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INTRODUCTION TO COMPUTATIONAL ENGINEERING HYDRAULICS

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PREFACE

As stated by Roberson, Cassidy and Chaudhry (1998): “Hydraulic engineering is the application of fluid mechanics and other science and engineering disciplines in the design of structures, and the development of projects and systems involving water resources”. An engineering consideration of any technical problem implies quantitative analysis, so obviously such an analysis in hydraulic engineering requires the computations of large range of the water flow problems. Indeed, the area of interest of hydraulic engineering covers all possible water flow cases, taking place in closed conduits (pipes and their systems), at the Earth’s surface (reservoirs, open channels) and in subsurface porous soils and rocks. The problems of water flow listed above are closely related to another discipline of science and technique, namely to environmental engineering, which focuses attention on the availability and quality of water resources. As the latter issue is strictly related to the contaminant migration in water bodies, mass transport phenomena should be considered as well.

Application of the basic principles of conservation to a control volume of water body leads to mathematical expression of the physical rules which govern the considered flow cases. These rules are written in the form of equations. Depending on the assumptions introduced during their derivation, they can take various particular forms. Consequently, a hydraulic engineer during his professional activity typically faces a very large spectrum of equations describing different cases of water flow. As the flow process of any fluid can be a very complex phenomenon, the corresponding equations are often relatively complicated and their solution can be a challenging task. From the fundamental course of fluid mechanics and hydraulics results that even simple flow cases are described by equations requiring a significant computational effort to be solved. This can be caused for instance by:

— nonlinearity appearing in many equations,
— non-uniform spatial distribution of the parameters,
— unsteadiness of flow process and the necessity of integration in long time intervals,
— irregular shape of integration domain,
— forced additional conditions which vary irregularly in time,
— large dimensions of the final systems of algebraic equations which must be solved.

The main aim of this book is to provide the reader with the fundamentals of computational methods used in hydraulic engineering. To make easier following of the presented problems by the reader, we decided to divide it into two parts.

In Part 1 some fundamental numerical techniques, the most frequently used in hydraulic and environmental engineering are briefly presented. Subsequent chapters of Part 1 are devoted to an overview of the typical computational techniques applied to solve of the systems of linear algebraic equations, the nonlinear equations and their systems and the ordinary differential equations frequently occurring in hydraulic engineering. Particular attention is focused on partial differential equations, playing very important role in flow dynamics analysis, as well as on the numerical methods commonly applied for their solution, i.e. the finite difference method and the finite element method. Moreover some other related computational problems as the approximation and numerical solution of simple optimization problems will be presented.

Part 2 of this book deals with presentation and derivation of some governing equations typically encountered in hydraulic engineering. In the subsequent sections the equations for steady and unsteady flow in open channels, in closed conduits and in the subsurface including those for transport of matter dissolved in flowing water are considered. As our aim is not to give a complete course dealing with the hydromechanics and hydraulics, descriptions of the considered flow problems are presented as simple as possible. For more information the reader is referred to the sources presenting a more comprehensive description of the discussed problems. For this reason our considerations are limited rather to the one dimensional flow problems, with the exception of groundwater flow. Apart from short presentation of the considered problems and description of the methods applied for their solution, examples of computer codes written in Fortran language are also provided. Moreover, many computational examples illustrating considered problems and the applied approaches for their solutions are included into the text. However, we will consider problems related to the water flow and mass transport phenomena only. Computational problems dealing with the design of engineering structures are outside the scope of this book.

The presented book is dedicated primarily to the students of civil and environmental engineering. It is well known that the basic courses of the numerical techniques applied in hydraulic engineering and given at various technical universities are very similar. Noticing this fact the authors coming from China (College of Environmental Science and Engineering at Nankai University in Tianjin) and from Poland (Faculty of Civil and Environmental Engineering at Gdańsk University of Technology), decided to elaborate commonly a textbook covering the areas defined by the respective syllabuses at both Universities. During the preparation of this textbook the experiences resulting from our earlier co-operation on mathematical modeling of the transport and flow phenomena of the surface and ground waters appeared very useful. We hope that the presented textbook will be useful for the students of both Universities – in Tianjin and in Gdańsk. We hope as well as that this textbook can be interesting and helpful not only for our students, but also for other readers interested in the numerical methods and in hydraulic engineering.

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