OFFSHORE HYDROMECHANICS

First Edition

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Contents

PREFACE

This text book is an attempt to provide a comprehensive treatment of hydromechanics for offshore engineers. This text has originally been written for students participating in the Interfaculty Offshore Technology curriculum at the Delft University of Technology. Offshore Hydromechanics forms the link in this curriculum between earlier courses on Oceanography and (regular as well as irregular) Ocean Waves on the one hand, and the design of Fixed, Floating and Subsea Structures on the other.
Topics have been selected for inclusion based upon their applicability in modern offshore engineering practice. The treatment of these selected topics includes both the background theory and its applications to realistic problems.
The book encompasses applied hydrodynamics for the seas outside the breaker zone. Popularly, one can say that this book uses information on wind, waves and currents to determine external forces on all sorts of structures in the sea as well as the stability and motions of floating structures and even of the sea bed itself. Only a short period of reflection is needed to conclude that this covers a lot of ocean and quite some topics as well! Indeed the following application examples illustrate this.
The notation used in this book is kept as standard as possible, but is explained as it is introduced in each chapter. In some cases the authors have chosen to use notation commonly found in the relevant literature - even if it is in conflict with a more universal standard or even with other parts of this text. This is done to prepare students better to read the literature if they wish to pursue such maters more deeply. In some other cases, the more or less standard notation and conventions have been adhered to in spite of more common practice. An example of this latter disparity can be found in chapter 14; conventions and notation used there do not always agree with those of the coastal engineers.
One will discover that many equations are used in the explanation of the theories presented in this book. In order to make reader reference easier, important theoretical results and equations have been enclosed in boxes. A few appendices have been used to collect relevant reference information which can be useful for reference or in more than one chapter.

Modular Structure of the Book

An Offshore Hydromechanics course based upon this text can be built up from four related modules. Each module has its own content and objectives; each module represents approximately the same amount of (student) work. Within certain limitations, readers can choose to work only with one or more from these modules relevant to their own needs:

1. Hydrostatics, Constant Flow Phenomena and Surface Waves.
   Upon completion of this segment students will understand hydrostatics as it relates to all forms of structures. Compressive buckling of free-hanging drill strings is explained Constant potential as well as real flows and the forces which they can exert on structures complete this module along with a review of wave theory and wave statistics.

[0] J.M.J. Journée and W.W. Massie, *"OFFSHORE HYDROMECHANICS"*, First Edition, January 2001, Delft University of Technology. For updates see web site: http://www.shipmotions.nl.

Module 1 covers chapter 1, a small part of chapter 2 and chapters 3, 4 and 5. It provides basic knowledge for all the succeeding modules; every course should include this module. Module 1 can be succeeded by modules 2 and/or 4.

2. Static Floating Stability, Principles of Loads and Motions and Potential Theories.
   Upon completion of this segment students will become experienced with stability computations for all sorts of floating structures - including those with partially filled water ballast tanks, etc. They will understand the basic application of linear potential theory to ships and other floating structures for the computation of external and internal forces, as well as the principle of motions of bodies in waves.
   Module 2 covers chapters 2, 6, and 7. It should be scheduled directly after module 1 and prepares the student for the further development of this topic in module 3.

3. Loads and Motions in Waves, Nonlinear Hydrodynamics, Station Keeping and Operability.
   Students completing this segment will be able to predict the behavior of floating or sailing bodies more completely. They will be familiar with first order ship motions in waves, as well as nonlinear phenomena such as mean and second order drift forces. Applications such as station keeping and the determination of offshore workability will be familiar.
   Module 3 covers the chapters 8, 9, 10 and 11. It should follow module 2 in the scheduling.

4. Slender Cylinder Hydrodynamics and Sea Bed Morphology.
   Students completing this segment will be familiar with the Morison equation and its extensions as well as with methods to determine its coefficients and approximate methods for predicting the survival loads on an offshore tower structure. The computation of forces on pipelines as well as the morphological interaction between the sea bed and pipelines and other small objects will be familiar too.
   Module 4 covers chapters 12, 13 and 14. It can be scheduled directly after module 1 and parallel with modules 2 and 3, if desired.

These modules are listed below and shown in the figure 0.1 as well.
Each of the following module combinations can be appropriate for specific groups of students; each path can be completed via a contiguous series of classes if desired.

Modules	**Objective**	**Suited for**
1,2,3,4	Complete Course	Offshore Technology and any others optionally
1,2,3	Complete Ship Motions	Marine Technology Dredging Technology
1,2	Limited Ship Motions	Dredging Technology, Civil and Mechanical Engineering
1,4	Slender Structure Loads	Civil and Mechanical Engineering

The overall objective of this text is to use theory where necessary to solve practical offshore engineering problems. Some sections which become rather mathematical contain a warning

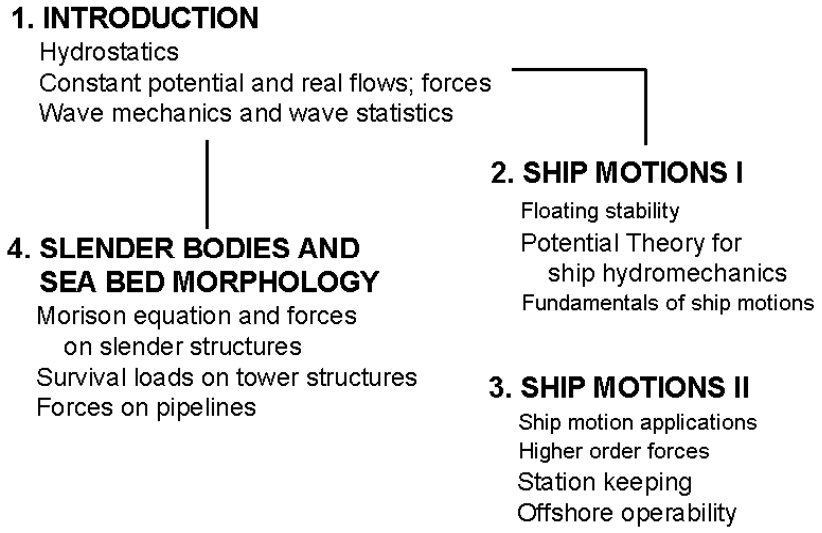

Figure 0.1: Offshore Hydromechanics Study Paths

such as "The result of this section is more important that the road leading to it". Even in such sections, however, the theory is summarized so that students can use and apply it for other purposes without excessive difficulty.

Separate exercise materials are used in several of the TU Delft classes. Much of this is available in a companion publication: *Exercises on Offshore Hydromechanics*. This includes various problems - including many old examination questions - along with solutions to many of the problems posed in the publication *Solutions of Exercises on Offshore Hydromechanics*. Both publications can be obtained from the Internet as freely downloadable files at web site http://dutw189.wbmt.tudelft.nl/~johan.

References to Other Books

References are listed by first author and year date in the text. More complete bibliographic data is included in an appendix. A few books and other materials provide such generally used information or insight that they are not repeatedly listed always in the various chapters. Instead, this section lists them with a short description of each.

Many are (or were when published) what could be considered classic works:

- J. Gerritsma, retired Professor of Maritime Technology at the Delft University of Technology, wrote Lecture Notes on *Waves, Shipmotions and Manoeuvring I* (in Dutch), Report 563-K, 1989, Ship Hydromechanics Laboratory, Maritime Technology Department, Delft University of Technology, Delft, The Netherlands. In particular, the sections on waves give just that information (and not more) that is of real importance here.

- G. Kuiper, Professor of Maritime Technology at the Delft University of Technology, wrote Lecture Notes on *Resistance and Propulsion of Ships*, Report 847-K, 1997, Ship Hydromechanics Laboratory, Maritime Technology Department, Delft University of Technology, Delft, The Netherlands.

- A.R.J.M. Lloyd published in 1989 his book on ship hydromechanics, *Seakeeping, Ship Behaviour in Rough Weather*, ISBN 0-7458-0230-3, Ellis Horwood Limited, Market Cross House, Cooper Street, Chichester, West Sussex, P019 1EB England.

- O.M. Faltinsen, Professor of Marine Technology at the Norwegian University of Science and Technology is the author of *Sea Loads on Ships and Offshore Structures,* published in 1990 in the Cambridge University Press Series on Ocean Technology.

- J.N. Newman, Professor of Marine Engineering at Massachusetts Institute of Technology, authored *Marine Hydrodynamics* in 1977. It was published by the MIT Press, Cambridge, Massachusetts, USA. It is standard work, especially in the area of ship hydromechanics.

- B. Kinsman wrote *Wind Waves - Their Generation and Propagation on the Ocean Surface* while he was Professor of Oceanography at The Johns Hopkins University in Baltimore, Maryland. The book, published in 1963 was complete for its time; the wit scattered throughout its contents makes is more readable than one might think at first glance.

- T. Sarpkaya and M. St. Dennis Isaacson are the authors of *Mechanics of Wave Forces on Offshore Structures* published in 1981 by Van Nostrand Reinhold Company. Sarpkaya, Professor at the U.S. Naval Postgraduate School in Monterey, California has been a leader in the experimental study of the hydrodynamics of slender cylinders for a generation.

- *Hydromechanics in Ship Design* was conceived by a retired United States Navy Captain, Harold E. Saunders with the assistance of a committee of the Society of Naval Architects and Marine Engineers. His work appeared in three volumes: Volume I was published in 1956; volume II followed in 1957, and volume III did not appear until 1965 - after Captain Saunders death in 1961. This set of books - especially volumes I and II - is a classic in that it was written before computers became popular. His explanations of topics such as potential theory seem therefore less abstract for many readers.

- *Fluid Mechanics - An Interactive Text* is a new publication at the most modern end of the publishing spectrum; it is a CD-ROM that can only be read with the aid of a computer! This work - covering much of basic fluid mechanics - was published in 1998 by the American Society of Civil Engineers. It includes a number of animations, and moving picture clips that enhance the visual understanding of the material presented.

Acknowledgments

Although more restricted Lecture Notes by the authors on Offshore Hydromechanics already existed, this book was little more than an idea in the minds of the authors until the spring of 1997. It goes without saying that many have contributed the past three years in a less direct way to what is now this text:

- The books given in the previous reference list were a very useful guide for writing lecture notes on Offshore Hydromechanics for students in the "Delft-Situation".

- Tristan Koempgen - a student from Ecole Nationale Superieure de Mechanique et d'Aeortechnique, ENSMA in Portiers, France - worked on first drafts of what has become parts of several chapters.

- Prof.dr.ir. G. Kuiper provided segments of his own Lecture Notes on "Resistance and Propulsion of Ships" for use in this text in Chapter 4.

- Lecture Notes by prof.ir. J. Gerritsma on waves and on the (linear) behavior of ships in waves have been gratefully used in Chapters 5 and 6.

- Many reports and publications by prof.dr.ir. J.A. Pinkster on the 3-D approach to the linear and nonlinear behavior of floating structures in waves have been gratefully used in Chapter 9 of this text.

- Drafts of parts of various chapters have been used in the classroom during the past three academic years. Many of the students then involved responded with comments about what was (or was not) clear to them, the persons for whom all this effort is primarily intended.

- In particular, Michiel van Tongeren - a student-assistant from the Maritime Technology Department of the Delft University of Technology - did very valuable work by giving his view and detailed comments on these lecture notes from a "student-point-of-view".

Last but not least, the authors are very thankful for the patience shown by their superiors at the university, as well as their families at home. They could not have delivered the extra but very intellectually rewarding effort without this (moral) support.

Authors

The author team brings together expertise from a wide variety of fields, including Naval Architecture as well as Civil and Mechanical Engineering. They have tried to demonstrate here that a team can know more. More specifically, the following two Delft University of Technology faculty members have taken primarily responsibility for producing this book:

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Feel free to contact them with positive as well as negative comments on this text.
Both authors are fortunate to have been educated before the digital computer revolution. Indeed, FORTRAN was developed only after they were in college. While they have both used computers extensively in their career, they have not become slaves to methods which rely exclusively on 'black box' computer programs.
The authors are aware that this first edition of Offshore Hydromechanics is still not complete in all details. Some references to materials, adapted from the work of others may still be missing, and an occasional additional figure can improve the presentation as well. In some ways a book such as this has much in common with software: It never works perfectly the first time it is run!