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Jack-up Barges' Jacking System Simulator

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Симулятор підйомної системи самопідйомних барж

Summary. *Jack-up barges are vital self-elevating platforms used in offshore oil and gas operations. Their sophisticated jacking systems, comprising extendable legs and high-pressure hydraulic systems, require precise control and comprehensive technical knowledge. There is a significant non-availabilities in simulator-based training for marine engineers responsible for these systems. This article emphasizes the urgent need for developing specialized simulators, outlining its potential to enhance safety, troubleshooting skills, and overall operational efficiency in high-risk offshore environments.*

Резюме. *Самопідйомні баржі є ключовими об'єктами офшорних операцій в нафто- та газовидобувній галузі. Їхні складні системи підйому, що включають висувні ноги та високонапірні гідравлічні мережі, вимагають точного керування і глибоких технічних знань. Існує суттєва нестача тренажерних програм для суднових механіків, відповідальних за ці системи. Стаття підкреслює необхідність розробки симуляторів, що сприятимуть підвищенню безпеки, розвитку навичок усунення несправностей та загальній ефективності роботи в умовах високих ризиків офшорних операцій.*

1 Introduction

Modern offshore operations demand both precision and uncompromised safety. Jack-up barges, also known as self-elevating platforms essential to oil and gas extraction as well as offshore maintenance rely on sophisticated jacking systems to achieve stability. These systems, which integrate high-pressure hydraulics (operating up to 4500 PSI), extendable legs, and complex electrical controls, are indispensable for elevating the platform above the water and withstanding environmental forces.

In complex operational conditions, even minor errors can lead to catastrophic consequences. Nowadays the advanced control systems give possibility for some operational tolerance; however, the risk remains high for both personnel and the environment. In such a situation, practicing and acquiring hands-on skills under real conditions are not feasible. As an alternative, a dedicated simulator offers a safe, controlled environment in which system behavior from routine adjustments to emergency responses can be verified without endangering life or equipment.

The Figure below illustrates a conceptual scheme of a jack-up barge, highlighting the positions of its legs and the hydraulic control systems.

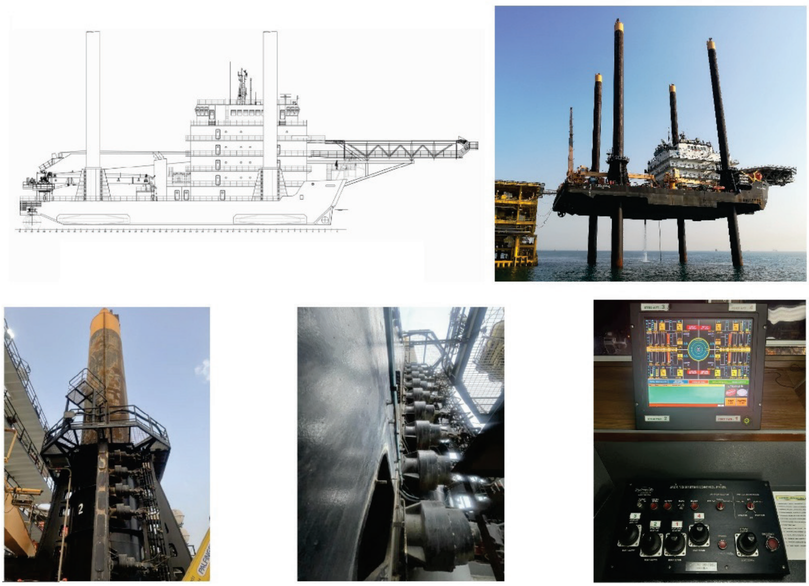

Fig. Schematic diagram of a jack-up barge highlighting its legs and hydraulic system.

2 Technical Characteristics of Jack-up Barges

Jack-up barges are designed to elevate their working decks above the water surface by extending their legs, which are firmly positioned on the seabed. The vertical movement of the structure is facilitated by sophisticated hydraulic systems that ensure accurate control of pressure and flow during the jacking process.

The hydraulic system incorporates electric motors, closed-loop hydraulic pumps, supercharge pumps, hydraulic motors, and specialized manifolds, all working in coordination to provide stable and precise vertical positioning of the platform. According to the Jacking System Manual, these systems typically employ electric motors rated at 300 HP, pressure-compensated flow control valves, and planetary gearboxes to maintain operational stability. The complexity of this system demands a high level of technical competence, especially during critical operational phases such as platform positioning, elevation, or departure from the site.

Precise synchronization between hydraulic components is essential to prevent structural overloading, minimize operational errors, and ensure the platform's structural integrity during jacking operations. The technical intricacies of these systems highlight the importance of advanced training for marine engineers involved in jack-up barge operations.

3 The Main Role of Jack-up Barges in Offshore Operations

Jack-up barges are indispensable in the oil and gas sector. They serve as stable bases for drilling rigs, maintenance operations, and the servicing of offshore platforms. By elevating the platform above the water, they ensure that all operational equipment remains safe from wave action and adverse weather. A malfunction during these operations can lead to severe damage not only to the platform but also to the surrounding infrastructure and the marine environment.

In recent years, incidents involving damage to oil platforms have underscored the need for enhanced operator training. Mishandling during the approach or departure such as improper leg deployment or unintentional contact with underwater pipes and cables can lead to catastrophic failures, resulting in environmental hazards and high economic costs.

4 Technical Complexity and Safety Challenges of Jacking Systems

The hydraulic jacking system on jack-up barges characterized by:

– *High-Pressure Hydraulics:* Operating at pressures up to 4500 PSI, the system uses precise control mechanisms to manage fluid flow and pressure.

– *Integrated Electrical Controls:* Advanced control panels and joysticks allow for smooth coordination between the Captain and the Chief Engineer on the bridge during maneuvers.

– *Mechanical Precision:* Multiple electric motors, hydraulic pumps, and gearboxes work in tandem to raise or lower the barge's legs, ensuring stable operation even in dynamic sea conditions.

Further, detailed documentation such as the Jacking System Manual outlines these components and emphasizes the importance of routine maintenance and system monitoring. Such technical precision is essential to prevent inadvertent contact with underwater structures and to ensure safe operations.

5 Current Operational Programs and Existing Gaps

While numerous simulator-based courses are available for navigators focusing on platform maneuvering and overall operational procedures a critical gap remains for marine engineers tasked with managing the hydraulic and mechanical intricacies of jack-up systems. As demonstrated in Table 1, a comparative analysis reveals that existing programs do not fully address the specific challenges of hydraulic diagnostics and leg control required for effective system operation.

Below is a Table 1 that provides a comparative analysis of existing training programs versus the proposed simulator features.

Table 1

Comparative analysis of existing training programs versus the proposed simulator features

Course Name	Provider	Services/Techniques Provided	Existing Gaps	Proposed Simulator Advantages
1	2	3	4	5
Jack-Up Barge Advanced Introduction	*Education Marine*	Provides a theoretical foundation and practical examples from real maritime practice covering jack-up barge operations, crew responsibilities, jacking system operation, and barge movement preparation.	Focuses primarily on shipmaster responsibilities; does not offer in-depth training on the technical aspects (e.g., hydraulic system troubleshooting and leg operation) needed by marine engineers.	A dedicated simulator can offer realistic hands-on training for marine engineers, focusing on detailed hydraulic control, emergency procedures, and precise leg operations.

Continuation Table 1

1	2	3	4	5
Jack-Up Barge – Complete Course	*Education Marine*	An online course taught by an experienced jack-up barge Captain that includes operational scenarios, interview preparation, maneuvering techniques, and practical insights from maritime practice.	Aimed at overall shipmaster operation with limited modules for technical maintenance and diagnostic procedures specific to marine engineers.	The simulator can be customized for marine engineers, incorporating modules on system diagnostics, technical troubleshooting, and maintenance of jacking systems.
Jack-Up Familiarization Course	*Lerus Training*	Delivers detailed information on jack-up operations, including various unit types, safety-critical equipment, operational planning, risk management, and emergency response procedures.	Emphasis is placed on overall platform operations and safety rather than the specific technical challenges encountered by marine engineers when managing hydraulic systems.	Provides an immersive, simulation-based environment for marine engineers focusing on the intricacies of hydraulic and mechanical systems, emergency drills, and system optimization.
Marine Operations of Self-Elevating Platforms	*Seaway Academy*	Offers an overview of operational procedures for self-elevating platforms, including platform positioning, basic maintenance practices, and general operational strategies.	General course content that does not address the specialized technical training required by marine engineers responsible for jacking system control and maintenance	A simulator tailored to marine engineers can deliver comprehensive technical training on jacking system dynamics, advanced hydraulic troubleshooting, and precise leg control

6 Functional Features and Algorithms of the Proposed Simulator

6.1 General Overview

The proposed simulator is designed to model the ship lifting system used in jack-up barges, allowing marine engineers to practice raising and lowering the platform safely. It emulates the behavior of hydraulic systems, electric motors, and control systems, enabling operators to develop essential skills for both routine operations and emergency scenarios.

6.2 List of Function

The proposed simulator incorporates a comprehensive set of functions covering all phases of the lifting process:

– ***System Cheking and Preparation:*** Checking the condition of hydraulic and electrical components.

– ***Barge Positioning:*** Simulating the movement of the barge and the alignment of the platform legs to ensure safe contact with the seabed.

– ***Jack Up:*** Manages the extension of the legs for seabed contact and the hydraulic lifting of the platform above the water, including real-time monitoring and adjustments to maintain stability especially under wave and wind influences.

– ***Jack Down:*** Controls the retraction of the legs for a safe descent.

– ***Monitoring and Control:*** Provides real-time tracking of key parameters (such as pressure, fluid flow, and leg positions) and allows operators to adjust settings via control panels and simulated joysticks that mirror actual interfaces.

– ***Emergency Handling:*** Simulates potential failure scenarios including hydraulic leaks, leg misalignments, and electrical system faults and enables operators to practice diagnostics and troubleshooting under adverse conditions.

6.3 Operational Algorithms

To accurately simulate the complex dynamics of the lifting system, the simulator uses modular algorithms that include:

– ***Hydraulic System Modeling:*** Utilizes specialized libraries (e.g., Simcenter or Hopsan) to model high-pressure fluid dynamics, accurately replicating the behavior of pumps, valves, and motors.

– ***Leg Movement Kinematics:*** Implements kinematic models that simulate the extension and retraction of the legs, considering factors such as leg length, speed, and interaction with the seabed.

– ***Control Logic:*** Simulates the behavior of valves, motors, and pumps in response to operator inputs, ensuring that the virtual system behaves in a realistic and predictable manner.

– ***User Interaction:*** Processes inputs from simulated control panels and joysticks to deliver real-time feedback, closely mimicking the operation of actual jack-up barge systems.

6.4 Technical and Software Requirements

Hardware Requirements:

– ***Computing Power:*** High-performance CPUs for real-time simulations, GPUs for 3D visualization, and sufficient RAM for complex model processing.

– ***Operating Systems:*** Compatibility with Windows or Linux.

– ***Peripheral Devices:*** Joysticks or similar input devices and high-quality displays for detailed visualization (especially for 3D-rendered environments).

– ***Network Connectivity:*** Optional support for multi-user scenarios or online training to enable remote access and collaborative learning.

Software Requirements:

– ***Programming Languages:*** C++ for performance-critical physics simulation components and Python for scripting and configuration.

– ***Simulation Libraries:*** For hydraulic systems, libraries such as Simcenter; for physical dynamics, engines like Bullet Physics or PhysX.

– ***3D Graphics:*** Utilization of OpenGL, DirectX, or game engines (e.g., Unity or Unreal Engine) to render the jack-up barge and its operational environment realistically.

– ***User Interface:*** GUI frameworks such as Qt or wxWidgets for desktop applications, or web interfaces based on HTML5 and JavaScript that replicate real control panels and joysticks.

Table 2

Comparison of Hydraulic Simulation Libraries

Library	Advantages	Limitations
Simcenter	Supports complex systems; integrates with other tools	High licensing cost
Hopsan	Free; developed in academic settings	Limited documentation for beginners
MATLAB/Simulink	Well-known; offers powerful simulation tools	Requires additional configuration

7 The Role of Leading Simulator Manufacturers

Industry leaders in maritime simulation such as Kongsberg Digital, Wärtsilä Voyage, ECA Group, ARI, etc. Simulation have already demonstrated their capability to develop high-fidelity simulation systems. By leveraging their technological expertise, these companies are well-positioned to create specialized simulators that accurately replicate the hydraulic and mechanical operations of jack-up systems. Such solutions can bridge the existing gap in operational support and contribute to enhanced safety and efficiency in offshore environments.

8 Conclusion and Recommendations

A comprehensive technical specification has been provided for developing a ship lifting system simulator, covering every aspect from functional features to equipment requirements. The simulator is envisioned as a critical training tool for marine engineers operating jack-up barges. By accurately replicating both routine operations and emergency scenarios such as hydraulic leaks or leg misalignments the system will enable effective hands-on training in a risk-free virtual environment.

Key Recommendations:

Enhanced Training Efficiency: The simulator will facilitate real-time practice and troubleshooting, reducing the risk of errors during live operations and significantly improving overall safety.

Comprehensive System Coverage: By integrating detailed models of hydraulic systems, electric motors, and control logic, the simulator addresses the training gaps currently present in conventional programs.

Robust Technical Infrastructure: Adoption of high-performance hardware and advanced simulation libraries will ensure that the system provides a realistic and responsive training experience.

Future-Proof Design: Its modular architecture allows for scalability and future integration of emerging technologies such as augmented or virtual reality, further enhancing training effectiveness and operational reliability.

In summary, the development of this simulator represents a vital step toward minimizing operational risks and enhancing the technical skills of marine engineers. It will contribute significantly to the safety, efficiency, and long-term sustainability of offshore operations.

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Анотація. *Самопідйомні баржі виступають критично важливим елементом офшорних операцій з видобутку нафти та газу, забезпечуючи стабільну, самопідйомну платформу, необхідну для буріння, технічного обслуговування та будівництва в суворих морських умовах. Їхні високотехнологічні системи підйому, що поєднують високонапірну гідравліку, висувні ноги та сучасні електричні системи управління, гарантують безпеку експлуатації та структурну стійкість. Незважаючи на широкодоступні тренажерні курси для судноводіїв, існує суттєва нестача спеціалізованих симуляційних засобів для суднових механіків, відповідальних за технічне обслуговування, усунення несправностей та експлуатацію цих складних систем. У статті розглядається необхідність розробки спеціалізованого симулятора, що точно відтворює реальні умови роботи, включаючи як щоденні операційні виклики, так і аварійні ситуації. Представлено всебічний аналіз технічних складнощів, притаманних гідравлічним мережам та механічним компонентам, а також показано, як елементарні, модульні алгоритми можуть ефективно використовуватися для симуляції динаміки системи. Запропонований симулятор дозволяє судновим механікам практикувати діагностику систем, ін'єкцію збоїв та регулювання управління у віртуальному середовищі без ризику, що сприяє підвищенню стандартів безпеки, зниженню витрат на обслуговування та покращенню загальної ефективності експлуатації. Крім того, стаття аналізує існуючі програми підготовки та виявляє їхні недоліки, підкреслюючи потенціал провідних виробників симуляторів у розвитку цієї технології. Завдяки створенню реалістичного та занурюючого*

симуляційного середовища запропонована система не лише задовольняє нагальну потребу в ефективному навчанні, але й створює основу для постійного вдосконалення офшорних операцій. Її модульний дизайн забезпечує масштабованість та адаптивність до майбутніх технологічних досягнень, сприяючи формуванню культури безпеки та технічної досконалості серед суднових механіків. Інтеграція цих симуляційних засобів, як очікується, революціонізує протоколи обслуговування та стратегії реагування на надзвичайні ситуації, що суттєво вплине на стабільність та прибутковість офшорних проектів.