A subsea pipeline (also known as an offshore pipeline or submarine pipeline) is a pipeline that is laid on the seabed or inside a specially constructed trench. The use of pipelines represents a reliable mode of transport of oil and gas. To prevent failure scenarios, such as improper pressurization, localized buckling, fatigue failure and instability, the limit strength, internal/external pressure, corrosion-resistant material selection, and stability management are the main concerns in the design, installation, and operation of submarine pipelines.

Fifteen recent research studies within the broad domain of structural design and analysis of subsea pipelines or risers are featured in this book. The applications of the digital twin in subsea pipelines are highlighted [1]. Classic structural topics including collapse strength [2–4], burst strength [5], tensile performance [6], buckling [7,8], fatigue [9–11], and bending [12] are investigated by numerical and experimental methods in this book. Computational fluid dynamics (CFD) simulations [13,14] and proportional integral derivative (PID) control [15] of the pipelines and risers are also included.

Digital twins are described as a concept that combines multi-physics modelling and data-driven analytics to replicate the behaviour of an entity in the real world. In [1], a review of the digital twins of the subsea pipelines is presented, which covers their present applications and the challenges associated with the design, construction, service, and assessments of life extension of the structures. The key opportunities in enhancing the integrity management of offshore assets using the digital twin include data contextualization, standardization, automated anomaly detection, and shared learning. However, the collection, interpretation, and sharing of data, and cybersecurity are among the main challenges identified.

The oil and gas industry is encountering difficulties in designing pipelines and risers that are well-insulated and capable of extreme operating conditions as they shift towards exploiting hydrocarbons in ultra-deep waters. Under these circumstances, the pipelines are exposed to extreme hydrostatic pressure and are primarily engineered to resist collapse. Li et al. [2] investigated the effect of ovality length on imperfect sandwich pipes (SP) using the three-dimensional finite element method (3D-FEM) in the scenario of local buckling of SPs subject to external pressure. Sandwich pipes are composite pipes consisting of three layers: an inner and outer layer made of steel or another material with high tensile strength, and a lightweight material such as foam or honeycomb between them. The sandwich structure provides better insulation and weight reduction compared to traditional pipes, making them suitable for use in harsh environments such as deep-sea oil and gas exploration. By analysing the results of 1200 cases, a predictive equation was developed in [2] to illustrate the correlation between the collapse strength and ovality length of imperfect SPs. The 3D-FEM was also used in [3] to analyse the collapse pressure of pipes with internal corrosion defects repaired with carbon-fibre-reinforced polymer (CFRP). The results showed that the collapse pressure of the composite-repaired pipe increased and the CFRP significantly reduced the strain in the defect region. In [4], it was assessed the structural safety of SPs for collapse failure and reliability-based design probabilistically.
Results were distinguished in fully bonded, partially bonded, and unbonded core categories based on SP interlayer adhesion conditions. Through First Order Reliability Method (FORM) based sensitivity analysis, external pressure is found to be the most important parameter for safety, followed by Young’s modulus of elasticity.

When pipelines corrode and are under internal pressure, they become vulnerable to burst failure. Therefore, accurate prediction of burst pressure is crucial for the safety of corroded pipelines. Aiming at providing vital guidance on the design and maintenance of different steel-grade pipelines, FORM was employed in [5] to estimate the partial safety factors and their uncertainty as a function of operational time. The probabilistic characteristics of the pipe burst strength were studied using Monte Carlo simulation (MCS) and the normal distribution is selected based on Chi-squared test results. The influence of the corrosion growth model on the evaluation of partial safety factors was assessed.

The tensile mechanical behaviour of a helically wound structure of marine flexible pipe/cables was investigated in [6] based on the curved beam theory. The deformation mechanisms of the flexible structures of umbilicals, flexible pipes, and cryogenic hoses with varying winding angles were discussed.

Subsea pipelines can experience lateral buckling when subjected to excessive axial compressive force resulting from high-temperature and high-pressure conditions. Taking the nonlinear pipe–soil interaction (NL-PSI) model into account, a mathematical model was proposed in [7] to investigate the lateral buckling of subsea pipelines triggered by a sleeper. A reduction in the deformation of the buckled pipeline and an increase in both the minimum critical temperature difference and the maximum stress along the buckled pipeline can be observed when the NL-PSI model is incorporated. The phenomenon of buckle propagation in a pipe-in-pipe (PIP) system under uniform external pressure was studied in [8]. It is revealed that the initial imperfections of PIP, i.e., the ovality and eccentricity of the inner pipe, have an insignificant influence on the buckle propagation pressure, and the relationship between the buckle propagation pressure and the ratio between the diameter and the thickness of pipes follows the format of power functions. A fitted formula was proposed for predicting the buckle propagation pressure of the PIP with good accuracy.

The experimental method plays a crucial role in the fatigue analysis of subsea pipelines by providing reliable data for validating numerical models and improving the understanding of the structural behaviour under cyclic loading. A full-scale fatigue test system for deepwater steel catenary risers, flexible pipes, and seabed pipelines was presented in [9]. The fatigue strength assessment of single-sided girth welds in offshore pipelines subjected to start-up and shut-down cycles was performed in [10]. The finite element analyses (FEAs) for the estimation of the effective notch stress were performed using ANSYS. For a specific study case, the plastic behaviour of the weld root was investigated to justify the use of the low cycle fatigue (LCF) approach, and the effect of weld root geometry on the notch stress factor was studied to identify the dominant geometrical parameters. A fracture mechanics-based fatigue reliability analysis of a submarine pipeline was investigated in [11] using the Bayesian approach based on limited experimental data. Bayesian updating method and Markov Chain MCS were used to estimate the posterior distribution of the parameters of the fatigue model regarding different sources of uncertainties. Failure load cycle distribution and the reliability-based performance assessment of API 5L X56 submarine pipelines as a case study were estimated for three different cases. The effects of the stress ratio, maximum load, uncertainties of stress range and initial crack size, and the corrosion-enhanced factor on the reliability of the investigated submarine pipeline were indicated through a sensitivity study.

FEM was also used in a parametric analysis model of an offshore screen pipe based on ABAQUS and Python software under pure bending load in [12]. The study identified and discussed the deformation patterns and mechanisms and developed an empirical formula for determining the ultimate moment of the screen pipe. Han et al. [13] presented a numerical investigation of turbulent flow in double-curved pipes with various spatial
configurations, examining the impact of spatial angle and interval distance between bends on secondary flow through analysis of vector fields, velocity distributions, vortex developments, and dissipations of swirl intensity. Anwar et al. [14] performed a numerical analysis to investigate the impact of surface roughness on vortex-induced vibration (VIV) in the crossflow direction of a circular cylinder. It was concluded that roughness on a cylinder results in a reduction in amplitude response.

Under severe external marine stresses, the coupling effect between the offshore platform and the riser in the offshore platform-riser multi-body system can be significantly amplified. In [15], a new PID control approach based on the unscented Kalman filter (UKF) for the dynamic positioning (DP) system was created, and the DP control of a rigid–flexible fluid coupling system composed of an offshore platform and risers was realized by combining the OrcaFlex application program interface (API) with a PID-DP control statement in UKF mode based on Python programming. This method is feasible when considering the interaction between the riser and DP offshore platform in the overall analysis.

We hope that this set of papers can be seen as a contribution to the subject area by covering various relevant aspects related to submarine pipelines, and can be a useful reference to those who work in the field.

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