

# Chapter 15

## A Video-Based Course on Random Vibrations



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**Abstract** Structures vibrate – this is known from structural dynamics courses and applied in design of structures. However, once the structure is there, the observable vibrations do not follow the well-defined shapes considered in modal analysis, the response of a structure is a random combination of those modal shapes. However, the random response contains all the information needed to evaluate on the dynamics of the structure. This course therefore deals with the analysis and interpretation of the random response of linear systems, such as a structure, through the principles of correlation and spectral densities. Furthermore, this course is a 100% e-learning course with video-based lectures and weekly webinars for questions and discussion. A first of its kind at the faculty of Civil Engineering at the Technical University of Denmark. The idea is that this will broaden the availability of an otherwise niche course. At the same time the format allows for the course to be run at three different levels, attempting to make the same course relevant for multiple levels, all the way from MSc to PhD and other interested researchers.

**Keywords** Random vibrations · Spectral density · Correlation function · e-learning · Self-paced

### 15.1 Introduction

The course is focusing on the classical problem of random vibration. Consider a measured random response from any structure. This response will be recorded in a number of measurement points, and thus the response will be a vector as a function of time.

The classical problem is that this response – in its raw visualisation – seems chaotic and difficult to interpret. It is preferable to plot the responses in a way where the properties of the system are more visible. The classical ways to do this is to plot correlation functions and spectral density functions. Thus, this course focus on these basic tools to visualise the system property content in random responses. Of course, this has to be understood well also in the case of several responses, i.e. cases where correlation functions and spectral densities turn into matrices.

The aim of the course is thus, to help the students to understand why correlation functions and spectral densities are estimates, how these quantities are estimated, and what they reveal about the properties of the system.

### 15.2 Structure

The course is run as a 100% self-paced e-learning course where all the content is available to the students from the beginning. This course material consist of video recordings, lecture slides, exercises, notes and readings for ten lectures at three different levels, A, B, and C. It is encouraged that the students orient themselves in the reading material, then watch the video or videos for the lecture with the slides readily available for note taking, move on to the exercises and on this basis prepare questions for the weekly webinar. With this, the students should be ready to complete all exercises and eventually compile their findings and takeaways in a portfolio that is the basis for evaluation of the student on a pass or fail basis.

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**Fig. 15.1** Snapshot from the introduction lecture to illustrate the format of the video lectures

For the reading material two books are used, the primary is the textbook *An Introduction to Random Vibrations, Spectral & Wavelet Analysis* by D.E. Newland [1] for theoretical understanding. This is supported by the textbook *Introduction to Operational Modal Analysis* by R. Brincker and C. Ventura [2] for more application uses and examples.

For the videos, they are recorded lectures by coauthor of this article Rune Brincker, see Fig. 15.1 for an idea of the format. There are 31 videos in total. An introduction video used to introduce the concept and content of the course followed by the ten lectures at the three different levels. Level A aims at the participant who wants to understand the basic concepts of random vibrations without too much technicality and application. Level B aims at the participant who wants to be able to understand what is going on in each topic introduced by the course. Level C aims at research participants who wish to challenge the boundaries of the curriculum and experience the possibilities of the methods. For each lecture and each level there are a number of corresponding exercises for the participant to solve and get familiar with the content.

For evaluation of the course the participants are asked to submit a written portfolio of no more than 30 pages. This portfolio encourage a free format where the participant can present exactly what he or she has learned from the course. Within this the participant should have takeaways representing the learning objectives for the course

**A student who has met the objectives of the course will be able to:**

- Define and estimate probabilistic quantities like mean values and variances from response data
- Define correlation and explain how the concept can be used to extract physical information
- Define auto-correlation and cross-correlation functions and explain how they can be used to extract physical information
- Use numerical methods to estimate auto-correlation and cross-correlation functions
- Explain classical Fourier transforms and use digital Fourier transforms to process response data in MATLAB [3]
- Define spectral density functions and explain how they can be used to extract physical information
- Use numerical methods to estimate spectral density functions
- Outline and describe the concept of linear systems and use MATLAB to perform simple response simulations

### 15.3 Vision

The main idea with this course is not only to teach the course content to the students of the Technical University of Denmark and guest students but also to make it available to as many as possible, which is why the video format was chosen. Furthermore the split level, e-learning, and self-paced format should allow for all types of participants whether it is MSC students, PhD students, continued education students or anything else.

## 15.4 Realisation

The course was run for the first time in the fall semester of 2019, starting in September and finishing off in December. Prior to the course it was announced to an international audience as well as internally at the university. However, it is well known that getting participants for a course running for the first time can be troublesome, and thus this proved also the case for this course. By the last day of registration, the course had two participants enrolled. Fortunately, the free format of the course allowed for latecomers and thus, especially the international participants joined over the first couple of weeks. At the time of writing this article the course is half way through and has a team of 11 active participants whereas approximately half are from elsewhere than the Technical University of Denmark.

The course is run on the new teaching platform of the university called DTU Learn [4] from where the participants has access to the webinar platform Adobe Connect [5]. For the purpose of this course the webinar room is set up such that the lecturers have camera and microphone active at all times, while participants can simply listen. There is then an option to raise a hand, which will lead to the lecturers give microphone and video rights, this way the questions are given in a way where a small discussion can arise. However, this format has proven to provide more distance between the lecturers and the participants than first expected and so at the time of writing this article, it is currently a work in progress to obtain feedback from the participants on how the discussion can be more liberate between the participants as well as with the lecturers.

## 15.5 Conclusion

In conclusion this course is showing good potential to cover geographical distance in order to spread the knowledge of processing random vibration data. However, there are some obstacles related to maintaining the good discussion known from a classic classroom setting that needs to be overcome to make the course satisfactory. Furthermore, there is a wish to expand the knowledge of this course so that the next team participating can be much larger and more people can come to realise the potential of this topic.

## References

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