



ADVANCES IN PIPES AND PIPELINES

FLEXIBLE  
**PIPES**

Qiang Bai  
Yong Bai  
Weidong Ruan

 Scrivener  
Publishing

WILEY



# Flexible Pipes

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**Qiang Bai, Yong Bai,  
and Weidong Ruan**



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## Preface

With the rapid development of pipeline engineering technology, flexible pipes have been widely used in the oil and gas industry, both onshore and offshore. They are considered to be an efficient solution in terms of technical as well as economic performance due to their easy and fast laying procedure, durability and recoverability. Nowadays, many researchers and engineers keep on exploring and advancing new design and analysis methods for different types of flexible pipes. However, there is no book available that systematically introduces the design procedures and analysis criteria for different types of flexible pipes.

This book mainly proposes ultimate strength criteria, strength-based cross-sectional design and damage assessment of different types of flexible pipes in the oil and gas industry. We wish that this book will be a useful reference source of flexible pipe design and analysis for pipeline engineers.

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OPR has offices in Houston, Texas, USA; and Hangzhou, China. OPR is engaged in the design, analysis, installation, engineering, and integrity management of pipelines, risers, and subsea systems such as subsea wellheads, trees, manifolds, and PLET/PLEMs.



**Part I**  
**DESIGN AND ANALYSIS**



# 1

## Flexible Pipes and Limit-States Design

### 1.1 Introduction

The origin of flexible pipes can be traced to pioneering work carried out in the late 1970 s. Initially, flexible pipes were used in relatively benign weather environments such as offshore Brazil, the Mediterranean and the Far East. However, flexible pipe technology has advanced so rapidly that they are now used in various areas in the North Sea [1] and have gained popularity among designers in the Gulf of Mexico. Flexible pipes can be applied in water depths up to 8,000 ft., pressures up to 10,000 *psi*, high temperatures above 150 °F and can withstand large vessel motions in adverse weather conditions. Figure 1.1 illustrates a typical flexible riser used in deep water and shows the different configurations used for different water depths. This type of dynamic application is typically used in floating production systems with high pressure production risers, export risers, chemical/water/injection lines and gas lift lines.

### 1.2 Applications of Flexible Pipe

This book explores the application of flexible pipes in the oil and gas industry, both onshore and offshore. The flexible pipe's advantages include its composite structure that combines an internal polymeric sealing layer that transports fluids, helical armoring layers that provide the required strength and a polymeric outer sheath that prevents

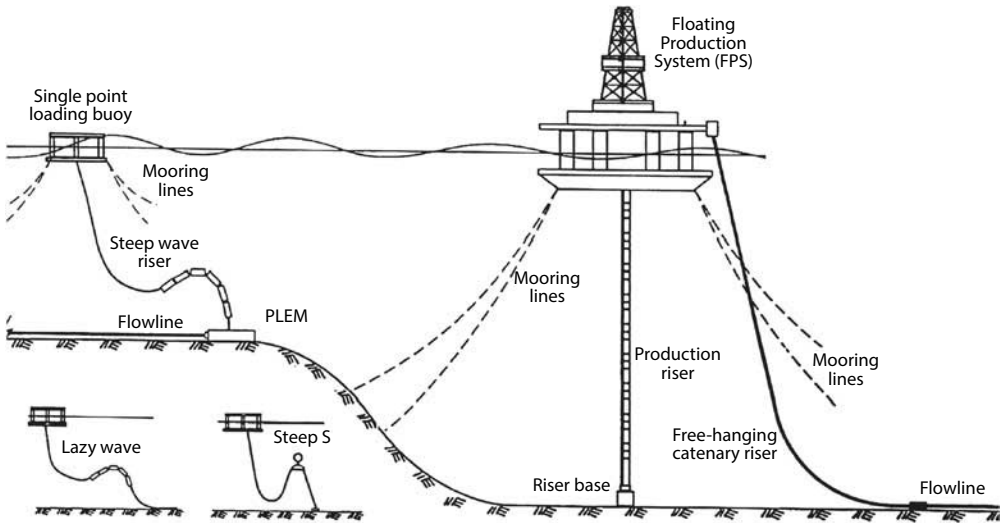


Figure 1.1 Typical flexible riser configurations [2].

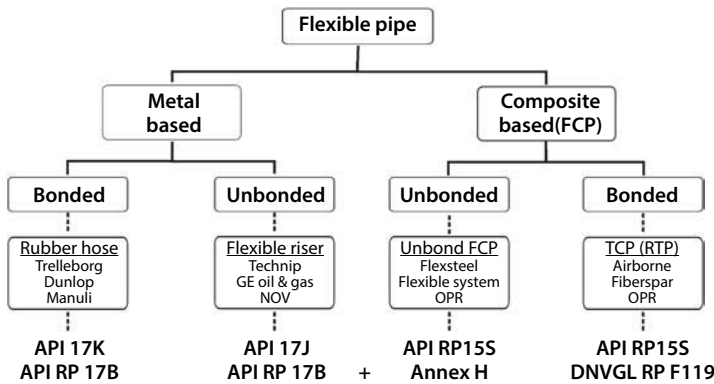


Figure 1.2 Categorization of flexible pipes.

seawater from interacting with the armor layers. As a result this kind of pipe has a low bending stiffness in comparison to axial tensile stiffness, allowing a much smaller radius of curvature than a homogenous pipe with the same anti-pressure capacity. This particular structure gives the flexible pipe a number of advantages over other types of pipelines and risers such as steel catenary risers, including inherent corrosion resistance, reduced transport and installation costs due to prefabrication and storage on reels and compatibility with compliant structures allowing a permanent connection between a floating support vessel and subsea installations.

Figure 1.2 shows the categorization of flexible pipes based on their configuration and functional requirements. The relationships of different type flexible pipes are illustrated in the figure, and in relation to the applied standards and recommended practices. Some main manufacturers for the different types of flexible pipe are also listed in the figure. Flexible pipes are divided based on the operating pressure and reinforcement