova.edu.

M. E. 7206 Dynamics of Rotating Machinery

Term:	Spring 2016
Instructor:	Dr. "Nat" C. Nataraj
Classes:	Thursdays, 6:15 – 9:015
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Course Description

This course will deal with the problems of dynamics and vibration associated with most kinds of rotating machinery. Examples include turbomachines (steam turbines, gas turbines, pumps, compressors), electric machines (motors, generators), and machines with rotating components such as centrifuges.

Rotating machinery are very common, yet they exhibit fascinating dynamic phenomena, many of which have not been explained to this day. This course can only be a peek into this fascinating world; the problems can be complex since they deal with interdisciplinary areas.

The aspects of modeling such rotor-disk-bearing assemblies will be explored in detail. Since fluid-film bearings are in wide use, the effect of these bearings on the dynamics of rotors will be studied. Apart from detailed analysis of some simplified models, general methods of modeling and analysis such as the finite element method will be discussed. Practical issues such as balancing techniques and fault diagnoses will be explored.

Provided there is time other aspects to be included in the course are the effect of various factors on the stability of the system, the phenomenon of oil whirl, and the influence of nonlinearities on the vibrational response of the system.

Prerequisites

Undergraduate vibration, numerical analysis. All other needed background information will be covered in the class with handouts and lectures. All computations will use MATLAB (including examples of code handed out).

Texts

There will be no required text. Lots of material will be provided on-line.

Suggested reference material is as follows.

- Nataraj, C., 2016, *Nonlinear Analysis of Rotor Dynamic Systems*, Springer Verlag [in preparation - you get to work with the preprint!].
- Dimentberg, F. M., 1961, *Flexural Vibrations of Rotating Shafts*, Butterworths, London.
- Tondl, A., 1965, *Some Problems of Rotor Dynamics*, Chapman and Hall, London.
- Lund, J. W., 1979, *Dynamics of Machines*, Ossolineum, Denmark.
- Rao, J. S., 1983, *Rotor Dynamics*, Wiley Eastern, New Delhi.
- Dimorogonas, A. D., and Paipetes, S. A., 1983, *Analytical Methods in Rotor Dynamics*, Applied Science Publishers.
- Adams, M. L., 2001, *Rotating Machinery Vibration*, Marcel-Dekker, Inc.
- Vance, J. M., 1988, *Rotordynamics of Turbomachinery*, Wiley Inter-Science.
- Nelson, H. D., Preliminary draft of *Rotor Dynamics*.
- Numerous technical publications.

Grading:

Homework will be assigned every week and should be submitted promptly for grading and subsequent discussion. In addition, small computer projects will be assigned.

An individual term project will be required of each student. The project topic may be either selected by the student, with approval, or be specified by the instructor. It is initiated at the mid-term date and is due in the last class week.

The semester grade is based on the following relative weights (subject to minor revisions).

Homework	10%
Quizzes (two)	20%
Small Computer projects	20%
Term project	25%
Final Exam (comprehensive)	25%

Grades:

F $<$ 65% C- $<$ 70% $<$ C $<$ 75% $<$ C+ $<$ 80%$<$ B- $<$ 82% $<$ B $<$ 85% $<$ B+ $<$ 87% $<$ A- $<$ 90% $<$ A

Course Syllabus[1]

1. Objectives of rotor dynamic Analysis
2. Coordinate systems and kinematics of rotor motion
3. Critical speeds
4. Jeffcott rotor equations: free and forced response, stability
5. Rigid rotor equations, forward and backward modes
6. Hydrodynamic bearings and Reynolds equation
7. Rolling element bearing modeling
8. Flexible MDOF systems - finite element modeling
9. Balancing procedures
10. Troubleshooting from vibration measurement
11. Instability mechanisms
12. Active control using magnetic bearings
13. Nonlinear effects due to bearings, couplings, cracks, etc.

[1]This a little optimistic, but we should be able to cover 1-10.