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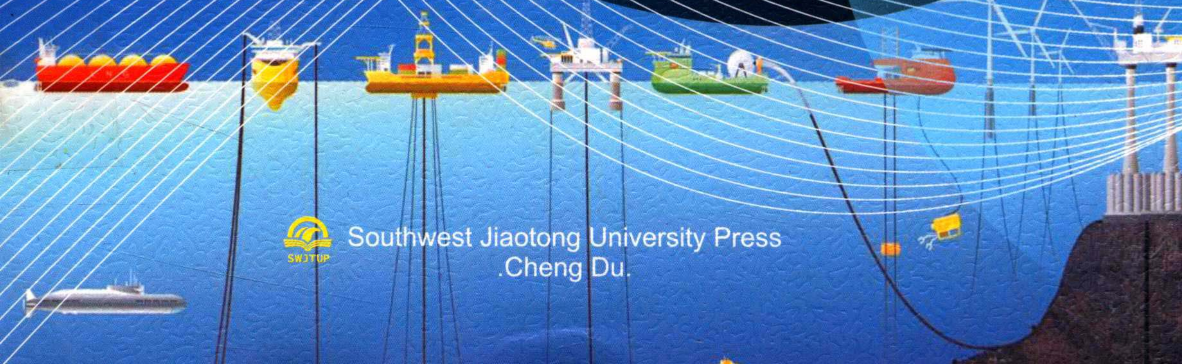
Aspects of Design and Analysis of Offshore Pipelines and Flexibles

Svein Sævik Naiquan Ye



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海洋工程柔性立管与海底管道设计及分析

Svein Sævik Naiquan Ye

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深海空间技术出版工程

海洋工程柔性立管与海底管道设计及分析

Aspects of Design and Analysis of Offshore Pipelines and Flexibles

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Preface

This book is meant to serve as a reference for research scientists, engineers as well as college students who have interests within methods for design analysis of pipelines, flexible pipes and umbilicals. The major purpose is to give the readers an in-depth understanding of the structural behaviour of such structures and the methods used to perform global and local strength analysis with focus on analytical as well as finite element methods.

The first part of the book deals with describing the design process in terms of which factors have to be considered during the engineering phases. Then the applied design principles including relevant loads and load conditions versus associated failure modes and issues of cross-section design are described. This is followed by a detailed description of the models used for cross-section analysis and the associated equations used in design checks. Some brief backgrounds on material selection and welding for steel pipelines as well as flow assurance issues have also been included. This is in order for the reader to understand the complexity of the engineering process and to give some overall understanding of the related aspects that need to be considered during the design process. Thereafter, different installation methods are discussed followed by an analytical treatment of fundamental concepts such as the effective tension and the differential equation which governs global buckling behaviour. With respect to the latter, the significance of different parameters is demonstrated from a probabilistic viewpoint. Then the basis for non-linear finite element methods as applied to slender structures is presented including a detailed description of important elements used for analysis of such structures. These are then applied in examples to investigate different aspects of slender structure physical behaviour including dynamic simulation of the S-lay pipeline installation, J-tube pull-in, pipeline walking, lateral buckling, trawl-gear interaction, dynamic stresses in flexible pipes and local buckling behaviour of flexible pipe tensile armour.

This book will be published both in English and Chinese. I would like to express my gratitude to Southwest Jiaotong University Press for their help in the publishing work. I would also like to thank my former colleagues in REINERTSEN and MARINTEK for enabling experiences over more than two decades.

Svein Sævik

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January, 2016

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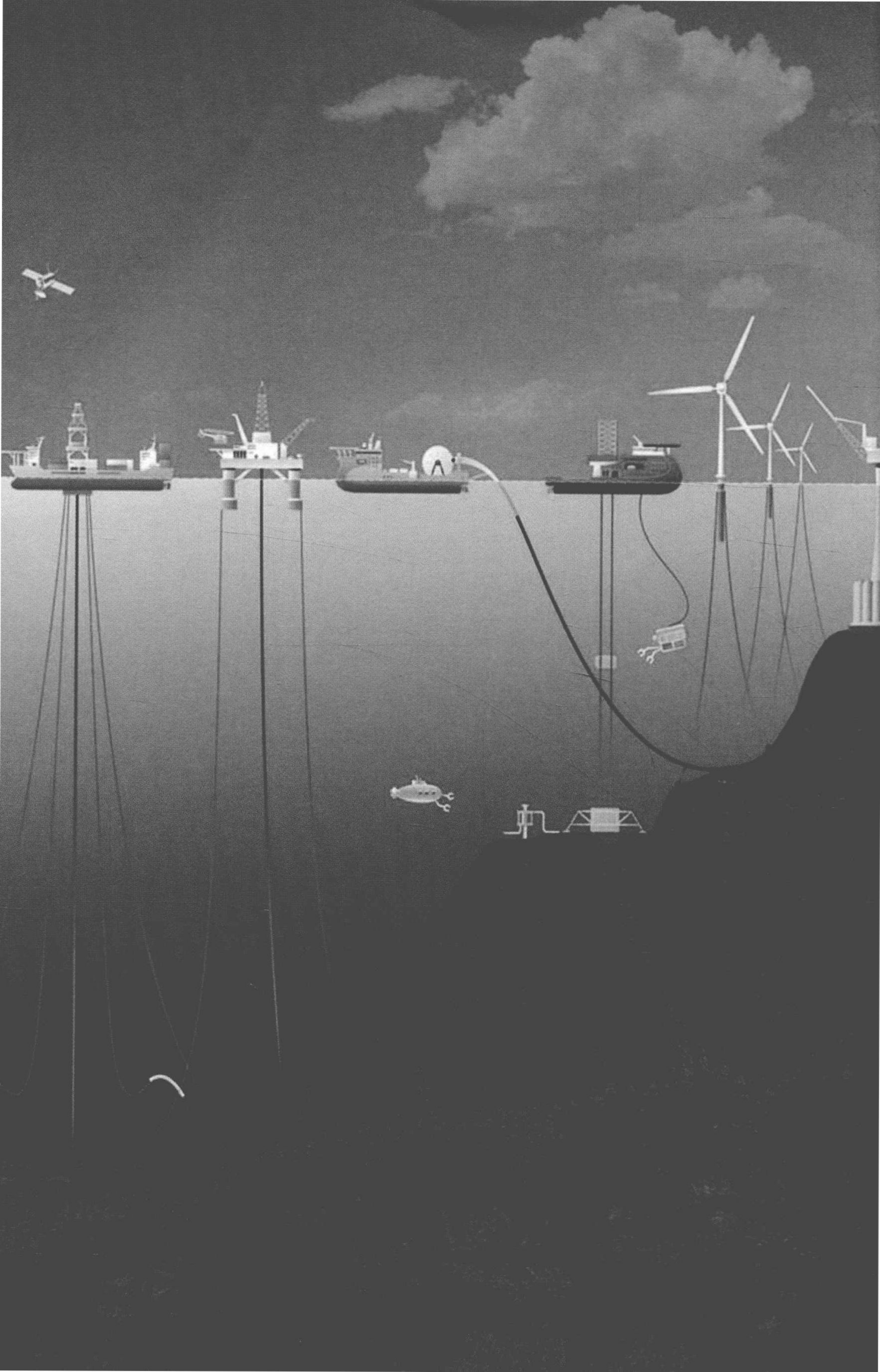
CHAPTER 1

Introduction



1.1 General remarks

Offshore pipelines are used for oil and gas transport world-wide. Depending on application, pipelines can be classified into:

(1) *Export pipelines*, large diameter lines for exporting processed oil and gas from the offshore installation to the onshore processing plant or to the market;

(2) *Flowlines*, small diameter lines for transporting the unprocessed well flow from the wellhead to the offshore processing plant;

(3) *Intra-field lines*, for transporting between offshore installations;

(4) *Chemical injection lines*, for providing anti-freeze and corrosion inhibitors that are injected into the pipeline/flowline well stream to control hydrate (hydrocarbon crystallization) formation and corrosion;

(5) *Water injection lines*, for pumping water into the reservoir to keep the reservoir pressure and improve the production rate;

(6) *Bundles*, normally based on installing the flowline, umbilical and injection lines into one pipe cross-section, a *carrier* pipe that provides mechanical protection and installation buoyancy.

If not otherwise noted, the term *pipeline* may refer to all the above applications whereas the term *flexible* will refer to *non-bonded* flexible pipe cross-sections. Non-bonded flexible pipes cannot be manufactured for large diameters and are therefore mostly used in flowline and riser applications.

Many oil and gas field developments include an offshore platform to process the incoming fluid from the reservoir. Depending on the water depth, this may be either a fixed platform (up to about 300 m water depth) or floaters in the form of semi-submersibles or ship shaped vessels. An example is shown in Figure 1.1. In this case a satellite template is used to tie a distant well into the floater infrastructure by means of a flowline and a riser section. The flowline is installed separately including flowline end termination (FLET) at both ends. At the template the flowline is connected to the wellhead piping by a spool piece in steel (L or U shaped to allow thermal expansion) or a flexible jumper (a short length of flexible pipe). At the floater end, the pipeline may be connected to the floater by either a catenary riser or a wave configuration riser. In addition to the sagging section, the wave configuration includes a hogging section with buoyancy elements that gives more flexibility. This is to avoid dynamic compressive forces and excessive bending at the touch down point (TDP) as a result of the vessel heave motion. Depending on water depth and environmental conditions, the latter requires compliant flexible risers to allow a sufficient motion envelope of the floater without over-stressing the pipe in bending. The flexibility requirement depends on the motion amplitude versus the water depth. Therefore, steel catenary risers or steel wave configuration risers might become an alternative at large water depths. Under North Sea condition the flexible riser would be the only alternative at 300 m water depth. However a water depth of 1 300 m as applicable for the Aasta-Hansteen field, steel wave configuration risers may be applied (Subsea7, 2013). In the Gulf of Mexico, the environmental conditions are somewhat calmer as compared to North Sea conditions and several field developments use steel catenary risers at more shallow waters, e.g. the Auger field at 872 m water depth (Phifer et al., 1994).

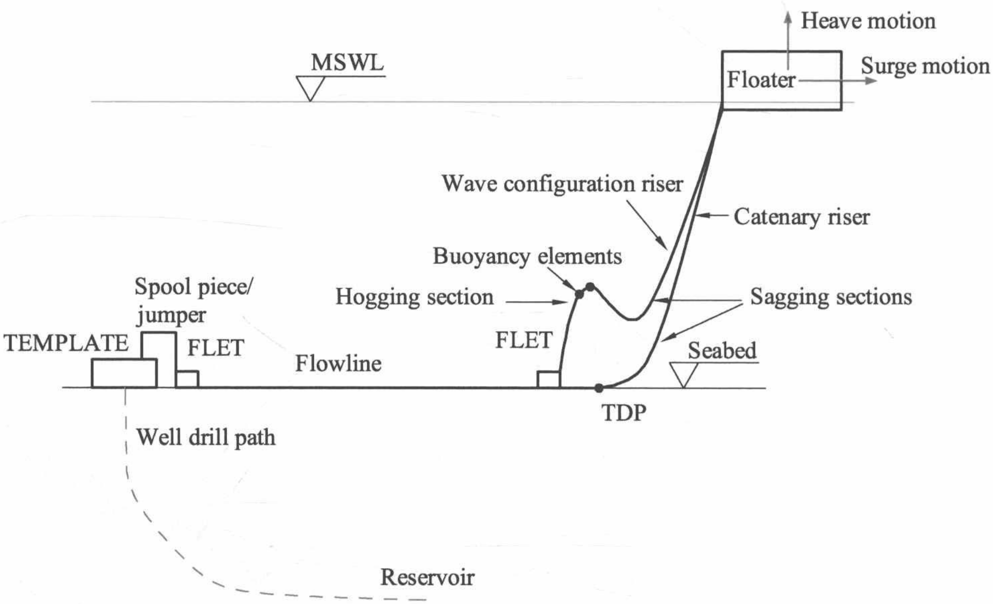


Figure 1.1 Example field lay-out with flowline and riser

In order to control the template infrastructure (e.g. valves, instrumentation etc.) electrical and hydraulic power as well as signal transmission between the template and the platform are needed. This is provided by umbilicals that may include power conductors, hydraulic tubing and fibre-optic cables. A typical umbilical cross-section is seen in Figure 1.2.

Figure 1.2 Typical umbilical cross-section

Steel pipelines are preferably made of carbon steel alloys that provides a favourable strength-cost ratio. However, the un-processed well flow may contain corrosive gases such as CO_2 or H_2S. The latter is a problem especially for old reservoirs where water injection is used to maintain the reservoir pressure and the production rate where H_2S may be developed due to bacterial activity. The presence of both gases in the well flow may either require corrosion resistant alloys to be used, chemical injection or a combination of both to control the corrosion process. The corrosion resistant alloys are based on increasing the chrome content in the steel matrix. In simple terms, the more chrome, the more corrosion resistance, however to a significant increased material cost. Therefore, in order to provide cost efficient transport over long distances, low cost carbon steel is favourable. This requires that the corrosive gases are either removed prior to export or neutralized by chemicals by application of a separate injection line.

The non-bonded flexible pipe is manufactured by layers of steel and plastic