

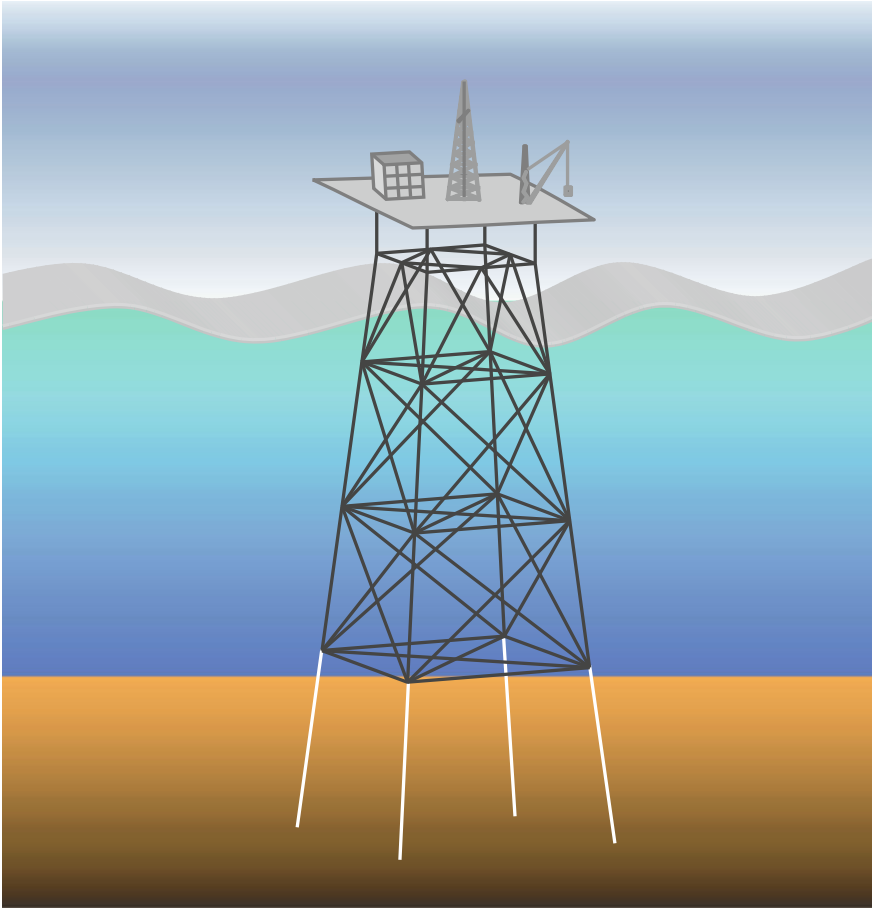
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Stochastic Analysis of Offshore Steel Structures

An Analytical Appraisal

 Springer

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Preface

Increasing oil consumption in the world and scarcity of land-oil resources due to political and economical reasons has caused offshore oil exploration and production to become a growing investigation field in the past six decades. The analysis of structures to use energy deposits and other recourses, or for other purposes, in ocean environments requires a special consideration since environmental and loading conditions offshore are very complicated and contain large uncertainties. Offshore structures are continuously subjected to random ocean waves producing stochastic loads that cause mainly fatigue failure in structural components. In tectonic offshore environments, structures are also subjected to earthquake and earthquake-induced hydrodynamic loadings, which are considered to be important as they can cause structural collapse in a short time. Since the ocean environment and random wave phenomenon are highly uncertain, a probabilistic structural analysis needs to be carried out essentially. This requires the knowledge of probability theory and applied probability models, which construct the basis of reliability analysis. For the fatigue damage and fatigue reliability analysis, theoretical knowledge is combined with experimental information to predict correct results. Under these complexities, offshore structures should be designed to give optimal performance within the safe margin. This can be achieved by applying methods of the reliability-based design optimization. This book aims to cover difficult issues encountered in the analysis of offshore steel structures under random wave and earthquake loadings. It provides broad analytical tools for advanced analysis of offshore structures. It serves as a stand-alone reference book for design engineers, researchers, graduate and post graduate students, and for higher education in the field of offshore structural engineering. A corresponding computer program, SAPOS, is also attached to the book via Springer Extras. The program is run at the responsibility of the users. The publisher and the authors of this book are not responsible in any form that may arise from the use of this program. The book contains seven independent chapters of which [Chaps. 1–6](#) have been written by Prof. Dr. H. Karadeniz and [Chap. 7](#) has been written by Prof. Dr. M. P. Saka and Dr. V. Togan. Each chapter is devoted to handle the specific subject as briefly summarized in the following paragraphs.

Chapter 1 explains the mechanics of space frame structures and presents necessary formulations for the finite element analysis of space frames since offshore steel structures are constituted from space frames. In this chapter, the 3D Timoshenko beam theory is presented with emphasis on formulation of partly and eccentrically connected members, as well as formulation of a soil-beam interface element to account for foundation effects in the analysis. This chapter highlights also the eigenvalue problem related to the dynamic analysis of offshore structures.

Chapter 2 presents basic information and essential formulation of random vibration and stochastic analysis that are needed in offshore structural analysis. Having presented commonly used probability models, stochastic processes are summarized. Then, the spectral analysis, transfer functions, and the crossing analysis are highlighted.

Chapter 3 is devoted to ocean wave mechanics and wave forces. Having summarized wave theories in general, the Airy wave theory is explained in detail and formulation for deep-water conditions is presented. The chapter first describes stochastic ocean waves, transfer functions, commonly used short-term sea spectra with directional distribution, wave-current interaction phenomenon, and probabilistic description of sea states in the long term. Then, attention is paid to the calculation of wave and member consistent forces with emphasis on added mass and hydrodynamic damping concept.

Chapter 4 presents spectral analysis of offshore structures under wave and earthquake actions. After describing the problem of spectral analysis and giving general information, formulation of dynamic analysis of offshore structures in the frequency domain, transfer functions of wave and earthquake forces are presented. Then, concentration is focused on response transfer functions of wave and earthquake forces, followed by formulation of the hydrodynamic and inertia forces produced by earthquakes and their combination. This chapter also explains calculation of response spectra of offshore structures under stochastic wave and earthquake forces with earthquake ground motion and its spectral representation including non-uniform earthquake ground motions. Finally, the calculation of response statistical quantities is presented with illustrative examples.

Chapter 5 is devoted to the fatigue phenomenon in structures. First, the fatigue process, source of fatigue, and modeling of fatigue is summarized in general. Then, the calculation of fatigue damages is explained by using the fracture mechanics and $S-N$ curve approaches. The cumulative damage is calculated according to the Palmgren–Miner’s rule. For non-narrow banded stress processes, the fatigue damage is estimated using probability distribution of random stress ranges obtained from the rain-flow cycle counting algorithm. Finally, calculation of total spectral fatigue damage is presented for a given lifetime by using a multilinear $S-N$ fatigue model.

Chapter 6 presents reliability analysis of offshore structures. Having explained uncertainties in general and given information about the reliability methods, basic definitions and structural reliability methods are presented in more detail. This is followed by the calculation of the reliability index β by the FORM and SORM methods for nonlinear failure functions and non-normal correlated design

variables. The calculation algorithms and flow diagrams are given. Then, after the Level III reliability methods are outlined, the inverse reliability method and its calculation algorithm are presented. In the final sections, uncertainties in spectral stresses and fatigue damages of offshore structures are explained in a reduced uncertainty space which follows the fatigue reliability calculation and its algorithms.

Chapter 7 is devoted to optimization techniques that are widely applied to determine the optimum solution of structural design problems. First, this chapter introduces the mathematical formulation of optimization problems and their solution techniques among which sequential programming technique and differential evolution algorithm are briefly explained. Second, it presents the mathematical formulation of reliability-based design optimization problems in the uncertainty space regarding load, resistance, and structural response. Then, it summarizes the available solution techniques and explains methods of sensitivity analysis of the reliability-based design optimization of offshore structures.

The first author of this book, Prof. Dr. H. Karadeniz, acknowledges Delft University of Technology (TUDelft), The Netherlands, for giving him the opportunity to carry out research work and to use their facilities for a long period, from 1978 until his retirement at the end of 2010. Especially, he acknowledges Prof. A. L. Bouma of the structural mechanics group in the Civil Engineering Department for accepting him into his research group in 1978. He thanks all the staff of the Structural Mechanics Group in the Civil Engineering Department at TUDelft for the memorable social atmosphere that they created. His special thanks and appreciation are for Prof. Ton Vrouwenvelder of the Civil Engineering Department, TUDelft, for his continuous, stimulating, and invaluable discussions during his stay at TUDelft. He appreciates and acknowledges all his colleagues, friends, and research collaborators from all over the world for their useful discussions and inspiring suggestions. Finally, all the authors of this book thank Springer-Verlag for publishing this book and making it available for interested readers in worldwide.

July 2012

H. Karadeniz
M. P. Saka
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