Engineering Tripos Part IIB, 4C7: Random & Non-Linear Vibrations, 2021-22

Module Leader
Prof AA Seshia [1]

Lecturers
Prof AA Seshia and Prof \R Langley

Lab Leader
Prof AA Seshia [1]

Timing and Structure
Michaelmas term. 12 lectures + 2 examples classes + coursework. Assessment: 75% exam/25% coursework

Prerequisites
3C6 useful.

Aims
The aims of the course are to:

- analyse the effects of random vibrations on machines and structures and the effects that occur as a result of non-linearities.
- describe the characteristics of random and non-linear vibrations, deriving the effects of a system's dynamic response on the input and giving methods of determining resulting deflections or stresses.
- describe some of the characteristics of self excited vibrations.

Objectives
As specific objectives, by the end of the course students should be able to:

- identify and describe random processes.
- predict the output from a system subjected to random forcing.
- predict how frequently output levels will be exceeded.
- apply the correct windows and filters for analysis.
- assess the reliability of frequency analyses.
- understand the effects of non-linearities on system response.
- calculate and use describing functions and harmonic balance.
- predict phase-plane behaviour of second-order systems.
- understand some of the common self excited vibrations and their characteristics.

Content
Non-linear and self-excited vibration. (6L, Dr A A Seshia)
• Types of non-linearities in engineering systems and their major qualitative effects. Method of harmonic balance, describing functions;
• Representation of second-order nonlinear systems in the phase plane. Stationary points and their classification. Periodic orbits;
• Introduction to self-excited vibration. Examples of systems which are excited by instability and dry friction. Self excited oscillations in micro electromechanical systems.

Random vibration. (6L, Professor R S Langley)

• Characteristics of random vibrations and the use of probability distributions and spectral densities to describe such vibration:
• Auto and cross spectra. Transmission of random vibration through linear systems and derivation of output statistics and spectral densities;
• Narrow-band processes and determination of level-crossing frequency, distribution of peaks and frequency of maxima;
• Spectral analysis. Fourier transforms. Problems with sampling and relevance of aliasing. Calculation of spectra for sampled points;
• Basic lag and use of windows and smoothing. Coherence. Accuracy of measurements.

Coursework

Coursework on non-linear vibrations. This involves a short lab, numerical modelling and simulation exercise, and 4 hours writing-up.

<table>
<thead>
<tr>
<th>Coursework</th>
<th>Format</th>
<th>Due date &amp; marks</th>
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<tbody>
<tr>
<td>Nonlinear vibration of a clamped beam</td>
<td>Individual Report</td>
<td>Weds Week 2 Dec [15/60]</td>
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Learning objective:

(i) To explore nonlinear effects due to high forcing amplitudes about resonance in mechanical structures.

(ii) To construct a model to explain the nonlinear behaviour of the mechanism provided and use this model to simulate the behaviour of the system under specified conditions.

(iii) Demonstrate use of the sonogram (time-varying spectrum) as an analytical tool to distinguish both frequency and temporal characteristics of a transient record.

Booklists

Please refer to the Booklist for Part IIB Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to Form & conduct of the examinations [2].

UK-SPEC

The UK Standard for Professional Engineering Competence (UK-SPEC) [3] describes the requirements that have
to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the 'Accreditation of Higher Education Programmes' (AHEP) document [4] which sets out the standard for degree accreditation.

The Output Standards Matrices [5] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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Links
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