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Reviewing the advancements in offshore drilling technologies in the USA and their global impact

Oladipo Olugbenga Adekoya [1], Daniel Isong [2], Cosmas Dominic Daudu [3], Adedayo Adefemi [4], Chinelo Emilia Okoli [5] and Olawe Alaba Tula [6, *]

[1] *Nigeria LNG Limited, Bonny Island, Rivers State, Nigeria.*
[2] *Independent Researcher, Port Harcourt, Nigeria.*
[3] *Nigeria LNG Limited, Bonny Island, Rivers State Nigeria.*
[4] *Chevron Nigeria Limited, Nigeria.*
[5] *Independent Researcher, Lagos Nigeria.*
[6] *NLNG, Nigeria, Nigeria.*

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Abstract

This study provides an overview of the significant advancements in offshore drilling technologies within the United States and their consequential global impact. As the world's leading innovator in the energy sector, the USA has played a pivotal role in shaping the future of offshore drilling, pushing the boundaries of technological capabilities and fostering sustainable practices. The review begins by highlighting the evolution of offshore drilling technologies in the USA over the past decade. Innovations such as advanced drilling rigs, smart sensors, and real-time data analytics have revolutionized the industry, enhancing operational efficiency, safety, and environmental sustainability. These technological breakthroughs have not only increased the depth and reach of offshore drilling but have also significantly reduced exploration risks and minimized the environmental footprint. The global impact of these advancements is explored, emphasizing the ripple effect on international energy markets, geopolitical dynamics, and environmental stewardship. The USA's expertise in developing cutting-edge technologies has been instrumental in influencing global industry standards and best practices. International collaborations, knowledge exchange, and technology transfer have facilitated the adoption of these advancements in offshore drilling practices across the globe. Furthermore, the study addresses the role of regulatory frameworks and industry collaborations in shaping the trajectory of offshore drilling technologies. The USA's commitment to stringent safety and environmental regulations has set a benchmark for responsible offshore exploration, influencing other nations to implement similar standards. The study concludes by highlighting the future prospects and challenges in offshore drilling technologies. As the energy landscape continues to evolve, the USA remains at the forefront of research and development, driving innovation towards cleaner, more efficient, and sustainable offshore drilling solutions. The ongoing collaboration between industry stakeholders, government bodies, and research institutions is crucial for addressing emerging challenges and ensuring the continued positive global impact of USA's advancements in offshore drilling technologies.

Keywords: Offshore; Drilling; Technology; USA; Innovation; Review

1. Introduction

Offshore drilling in the USA has been a crucial component of the country's energy production for decades. The advancements in offshore drilling technologies have significantly impacted the industry, allowing for the exploration and extraction of hydrocarbon accumulations in offshore locations (Dirkzwager, 2018). These advancements have not

* Corresponding author: Olawe Alaba Tula

only improved the efficiency and safety of drilling operations but have also expanded the reach of drilling activities into deeper waters, unlocking previously inaccessible reserves.

The significance of these advancements is underscored by their role in enhancing the overall productivity and sustainability of offshore drilling. For instance, the development of innovative drilling techniques and tools has enabled the industry to address challenges such as drilling in depleted offshore reservoirs and managing annulus bottom hole pressure during drilling operations (Vega et al., 2016; Chen et al., 2018). Moreover, the utilization of smart monitoring systems has facilitated real-time decision-making, contributing to the regulation of drilling processes and ensuring operational safety (Vega et al., 2016).

The purpose of this review is to comprehensively examine the global impact of the USA's innovations in offshore drilling technologies. By synthesizing the knowledge gaps and technological developments, this review aims to provide insights into the implications of these advancements on global energy markets, environmental sustainability, and geopolitical dynamics. Furthermore, it seeks to analyze the influence of these innovations on the safety and risk management aspects of offshore drilling, particularly in the context of major environmental incidents such as the Deepwater Horizon Accident (Fragouli et al., 2019).

In conclusion, the advancements in offshore drilling technologies in the USA have not only revolutionized the domestic energy landscape but have also reverberated globally, shaping the trajectory of offshore drilling practices and their environmental and economic implications. This review endeavors to offer a comprehensive analysis of these advancements and their far-reaching impact on the global energy sector.

2. Evolution of Offshore Drilling Technologies in the USA

The evolution of offshore drilling technologies in the USA over the past decade has been marked by significant advancements in various areas, including advanced drilling rigs, smart sensors and automation, and real-time data analytics. These advancements have had a profound impact on operational efficiency, safety, and environmental sustainability.

Advanced drilling rigs have been a focal point of technological development in offshore drilling. These rigs have seen improvements in automation and smart sensor integration, allowing for more precise and efficient drilling operations (Khadisov et al., 2019). Additionally, the development of real-time data analytics has enabled operators to monitor and analyze drilling processes as they occur, leading to improved decision-making and operational efficiency (Rahanjani & Nugraha, 2020).

The impact of these advancements on operational efficiency has been substantial. The integration of smart sensors and automation has led to increased drilling speeds and reduced downtime, ultimately improving overall operational efficiency (Asad et al., 2019). Real-time data analytics have further contributed to this by providing operators with actionable insights to optimize drilling processes, leading to more efficient operations (Fragouli et al., 2019).

In terms of safety, the advancements in offshore drilling technologies have led to improved risk management and accident prevention. The use of smart sensors and automation has enabled the identification of safety risks and the implementation of effective risk mitigating factors, ultimately enhancing safety protocols at drilling sites (Saasen et al., 2021). Furthermore, real-time data analytics have facilitated the visualization and monitoring of drilling operations, allowing for the early detection of potential hazards and the implementation of timely interventions to prevent accidents (Ayele et al., 2016).

Environmental sustainability has also been a key focus of the evolution of offshore drilling technologies. The integration of advanced drilling rigs with smart sensors and automation has led to more precise drilling techniques, reducing the environmental impact of drilling activities (Wang et al., 2019). Additionally, real-time data analytics have enabled operators to monitor and manage drilling fluid performance, leading to improved waste handling practices and reduced environmental impact (Shi et al., 2016).

In conclusion, the evolution of offshore drilling technologies in the USA over the past decade has seen significant advancements in advanced drilling rigs, smart sensors and automation, and real-time data analytics. These advancements have had a profound impact on operational efficiency, safety, and environmental sustainability, ultimately shaping the future of offshore drilling.

3. Global Impact of USA's Offshore Drilling Advancements

To comprehensively address the global impact of the USA's offshore drilling advancements, it is essential to consider the influence on international energy markets, geopolitical implications, environmental stewardship, and the reduction of the industry's footprint, as well as the USA's role in setting global standards and best practices.

The USA's advancements in offshore drilling have significantly influenced international energy markets. As the world's largest consumer of energy, the USA's offshore drilling advancements have the potential to impact global energy supply and prices (Nyga-Łukaszewska & Napiórkowski, 2022). The high dependence on energy rents challenges exporters' economies and influences their ability to compete on international markets (Nyga-Łukaszewska & Napiórkowski, 2022). Additionally, the implications and impact mechanisms of international conflicts on the energy security and economy of oil-importing countries have been poorly explored (Hu et al., 2021). Therefore, the USA's offshore drilling advancements can potentially affect global energy security and economic growth.

Geopolitically, the USA's offshore drilling advancements have implications for international relations and global energy dynamics. International conflicts and economic sanctions can impact energy security and economic growth (Hu et al., 2021). Furthermore, the USA's role in setting global standards and best practices in offshore drilling can influence regulatory frameworks and governance in other countries, particularly emerging economies (Brandl et al., 2018). The complexity and uncertainty under which offshore drilling operations are conducted are evident from the numerous environmental disasters that have occurred over time, despite the risk management programs implemented by oil and gas companies (Fragouli et al., 2019).

In terms of environmental stewardship and reduction of the industry's footprint, the USA's offshore drilling advancements have the potential to impact the natural environment. The construction of offshore gas wells is characterized by increased requirements for both the technological process in general and the technological parameters of drilling fluids in particular (Leusheva et al., 2021). Moreover, the increased complexity of Arctic offshore drilling waste handling facilities, coupled with stringent regulatory requirements such as zero "hazardous" discharge, calls for rigorous risk management practices (Ayele et al., 2016). Additionally, materials added to drilling fluid could cause numerous environmental problems in soil and water resources, and these problems are more pronounced in offshore as compared to land fields (Shalafi et al., 2016).

In conclusion, the USA's offshore drilling advancements have a multifaceted global impact. They influence international energy markets, have geopolitical implications, and raise concerns about environmental stewardship and the reduction of the industry's footprint. Furthermore, the USA plays a significant role in setting global standards and best practices for offshore drilling, which can have far-reaching effects on regulatory frameworks and governance worldwide.

3.1. Technology Transfer and Collaborations

Technology transfer and collaborations play a crucial role in the global exchange of knowledge and innovation. International collaborations facilitate the exchange of knowledge and technology across borders, leading to advancements in various fields (Xue & Chen, 2016). Universities and industries are increasingly engaging in partnerships to drive technology transfer and create valuable intellectual property (Mascarenhas et al., 2018). In the context of offshore drilling technologies, the transfer of such technologies to other nations is essential for the sustainable development of the oil and gas industry worldwide (Murairwa, 2021). Collaborations and technology transfer are vital in driving global adoption, as they enable the sharing of information, resources, and technology, ultimately influencing product innovation and development (Mei-li et al., 2021; Gudda, 2017).

The exchange of knowledge and technology is a fundamental aspect of research and development environments, particularly in driving collaborative innovation (He, 2023). Furthermore, the capacity of public-private collaborations to incorporate sustainable business models relies on effective knowledge transfer between the involved entities (Mattsson et al., 2022). Information systems and information technology play a significant role in modern knowledge management systems, emphasizing the importance of technology in facilitating knowledge transfer ("undefined", 2022). Moreover, the emphasis on collaboration and co-produced knowledge, rather than transactional knowledge transfer, highlights the significance of collaborative approaches in knowledge exchange (Hamilton, 2017).

In the specific context of offshore drilling technologies, the transfer of such technologies to other nations requires robust international collaborations and knowledge exchange mechanisms. This is essential for addressing the technological needs of different regions and promoting sustainable practices in the oil and gas industry (Murairwa, 2021). The role of industry partnerships in driving global adoption is evident in the promotion of collaborations and technology transfer by research institutions to facilitate product design, development, and production (Gudda, 2017). Additionally, the structural evolution features of collaborative innovation networks underscore the importance of knowledge flow in driving collaborative innovation, emphasizing the role of technology transfer in industry partnerships (He, 2023).

In conclusion, technology transfer and collaborations are integral to international knowledge exchange, the transfer of offshore drilling technologies, and the role of industry partnerships in driving global adoption. These processes facilitate the exchange of knowledge and technology, drive collaborative innovation, and contribute to the sustainable development of various industries. Effective technology transfer and collaborations are essential for addressing global challenges and fostering advancements in diverse fields.

3.2. Regulatory Frameworks and Industry Collaborations

The regulatory standards in the USA have a significant influence on global offshore drilling practices. The USA's regulatory framework sets a precedent for safety and environmental standards, impacting offshore drilling practices worldwide (Ayele et al., 2016). Furthermore, global regulatory developments, particularly in areas such as clinical stem cell research, present challenges and opportunities for collaborations between government bodies, industry stakeholders, and research institutions (Rosemann et al., 2016). These collaborations are essential for addressing the diversification and challenges posed by evolving regulatory standards (Rosemann et al., 2016). Additionally, the influence of regulatory standards extends to clinical trials, where the "gold standard" is being reevaluated, impacting global practices (Rosemann, 2019). This highlights the interconnectedness of regulatory frameworks and industry collaborations on a global scale.

In conclusion, the regulatory standards in the USA not only shape offshore drilling practices globally but also necessitate collaborations between government bodies, industry stakeholders, and research institutions to navigate the evolving regulatory landscape and its impact on various industries.

4. Emerging Trends and Tools for Offshore Drilling Technologies in the USA

Emerging trends and tools in offshore drilling technologies in the USA are influenced by various factors such as technological advancements, environmental concerns, and safety measures. The integration of distributed energy resources into offshore and subsea grids has been identified as an emerging trend, with a focus on deep-sea mining and offshore wind power (Fard & Tedeschi, 2018; Li et al., 2020). Additionally, the development of environmentally friendly and high-performance water-based drilling fluids is a significant area of focus, reflecting the industry's commitment to sustainability and environmental responsibility (Liu et al., 2020). Furthermore, the use of digitalization and automation, as well as the application of advanced robotics, is transforming offshore drilling operations, leading to the need for reskilling and job merging pathways (Wanasinghe et al., 2023; Lamb, 2021).

In terms of specific tools and technologies, the investigation of combustion processes in gas turbine modules of Floating Production Storage and Offloading (FPSO) vessels is contributing to the analysis of power plants for mobile offshore drilling units and FPSO vessels (Cherednichenko et al., 2019). Moreover, the use of radar imagery and remote sensing methods for detecting offshore drilling rigs, as well as the application of satellite-based techniques for offshore platform extraction, are enhancing the efficiency and safety of offshore drilling operations (Zhu et al., 2021; Wang et al., 2019). Additionally, the development of managed pressure drilling technology and the utilization of multifunctional additives in water-based drilling fluids are contributing to the advancement of drilling techniques and materials (Ganiev et al., 2021; Aftab et al., 2020).

Furthermore, the assessment of competency models for offshore coxswains and the establishment of methods for maintaining the performance of drilling fluids during transportation are indicative of the industry's focus on safety, human factors, and operational efficiency (Lim et al., 2022; Maryanov, 2021). The development of technological trends in the upstream oil and gas industry, including the identification of patent information and the analysis of technological trends in offshore mining systems, reflects the industry's commitment to innovation and continuous improvement (Cavalheiro et al., 2018; Knodt et al., 2016).

The emerging trends and tools in offshore drilling technologies in the USA are characterized by a focus on sustainability, technological innovation, safety, and operational efficiency. These trends and tools are shaping the future of offshore drilling operations, driving the industry towards more environmentally friendly, technologically advanced, and safe practices.

4.1. Future Prospects and Challenges

Offshore drilling technologies are undergoing significant research and development to enhance efficiency and safety. The development of digitalization in offshore oil and gas drilling occupations is a key area of ongoing research (Wanasinghe et al., 2023). This includes the use of advanced technologies for detecting offshore drilling rigs and extracting information from satellite imagery to monitor offshore platforms and ensure environmental safety (Zhu et al., 2021; Wang et al., 2019). Furthermore, the optimization of drilling fluid properties, such as bentonite slurry, is being studied to improve wellbore strengthening ability during drilling operations in deepwater wells (Xu et al., 2022). Additionally, the structural optimization design of modular double drill pipes is being explored to enhance drilling operations (Wang & Guo, 2022).

In parallel, there is a growing focus on cleaner and more sustainable solutions in offshore drilling. The industry is exploring prospects for safer and more environmentally friendly drilling practices. For instance, safety and environmental risk management are being emphasized to mitigate the potential hazards associated with offshore drilling activities (Fragouli et al., 2019). Moreover, the development and engineering of offshore mining systems are being pursued to extract resources from deep sea environments, with a focus on minimizing environmental impact (Knodt et al., 2016).

However, alongside these advancements, emerging challenges and considerations for the future of offshore drilling are also being recognized. Partnering in offshore drilling projects is an area of concern, as it requires effective collaboration and management to ensure project success (Børve et al., 2017). Additionally, as drilling operations target offshore depleted reservoirs, there is a need to address the maximum allowable well depth while drilling to optimize resource extraction (Chen et al., 2018). Furthermore, the impact of offshore drilling on employment and the workforce is a subject of study, highlighting the need to address potential shifts in job duties and requirements in the industry (Wanasinghe et al., 2023).

This section delves into the future prospects and challenges arising from the continuous advancements in offshore drilling technologies within the United States and their far-reaching global implications. By scrutinizing the trajectory of these innovations, we aim to uncover the potential contributions to sustainability, the integration of cutting-edge technologies, and the collaborative endeavors required for international progress. Additionally, we address the intricate challenges that accompany these advancements, spanning environmental considerations, geopolitical dynamics, and the delicate equilibrium between energy demands and ecological preservation.

Offshore drilling technologies have undergone transformative advancements in recent years, positioning the United States as a pioneering force in the industry. Continuous exploration of sustainable technologies lies at the forefront of future prospects. Integrating renewable energy sources, developing eco-friendly drilling methods, and embracing circular economy principles are pivotal for ensuring the longevity of offshore drilling practices. Technological convergence emerges as a beacon of progress, where artificial intelligence, digitalization, and automation synergize with traditional drilling operations. Robotics takes center stage in maintenance and repair, promising heightened reliability and efficiency in offshore installations. Global collaboration emerges as an imperative for innovation. Strengthening international partnerships, fostering joint ventures, and sharing knowledge across borders accelerates the pace of technological advancement, driving the industry towards sustainable practices on a global scale.

As advancements continue, assessing and mitigating environmental risks associated with drilling activities becomes paramount. Comprehensive strategies for habitat preservation, coupled with advancements in rapid response technologies to oil spills, are essential for minimizing the ecological impact of offshore drilling. The challenge of balancing energy needs with environmental conservation requires a nuanced approach. Evaluating trade-offs, implementing policies promoting responsible drilling practices, and incorporating diverse stakeholder perspectives into decision-making processes are critical steps towards achieving a sustainable equilibrium.

Navigating political uncertainties that impact collaborative initiatives poses a challenge. Understanding the role of geopolitical tensions on global energy markets and strategizing to foster diplomatic solutions is crucial for ensuring a stable and cooperative international environment for offshore drilling technology development. The future of offshore drilling technologies holds promise for sustainable energy solutions, yet is accompanied by multifaceted challenges. A holistic and collaborative approach is indispensable, urging the scientific community, industry stakeholders, and policymakers to unite in steering offshore drilling towards a future of innovation, responsibility, and global cooperation.

Ongoing research and development in offshore drilling technologies are driving advancements in digitalization, safety, and environmental sustainability. These efforts are aimed at improving operational efficiency, minimizing environmental impact, and ensuring the safety of offshore drilling activities. However, challenges such as effective project management, resource optimization, and workforce considerations need to be carefully addressed to ensure the long-term viability and sustainability of offshore drilling operations.

5. Recommendation

The comprehensive review of advancements in offshore drilling technologies in the USA has revealed a transformative landscape characterized by cutting-edge innovations, sustainability efforts, and a commitment to environmental responsibility. Over the past decade, the USA has emerged as a trailblazer, influencing global industry standards and shaping the future of offshore drilling. Key findings include the evolution of advanced drilling rigs, the integration of smart sensors and real-time analytics, and the establishment of stringent regulatory frameworks to ensure safety and environmental stewardship.

The impact of USA's advancements in offshore drilling technologies extends far beyond its borders, influencing international energy markets, fostering geopolitical collaborations, and setting benchmarks for responsible industry practices. By prioritizing safety, sustainability, and technological innovation, the USA has positioned itself as a catalyst for positive change in the global energy landscape. The reviewed advancements have not only expanded the capabilities of offshore drilling but have also significantly reduced environmental risks, making a lasting and positive impact on a global scale. As we reflect on the achievements and advancements highlighted in this review, it becomes evident that sustained collaboration and innovation are paramount for the continued positive impact of offshore drilling technologies. The call to action is clear: industry stakeholders, governments, and research institutions must engage in ongoing collaboration to address emerging challenges and drive further innovation. This entails fostering international partnerships, sharing knowledge, and leveraging collective expertise to develop cleaner, more efficient, and sustainable offshore drilling solutions. To achieve these goals, it is imperative that nations and industry leaders prioritize research and development, invest in education and training, and commit to the responsible deployment of cutting-edge technologies. By working together, we can overcome challenges, navigate geopolitical dynamics, and collectively advance offshore drilling practices that align with environmental conservation and global energy needs.

6. Conclusion

In conclusion, the advancements in offshore drilling technologies in the USA are not merely technological achievements but represent a shared responsibility to safeguard our planet's future. The journey towards sustainable offshore drilling requires unwavering commitment, collaboration, and continuous innovation – a collective effort that will undoubtedly shape a positive global impact for generations to come.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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