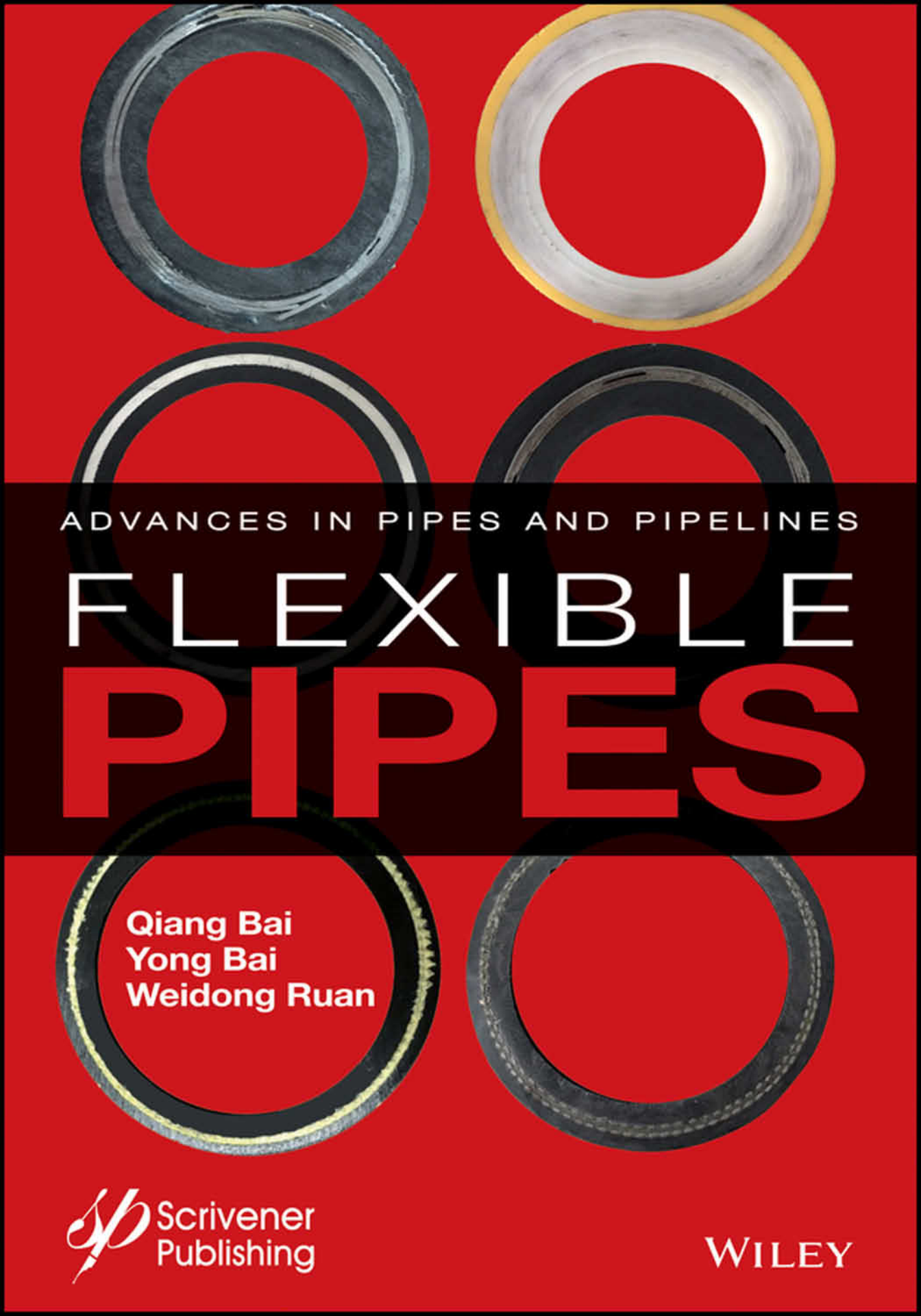
ADVANCES IN PIPES AND PIPELINES
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Qiang Bai
Yong Bai
Weidong Ruan
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Flexible Pipes

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Flexible Pipes

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and Weidong Ruan

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Part III Steel Reinforced Flexible Pipes

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.

The authors would like to thank Mr. Phil Carmical of Scrivener Publishing, for his continuous encouragement. The authors would like to appreciate Dr. Yong Bai's graduate students and post-doctoral fellows at Zhejiang University who provided the initial technical writing for Chapter 4 (Mr. Weishun Dai), Chapters 9, 10, & 13 (Mr. Yutian Lu), Chapters 7, 8, & 11 (Mr. Shuai Yuan), Chapter 12 (Mr. Shuai Yuan & Mr. Peihua Han), Chapters 14 & 18 (Mr. Wei Chen), Chapters 15-17 & 20 (Ms. Ting Liu), Chapters 19, 29, & 30 (Ms. Shanying Lin), Chapter 21 (Ms. Ting Liu & Mr. Peihua Han), Chapter 22 (Dr. Wei Dai), Chapter 24 (Ms. Yuxin Xu), Chapters 25 & 26 (Mr. Weidong Ruan), Chapters 27 & 28 (Mr. Tianyu Zhang & Mr. Jiandong Tang), Chapter 31 (Mr. Zhaohui Shang & Mr. Haichao Xiong), Chapter 32 (Mr. Peng Wang), Chapter 33 (Ms. Songhua Liu), Chapter 34 (Mr. Peihua Han), Chapter 35 (Dr. Gao Tang & Mr. Pan Fang) and Chapter 36 (Dr. Gao Tang & Mr. Kaien Jiang). Thanks to all persons involved in reviewing the book, particularly Mr. Akira Bai of University of California at Berkeley, who reviewed the whole book.

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Dr. Q. Bai, Prof. Y. Bai, and Mr. W.D. Ruan
October 1, 2016

About the Authors

Dr. Qiang Bai has more than 20 years of experience in subsea/offshore engineering including research and engineering execution. Experienced in different aspects of subsea engineering for shallow water and deep water and mechanical engineering. He has worked at Kyushu University in Japan, UCLA, OPE, JP Kenny, and Technip. His experience includes various aspects of flow assurance and the design and installation of subsea structures, pipelines, and riser systems. Dr. Bai is the coauthor of the books of "Subsea Pipelines and Risers", "Subsea Engineering Handbook", and "Subsea Pipeline Design, Analysis and Installation".

Professor Yong Bai is the president of Offshore Pipelines & Risers Inc. in Houston, and also the director of the Offshore Engineering Research Center at Zhejiang University. He has previously taught at Stavanger University in Norway where he was a professor of offshore structures. He has also worked with ABS as manager of the Offshore Technology Department and DNV as the JIP project manager.

Professor Yong Bai has also worked for Shell International E & P as a staff engineer. Through working at JP Kenny as manager of advanced engineering and at MCS as vice president of engineering, he has contributed to the advancement of methods and tools for the design and analysis of subsea pipelines and risers. Professor Bai is the author of the books "Marine Structural Design" and "Subsea Pipelines and Risers" and more than 100 papers on the design and installation of subsea pipelines and risers.

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

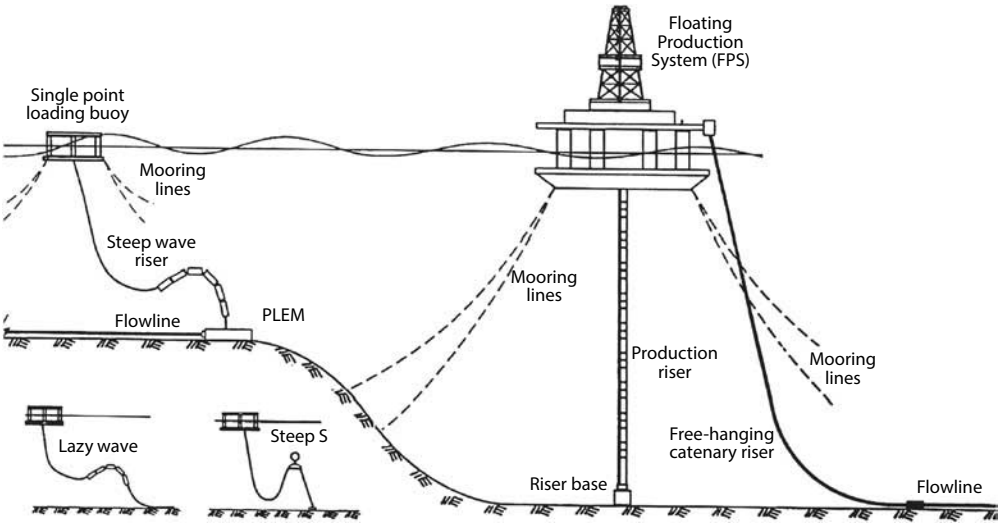

Figure 1.1 Typical flexible riser configurations [2].

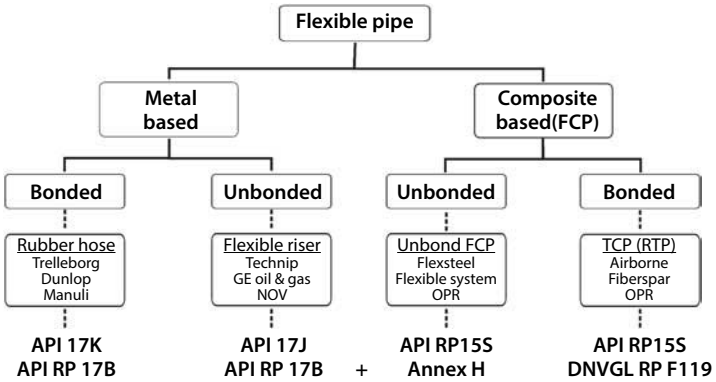

Figure 1.2 Categorization of flexible pipes.

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