1 Introduction

Following the depletion of land natural resources (oil, gas, minerals etc.), methods of obtaining them from beds of seas and oceans are gaining more and more importance. However, exploiting undersea resources poses a number of challenging technical problems pertaining to their extraction, transport and processing in a specific, inhospitable environment. Important groups of machines used in offshore engineering are cranes applied to reloading and assembly works and specialized devices for laying pipes which transport oil and gas. A characteristic feature of their working conditions is sea waves causing significant movement of the base on which offshore structures are installed. This is a phenomenon which must be taken into consideration in design of such machines.

The structures which are used in offshore engineering, very often have flexible links and joints. This causes problems especially in the case then links deflections are large. That is the reason why the computer methods are used in design process of offshore machines and devices. On the market there is a significant number of general commercial packages, mostly based on finite element method, such as Nastran, Ansys, Abaqus. They have special modulus for modelling multibody systems with flexible links, and enable to take into consideration mentioned above phenomena, like base motion and large deflection of beam like links. Commercial computer packages are mainly used in large designing and production centers because they require from users special knowledge and experience. The small and middle firms very often prefer less general computer models and programs. Less general but better fitted to specific kind of designed structures, with limited data necessary for performing calculations and dedicated interface. That is the reason why some designers are still looking for models, methods and programs oriented for their specific machines and structures. The examples of methods that can be successfully applied in these cases are presented in the book.

The joint coordinates and homogenous transformations are applied to modelling multibody system presented herein. In order to take into account flexibility of beam like links, the rigid finite element method is proposed. These methods for many years have been developed at the Gdańsk University of Technology and the University of Bielsko-Biała. The base and detailed description of these methods is given in the book [Wittbrodt E., et al., 2006]. Hence in this monograph the base of homogenous transformations and rigid finite element method are presented succinctly, as necessary to understand the way in which the

E. Wittbrodt et al.: Rigid Finite Element Method, OEO 1, pp. 1–3.
springerlink.com

models are formulated. More attention is devoted to new models and methods developed for modelling offshore structures.

The present book contains new formulation of the rigid finite element method which allows to take into consideration nonlinear physical relations, as well as large deflections of links. The floating reference frames are introduced in this case. As in base formulation, the beam like links are divided into rigid elements, which reflect inertial features of links, and mass less spring-damping elements. Each rigid element has six degrees of freedom (three translations and three rotations). However, the flexible features of spring-damping elements are introduced as external forces and moments calculated according to physical dependencies. It allows to take into consideration different physical models of materials: linear, elasto-plastic, visco-plastic and others.

The models and methods presented in the book are applied to description of dynamics of some offshore structures, mainly cranes, ramps and pipes. Results of numerical calculations concern: crane used for transportation of BOP, column crane, A-frame. Also the results of numerical simulations for different methods of laying pipes on the see bottom are presented. The J-lay, S-lay and reel method are considered. The models, which allow their static and dynamic analysis to perform, are developed. The models take into account large base motion of ships or platform, on which considered structures are mounted, caused by sea waves. Important problems related to the control of offshore structures ensuring their safe operation are also discussed. Control enables compensation for the movement of the base caused by waves and reduction of dynamic loads of the elements of considered systems.

For selected models, their accuracy is verified by comparing their results with those yielded by other methods, including commercial finite element method packages.

In chapter 2 selected offshore engineering problems are briefly presented. Most prominent elements of the infrastructure necessary for the extraction of oil and gas as well as methods of offshore pipelines installation are introduced. Also given are the specifics of operation of offshore cranes and their basic typology.

Chapter 3 is devoted to the description of the impact of water on offshore structures. It includes basics of mechanics of the wave motion of water, the problem of determination of the values of forces acting on elements immersed in water and methods of simplified description of the motion of the base of offshore structures.

Preliminary information about defining the positions and orientations of coordinate systems, transformations of vectors and joint coordinates are contained in chapter 4. It also deals with application of homogeneous transformations and joint coordinates to describe the geometry of multibody systems.

In chapter 5, a method is presented to determine the elements of a Lagrange equation of the second order in the case of description of the dynamics of open kinematic chains consisting of rigid links. The equations of motion are obtained taking into account the kinetic and potential energy of gravity forces as well as external forces and moments acting on the multibody system. It is further assumed that the system is located on a movable base.

The next chapter treats the elements connecting links belonging to different branches of the system (in particular, one of the links may be the base). Two approaches to modelling constraints are also presented: the classical one consisting in the introduction of constraint equations and another one whereby the constraints are modelled as spring-damping elements with large stiffness and damping coefficients.

Basic information related to elasto-plastic and visco-elastic models of materials can be found in chapter 7.

The focus of chapter 8 is the rigid finite element method (the RFE method) which serves to discretise flexible links. Its concepts are presented along with the way of defining the generalized forces, formulating the equations of motion and determining the following energies: kinetic, potential of the gravity forces and elastic deformation of a link. The RFE method is described in two forms: classical and modified. A new approach to modelling large deflections based on this method is also discussed.

Chapter 9 contains examples of dynamic models of selected offshore structures. In addition to basic assumptions and mathematical descriptions, results of selected numerical simulations are also given. Presented are models of the following machines: a gantry for transporting BlowOut Preventor valves, a column crane with a shock absorber and the devices for laying pipes.

Problems pertaining to control are shown in chapter 10. The task of dynamic optimization in device control is discussed. A method is presented enabling vertical stabilization of the load of an offshore crane and its stabilization in three directions using a specialized auxiliary system. Analyses related to a system of active compensation for waves in the reel drive of the device for laying pipes are also included.

The book leverages some previous results of the authors' work, especially those present in Marek Szczotka's monograph entitled “The rigid finite element method in modelling of nonlinear offshore systems” [Szczotka M., 2011 b].

The authors wish to thank the co-authors of their publications from which some analyses presented in this volume are drawn, especially Dr. Paweł Fałat and Dr. Andrzej Urbaś.