Ship-Shaped Offshore Installations

Second Edition

Extensively updated for the second edition, this handy guide covers the safety engineering of ship-shaped offshore installations at every stage of design, construction, operation, lifetime healthcare and decommissioning. New sections cover additional types of offshore structures, including offshore power plants, as well as cutting-edge technologies and all the latest advances in the field. The text focuses on minimising accidents and the effects of extreme conditions, with new chapters covering earthquakes, hurricanes and terrorist attacks, as well as traditional types of accidental events such as hull girder collapse, collisions, fires and explosions. This is an invaluable resource for students who will be approaching the subject for the first time as well as practising engineers and researchers.

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Design, Construction, Operation, Healthcare and Decommissioning

Second Edition

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Preface to the Second Edition

Advances in human civilisation have led the development of various types of engineered structures. The ship-shaped offshore installation is a type of engineered structure that uses the space and resources of the ocean to develop energy. Ship-shaped offshore installations are exemplified by floating storage and offloading (FSO) units; floating production, storage and offloading (FPSO) units (for the development of offshore oil or gas); floating power plants (fuelled by liquefied natural gas or nuclear reactors) and floating storage and regasification units (FSRUs).

In the offshore oil and gas industry, fixed offshore platforms have been used in relatively shallow waters but are unsuitable for use in developing oil and gas fields in deep and ultra-deep areas (depth >1,000 m). Instead, floating offshore installations such as FPSO units are preferred for developments in remote and/or deep and ultra-deep areas, where they perform multiple functions in the production, storage and offloading of oil or gas. These installations enable these energy resources to be transported to shore via shuttle tankers, thus obviating the need for pipeline infrastructure and facilitating fast-track functionality. FPSOs are also preferred for use in marginal fields, where the reservoirs are not necessarily abundant.

Floating power plants fuelled by liquefied natural gas or nuclear reactors are used to generate electrical power at sea. Uniquely, these plants can provide electricity and heat to remote, relatively inaccessible sites. FSRUs are floating offshore installations that are used as near-shore liquefied natural gas terminals, with functions such as storage and regasification. FSO units are also utilised near onshore oil terminals.

Ship-shaped offshore installations have been used since the late 1970s, and their complexity and size have been gradually increasing. Many engineering challenges associated with structural safety and tolerance to extreme conditions and accidents, and with economics and financial expenditures in design, construction and operation, remain to be solved. Safer end-of-life decommissioning is essential to ensure the health and safety of the environment, as aged installations have substantial accumulations of structural damage resulting from natural deterioration or accidents.

Ship-shaped offshore installations are similar to trading tankers in terms of structural geometry, but differ in terms of their design, construction, operation, lifetime care and decommissioning. For example, the different design loads require substantially different structural design concepts. Trading tankers can avoid rough weather or alter their heading while in operation, whereas ship-shaped offshore installations have fixed locations and thus are continuously exposed to site-specific environmental conditions. In addition, unlike trading tankers, ship-shaped offshore installations typically cannot be periodically dry-docked for inspection and maintenance, meaning that the designs must enable greater long-term durability and reliability. Furthermore, ship-shaped offshore installations are likely to be subjected to significant environmental actions during loading and offloading, whereas trading tankers are typically loaded and unloaded under still-water harbour conditions. Finally, for historical reasons, the design return period of a ship-shaped offshore installation is typically 100 years, while that of a trading tanker is considered to be 25 years.

Despite significant efforts, accidents invariably occur at every stage of the design, construction, operation, lifetime care and decommissioning of a ship-shaped offshore installation, and these may have catastrophic effects on personnel, assets and the environment. Thus, there is an obvious need for a textbook on the safety engineering of ship-shaped offshore installation structures that provides an exposition of the emerging technologies and industry practices. This book is therefore intended as a comprehensive text and handy guide to the first principles, current practices, recent advances and cutting-edge trends in safety engineering for ship-shaped offshore installations, with a focus on extreme conditions and accidents. This edition represents an extensive update of the first edition (published in 2007 with Dr A. K. Thayamballi), as it covers the latest advances in the field and comprehensively examines new approaches to structural safety intended to minimise accidents and the effects of extreme conditions.

I hope that this book will be useful for practising engineers and will increase their awareness and use of advanced and sophisticated technologies, in addition to existing industrial practices, in the safety engineering of ship-shaped offshore installations. Because of its coverage of the fundamentals and principles of individual technologies, this book will also be useful for university students at all levels of study. Readers are also recommended to refer to my sister textbooks, *Ultimate Limit State Analysis and Design of Plated Structures*, second edition (John Wiley & Sons, 2018) and *Advanced Structural Safety Studies with Extreme Conditions and Accidents* (Springer, 2020), as the first describes the fundamentals and detailed derivations of theories, and the second presents industrial practices and applications.

I gratefully acknowledge all of those who have helped to make this book possible. Most of all, I am grateful to Dr A. K. Thayamballi (formerly a senior technical advisor at Chevron Shipping Company), who was the co-author of the first edition, and Dr G. Wang (formerly a principal surveyor at the American Bureau of Shipping) and Dr I. Lotsberg (a specialist engineer at DNV), who provided valuable and comprehensive comments that greatly improved this book. Finally, I thank my wife, Yunhee Kim (a sculptor), my son, Myunghoon Paik, Esq. (an international lawyer) and my daughter, Yunjung Paik (a product designer), for their unfailing patience and support.

Preface to the First Edition

Today, the need for development of offshore oil and gas resources in increasingly deeper waters is becoming more important because of many reasons associated with the world economy and the related energy resource development constraints and strategies.

Fixed-type offshore platforms, which have been useful for oil and gas developments in relatively shallow waters, are now much less feasible as we move further in developing oil and gas fields in deep- and ultradeep-water areas, now reaching more than 1,000 m water depth. Floating-type offshore structures have to be increasingly considered to develop these deep-water areas. In addition to ship-shaped offshore units, at least three other types of floating production systems – semisubmersibles, spars, and tension leg platforms (TLP) – are also available today for that purpose. All of these types of floating systems require storage, pipeline infrastructure, and other associated field structures and systems to transport produced oil and gas to the facilities on shore, but perhaps to varying degrees.

That the use of ship-shaped offshore units remains a very attractive alternative in many cases of field development is attributable to its ability to successfully serve multiple functions, such as production, storage, and offloading, and the capability for oil or gas to be transported to shore via shuttle tankers. Ship-shaped offshore units reduce need for pipeline infrastructure and are functional on a fast-track basis.

Ship-shaped offshore units are now recognized as perhaps one of the most economical of all systems for potential developments of offshore oil and gas and are often the preferred choice in marginal fields. These systems are becoming more attractive for developing oil and gas fields in deep- and ultradeep-water areas and locations remote from the existing pipeline infrastructures. Recently, the ship-shaped offshore units have also begun to be applied to near-shore oil and gas terminals.

Although the use of ship-shaped offshore units has been in existence since the late 1970s, the complexity and size of the units have been gradually increasing, and there are still many issues related to design, building, and operation to be resolved for achieving high integrity in terms of safety, health, environment, and economics/financial expenditures.

Although ship-shaped offshore units are similar to trading tankers in structural geometry, they are different in a variety of ways. Environmental conditions are unique in each case, and structural design concepts must be tailored to a specific location. Trading tankers may avoid rough weather or alter their heading in operation, but ship-shaped offshore units must be continuously located in the same area with site-specific environments and do not have the ability to periodically dry-dock for the necessary inspection and maintenance. This is an aspect that must be reflected in some fashion in the design and long-term durability and reliability of the units concerned.

To continue further on the subject of differences from trading tankers, one should note that ship-shaped offshore units are likely to be subjected to significant environmental actions even during loading and unloading; however, trading tankers are typically loaded and unloaded at still-water condition in harbor. And, for historical reasons, the design return period of ship-shaped offshore units is typically taken as 100 years, and that of trading tankers is considered to be 20–25 years or so.

The application of existing procedures, criteria, and standards to the structural design of ship-shaped offshore units also requires additional thought and discussion. This can be particularly important for the many interface areas between the hull and topsides. Even for the hull part, the shipbuilding industry standards may need to be selectively upgraded to ensure the long life and onsite reliability needed. Similarly, for the topsides part, it is often not straightforward to apply the relatively more economical shipbuilding industry standards, in part perhaps because of differences in the background, experience, and culture of the operating personnel involved. In any event, the complexities of the design are enormous, and there are many interface issues (e.g., those related to the interaction between hull and topsides facilities and related consistency in design information) that need to be identified up front and addressed and managed on a continuous basis.

In such a situation, direct analyses from first principles, advanced engineering, and practices are increasingly desired so that practicing engineers and academic researchers can resolve the issues that remain, reconcile differences in standards and practices, and improve structural and other design procedures and criteria. In the never-ending quest for safe, reliable, yet economical structures and systems effectively designed and constructed, there are often demanding schedules and other constraints and challenges.

Also, many diverse international organizations in the maritime industry such as the International Maritime Organization (IMO), International Organization for Standardization (ISO), International Association of Classification Societies (IACS), and the industry in general are now increasingly applying the limit-state design approach for both trading ships and ship-shaped offshore installations, making related knowledge and training even more relevant. Another emerging and increasingly more important technology consists of risk-based approaches to design, operation, and human and environmental safety, with much of the same accompanying knowledge, training, and familiarization needs.

The intention behind writing this book is to develop a textbook and handy resource that sufficiently addresses current practices, recent advances, and emerging trends on core technologies for designing, building, and operating ship-shaped offshore units, within certain inevitable space (and time) requirements. This book covers a wide range of topics, from the initial contracting strategy to the decommissioning and even the removal of the units concerned, but not always to a depth some might have wished for. Although a large number of research papers and references and industry standards useful for specific topics in the areas do exist, we did our best to high-light selected and useful ones among them in the various chapters and appendices.

We have also tried our utmost to always refer to relevant past work, with proper acknowledgments. It is respectfully requested that any unintentional oversights in this regard be brought to our attention for correction in future editions.

We believe and hope that this book will be very useful for practicing engineers and engineers-in-training and will contribute to their increased awareness and potentially greater use of advanced and sophisticated technologies as well as existing and emerging practices. Because of its coverage of the fundamentals and principles of the individual technologies, this book will also be useful for university students who are approaching both the initial and more intensive studies of advanced engineering for ship-shaped offshore installations. With regard to the scope, emphasis, and other relevant aspects of this book, we encourage all related and pertinent feedback and suggestions for the future; these will be gratefully received.

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