## Contents

Foreword xi  
Preface xiii

### Part One  Mechanical Design  1

1. Introduction  3  
   1. Introduction  3  
   2. Design Stages and Process  4  
   3. Design through Analysis  8  
   4. Pipeline Design Analysis  9  
   5. Finite Element Analysis  19

2. Wall Thickness and Material Grade Selection  23  
   1. Introduction  23  
   2. Material Grade Selection  26  
   3. Pressure Containment Design  27  
   4. Equivalent Stress Criterion  32  
   5. Hydrostatic Collapse  33  
   6. Buckle Arrestors  35

3. Buckling and Collapse of Metallic Pipes  41  
   1. Introduction  41  
   2. Analytical Solution of Limit Moment  48  
   3. Finite Element Analysis  52  
   4. Guidelines for Bending Strength Calculations  61

4. Limit-State Based Strength Design  67  
   1. Introduction  67  
   2. Stress Based Design and Strain Based Design  71  
   3. Ultimate Limit State  76  
   4. Serviceability Limit State  81  
   5. Fatigue Limit State  83  
   6. Accidental Limit State  84
## Part Two  Pipeline Design

5. **Hydraulic and Thermal Analysis of Subsea Pipelines**
   1. Introduction
   2. Crude Oil Transportation Pipelines
   3. Gas Transmission Pipelines
   4. Hydraulic Analysis of Oil-Gas Production Pipelines
   5. Water Transportation Pipelines
   6. Commercial Software for Design and Analysis

6. **Soil and Pipe Interaction**
   1. Introduction
   2. Pipe Penetration in Cohesive Soil
   3. Pipe Penetration in Noncohesive Soils
   4. Axial Load–Displacement Response of Pipelines
   5. Lateral Load–Displacement Response of Pipelines

7. **Hydrodynamics around Pipes**
   1. Introduction
   2. Wave Theory
   3. Steady Currents
   4. Hydrodynamic Forces

8. **Finite Element Analysis of In Situ Behavior**
   1. Introduction
   2. Finite Element Modeling of the Pipeline System
   3. Procedure and Load Steps in Finite Element Analysis
   4. Element Types Used in the Model
   5. Nonlinearity and the Seabed Model
   6. Validation of the Finite Element Model
   7. Dynamic Buckling Analysis
   8. Cyclic In-Place Behavior During Shutdown Operations

9. **Thermal Expansion Design**
   1. Introduction
   2. Pipeline Strains
   3. Pipeline Stresses
   4. Effective Axial Force of the Pipeline
   5. Expansion of a Single-Pipe Pipeline
   6. Expansion of the Pipe-in-Pipe System
   7. Examples of Expansion Analysis

10. **Lateral Buckling and Pipeline Walking**
   1. Introduction
   2. Buckle Initiation

11. **Mitigation of Lateral Buckling During Shutdown Operations**

12. **Fatigue and Fracture**
   1. Introduction
   2. Fatigue S-N Approach
   3. Fracture
   4. Recognized Industry Standards

13. **On-Bottom Stability**
   1. Introduction
   2. Vertical On-Bottom Stability
   3. Lateral On-Bottom Stability
   4. Pipe-Soil Interaction
   5. Stabilization Measures
   6. Acceptance Criteria
   7. Stability Analysis

14. **Pipeline Spans and VIV**
   1. Introduction
   2. Static Analysis
   3. Dynamic Analysis
   4. VIV Mitigation and Control
   5. Example Case

15. **Force Model and Wave Impact**
   1. Introduction
   2. Fatigue Analysis
   3. Force Model
   4. Comparison of Forces
   5. Summary

16. **Trawl Impact, Pullover Loads**
   1. Introduction
   2. Trawl Gears
   3. Acceptance Criteria
   4. Impact Response Analysis
   5. Pullover Loads
3. Mitigation of Lateral Buckling
4. Pipeline Walking

11. Upheaval Buckling
   1. Introduction
   2. Analytical Solution of Upheaval Buckling
   3. Finite Element Analysis of Upheaval Buckling
   4. Stabilization Against Upheaval Buckling
   5. Design Against Upheaval Buckling

12. Fatigue and Fracture
   1. Introduction
   2. Fatigue S-N Approach
   3. Fracture
   4. Recognized Industry Codes of ECA

13. On-Bottom Stability
   1. Introduction
   2. Vertical On-Bottom Stability
   3. Lateral On-Bottom Stability
   4. Pipe-Soil Interaction
   5. Stabilization Measures
   6. Acceptance Criteria
   7. Stability Analysis

14. Pipeline Spans and VIV Fatigue
   1. Introduction
   2. Static Analysis
   3. Dynamic Analysis
   4. VIV Mitigation and Span Correction
   5. Example Case

15. Force Model and Wave Fatigue
   1. Introduction
   2. Fatigue Analysis
   3. Force Model
   4. Comparison of Frequency Domain and Time Domain Approaches
   5. Summary

16. Trawl Impact, Pullover, and Drop Objects
   1. Introduction
   2. Trawl Gears
   3. Acceptance Criteria
   4. Impact Response Analysis
   5. Pullover Loads
## Contents

6. FE Model for Pullover Response Analyses 397
7. Case Study 399

17. Pipe-in-Pipe and Bundle Systems
   1. Introduction 405
   2. PIP Systems 408
   3. Bundle Systems 421

18. Seismic Design
   1. Introduction 435
   2. Seismic Hazards 436
   3. Pipeline Seismic Design Guidelines 438
   4. Seismic Design Methodology 441
   5. Analysis Example 444
   6. Mitigation Methods 447

19. Corrosion Prevention and Advanced CP Design
   1. Introduction 451
   2. Fundamentals of Cathodic Protection 452
   3. Pipeline Coatings 454
   4. CP Design Parameters 455
   5. Galvanic Anodes System Design 459
   6. Internal Corrosion Inhibitors 463

20. Arctic Pipelines
   1. Introduction 465
   2. Arctic Pipeline Considerations 467
   3. Arctic Pipeline Design Approach 472
   4. Geothermal Analysis 477
   5. Ice Scour Analysis 479
   6. Installation Techniques 482

21. Subsea Survey and Positioning
   1. Introduction 487
   2. Subsea Survey 488
   3. Subsea Metrology and Positioning 497
   4. Subsea Soil Investigation 502

22. Route Optimization, Shore Approach, Tie-in, and Protection
   1. Introduction 511
   2. Pipeline Routing 512
   3. Shore Approach 515
   4. Pipeline Tie-Ins 521
   5. Pipeline Trenching and Burying 529
   6. Pipeline Rock Dumping 532

23. Åsgard Flowlines
   1. Introduction 533
   2. Wall Thickness
   3. Limit States
   4. Installation
   5. Design

Part Three Flexibility

24. Flexible Pipe
   1. Introduction
   2. Application
   3. Flexible Pipe

25. Cross-Sectional Flexibility
   1. Introduction
   2. Flexible Pipe
   3. Material and Design
   4. Analytical Evaluation
   5. FE Analysis

26. Tensile and Circular Flexibility
   1. Introduction
   2. Code Requirements
   3. RTP Pipe
   4. RTP Pipe

27. Burst Strength
   1. Introduction
   2. Experimental
   3. Analytical
   4. Finite Element
   5. Results and Conclusions

28. Collapse of RTP Pipes
   1. Introduction
   2. Analytical
   3. FE Analysis
   4. Analysis Example
   5. Sensitivity Analysis

29. Offshore Installation
   1. Introduction
   2. Code Requirements
   3. Analytical
   4. FE Analysis
Contents

23. Åsgard Flowlines Design Examples
   1. Introduction
   2. Wall Thickness and Line Pipe Material Selection
   3. Limit State Strength Criteria
   4. Installation and On-Bottom Stability
   5. Design for Global Buckling, Fishing Gear Loads, and VIV

Part Three Flexible and RTP Pipelines

24. Flexible Pipe
   1. Introduction
   2. Applications of Flexible Pipe
   3. Flexible Pipe System and Components

25. Cross-Sectional and Dynamic Analyses of Flexible Pipes
   1. Introduction
   2. Flexible Pipe Guidelines
   3. Material and Mechanical of Properties Flexible Pipes
   4. Analytical Formulations in Flexible Pipe Design
   5. FE Analysis of Unbonded Flexible Pipe

26. Tensile and Compressive Strengths of RTP Pipeline
   1. Introduction
   2. Code Requirements
   3. RTP Pipe Under Tension
   4. RTP Pipe Under Compression

27. Burst Strength of RTP Pipeline
   1. Introduction
   2. Experimental Analysis
   3. Analytical Analysis
   4. Finite Element Analysis
   5. Results and Comparison

28. Collapse of RTP Pipelines
   1. Introduction
   2. Analytical Analysis of RTP Collapse
   3. FE Analysis of RTP Collapse
   4. Analysis Example of RTP Collapse
   5. Sensitivity Analysis

29. Offshore Installation of RTP
   1. Introduction
   2. Code Requirements
   3. Analytical Analysis of RTP Installation
   4. FE Analysis of RTP Installation
Part Four  Welding, Installation, and Precommissioning 673

31. Use of High-Strength Pipeline Steels 675
1. Introduction 675
2. Usage of High-Strength Steel Line Pipes 676
3. Potential Benefits and Disadvantages of High-Strength Steel 683
4. Welding of High-Strength Line Pipe 688
5. Cathodic Protection 691
6. Fatigue and Fracture of High-Strength Steel 692
7. Material Property Requirements 692

32. Welding and Defect Acceptance 695
1. Introduction 695
2. Weld Repair Analysis 695
3. Allowable Excavation Length Assessment 700
4. Conclusions 705

33. Installation Design 707
1. Introduction 708
2. Pipeline Installation Vessels 709
3. Pipe Laying Methods 713
4. Installation Software and Code Requirements 718
5. Physical Background for Installation 722
6. Analytical Method for S-Lay Installation 734
7. FEA of Pipeline Installation with an In-line Valve 741
8. Two-Medium Pipeline Design Concept 744

34. Pipeline Commissioning, Operations, and Maintenance 753
1. Introduction 753
2. Precommissioning Activities 753
3. Commissioning 759
4. Operations 759
5. Maintenance 764

Index 767