Chapter 4.18
Design Wind Speeds Using Fast Fourier Transform:
A Case Study

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ABSTRACT

In this chapter, a study on the effects of transforming wind speed data, from a time series domain into a frequency domain via Fast Fourier Transform (FFT), is presented. The wind data is first transformed into a stationary pattern from a non-stationary pattern of time series data using statistical software. This set of time series is then transformed using FFT for the main purpose of the chapter. The analysis is done through MATLAB software, which provides a very useful function in FFT algorithm. Parameters of engineering significance such as hidden periodicities, frequency components, absolute magnitude and phase of the transformed data, power spectral density and cross spectral density can be obtained. Results obtained using data from case studies involving thirty-one weather stations in Malaysia show great potential for application in verifying the current criteria used for design practices.

INTRODUCTION

In the design of civil engineering structures, the effects of the natural environment on these structures have to be taken into consideration. Some examples of these are the effects of wind, current and waves on offshore structures; and the effects of wind and seismic activities on buildings. This chapter focuses mainly on the effects of wind on buildings. The parameter of interest in the design and construction of a structure is the design wind speed. This can be obtained from fundamental principles backed by verification through field studies of the dynamic characteristics of the structure. In many cases involving large structures, the input force cannot be created at will or be controlled. This shortcoming is overcome through ambient vibration testing and the use of Fast Fourier Transform (FFT) to convert the raw wind data into wind loads.

The chapter starts with a review of the general effects of wind on structures and the inhabitants. The parameters used in the design of structures including buildings are discussed. It is shown here that Fast Fourier Transform (FFT) which include Power Spectral Density (PSD), Cross Spectral Density (CSD) and Turbulence Intensities (TI) can be applied to derive the design parameters and subsequently, improve a wind code for structures. Examples of early studies on wind loads are given, and the limits of tolerance for civil engineering structures and the inhabitants therein are mentioned. It is noted that the criteria for design are more concerned with the human tolerance rather than the structural tolerance. In the design of structures, there is a need for a full understanding of the effects of wind at each stage of construction since the tolerance for the final structure could vary appreciably with the tolerance at each intermediate stage of the structure during construction. Vibration effects due to wind on structures are given, and examples of vibration effects on mechanical structures are also given as a comparison.

Methods of structural analysis and structural monitoring including vibration analysis and modal analysis are mentioned. Field tests including forced vibration methods as well as ambient vibration methods are described. Factors affecting the design of structures as well as the incentives to better understand the complex effects of wind on structures result in the approach to simplify these effects into components. These components can then be utilized in defining design wind speed and deriving design wind load, which can be used to develop the local design wind code for civil engineering structures such as buildings.

The analysis using FFT in this chapter can be taken one step further through frequency response function (FRF). FRF is the ratio of the output response to the input excitation force. This measurement is typically acquired using a dedicated instrument such as an FFT analyzer or a data acquisition system with software that performs the FFT. The input data in this case would be the measured wind speed using several anemometers, which can be converted into dynamic pressure experienced by the structure. The output data would be the dynamic response of the structure measured using several transducers such as accelerometers. Once the data are sampled, the FFT is computed to form linear spectra of the input excitation and output response. Typically, averaging is performed on power spectra obtained from the linear spectra. The main averaged spectra computed are the input power spectrum, the output and input signals.

These functions are averaged and used to compute two important functions that are used for modal data acquisition, which are the FRF and the coherence. The coherence function is used as a data quality assessment tool which identifies how much of the output signal is related to the measured input signal. The FRF contains information regarding the system frequency and damping, and a collection of FRF contains information regarding the mode shape of the system at the measured locations. This is the most important measurement related to experimental modal analysis.

The FRF can be viewed in the form of acceleration or displacement experienced by the structure due to the wind speed. Information such as this as well as the mode shape obtained provides vital information from the design aspect. This will help to provide additional meaningful and significant engineering data to structural design engineers (Avitable, 2001).

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