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Evaluation of the Effectiveness of Using Buckle Arrestors to Prevent Subsea Pipeline Propagation Buckling in West Africa Fields

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Abstract

Propagation buckling, a phenomenon brought about by external pressures, temperature fluctuations, and operational loads, frequently compromises the structural integrity of subsea pipelines. This research evaluates the effectiveness of buckle arrestors in preventing propagation buckling in subsea pipelines, particularly in the oil and gas fields of West Africa. A structured questionnaire survey was given to subject matter and industry experts as part of the study, which combined qualitative and quantitative research methods. A thorough literature search and survey responses brought to light important variables leading to propagation buckling in subsea pipelines in the West Africa region, including high temperature and external pressure. Among other mitigation strategies, buckle arrestors were shown to be very successful. The most prominent designs were clamp-on and integral collar designs because of their versatility and dependability in a range of subsea conditions. Key findings highlight the importance of material selection, design optimization, and the use of real-time monitoring systems to improve buckle arrestor performance. Economic concerns, such as high costs and installation challenges, were cited as impediments to widespread adoption in the region. The study recommends the use of advanced technologies such as smart sensors for the early detection of propagation buckling and autonomous subsea robotics for the installation of buckle arrestors to overcome these barriers in the West Africa oil and gas fields. This thesis will help advance our understanding of propagation buckling and make practical recommendations for enhancing subsea pipeline integrity in West Africa. The findings also propose future study areas, including cost-benefit assessments, computational modeling of propagation buckling in subsea pipelines, and various parameters that could help prevent failures in the West Africa oil and gas fields.

Keywords: Subsea Pipelines, Buckle Arrestor, Pipeline Integrity, West Africa, Subsea Engineering.

Introduction

Subsea pipelines are essential units as an energy transportation method nowadays. Pipelines are designed to carry a fluid from one point to another. As a transportation method, underwater pipelines are widely used in the oil and gas industry today rather than tank options. Using a vessel to carry oil or gas is preferred due to flexibility and low capital costs, despite high operational costs. However, the pipeline option has relatively small operation and maintenance expenses, besides less energy consumption compared to liquefaction and re-gasification [1].

Pipelines are normally subjected to external pressure and bending due to factors such as soil movement, changes in temperature, pressure, or external forces from installation/construction activities. Shallow soils typically bury subsea pipelines to prevent environmental harm from issues like water scouring, repair, and attacks by sea life [2]. One of the difficulties subsea production systems faces is the transportation of crude oil. A number of significant problems arise, especially when it comes to subsea pipelines that need to be inspected to guarantee flow assurance [3]. Moving oil and gas production over deep water presents considerable problems, according to a pilot study for a deep pipeline project released. High building and operational expenses are the outcome of this challenge. An issue is that vulnerable hydrocarbons are exposed to high temperatures and pressures under the deep sea. In order to operate the oil and gas transportation safely, pipelines eventually face challenges. During hydraulic pressure tests and installation procedures, pipelines on the seabed may obtain residual lay tension. The operational process entails high temperature and pressure (HT/HP) conditions in order to ensure the flow of crude oil and gas. Thermal stress by high temperature and internal pressure of pipeline cause longitudinal expansion [4]. For seamless steel or welded pipes, the influence on this limit surface of manufacturing imperfections has been thoroughly studied using finite element models that have been validated via laboratory full-scale tests [5-8].

Deep and ultra-deep-water pipelines are vulnerable to propagation buckling due to the high external pressures. The pipeline may collapse due to the local dents, imperfections, and ovalizations in the pipe-wall. This collapse will change the cross-section of the pipeline from a circular shape into a dog-bone or even flat shape. The buckle may then propagate along the pipeline and cause the pipeline to be shut down [9]. The purpose of this study is to evaluate the effectiveness of buckle arrestors to prevent propagation buckling in subsea pipelines in the oil and gas fields of West Africa.

Materials and Methods

This study focused on evaluating the effectiveness of using buckle arrestors to prevent subsea pipeline propagation buckling in the West Africa oil and gas fields. A survey with 23 questions was prepared and circulated for this study.

The survey questions were mostly closed-ended, and few were open-ended, allowing participants to choose the most appropriate response from predetermined categories based on their experience. The distribution of the survey took place from September 2024 to December 2024. Two organizations (Tullow oil & TechnipFmc) within the West Africa offshore oil and gas industry were assessed in this multiple case study. At upstream stages of its operational activities, the petroleum industry is a tremendously diverse sector with a large number of organizations and participants.

This research lacks the necessary resources (money, time, staff, and tools) to conduct a thorough examination to evaluate the effectiveness of using buckle arrestors to prevent propagation buckling in subsea pipelines within the West Africa fields. This report had to use a case study approach to address its research questions, concentrating on the subsea pipeline sectors of the industry because there were not many resources available for this kind of research, and it was necessary to be brief and concentrate on the research intersection (research questions). The researcher recognized these case-study organizations as leaders in subsea, offshore & onshore, and surface projects in order to obtain the proper responses and explanations to the problems that the research aims to answer. Data collected by the survey were analyzed and represented through pie charts, bar graphs, and tables, enabling clear visualization of the findings and ensuring data-driven conclusions based on the study's aim and research questions.

Mitigation measures for Subsea Pipeline Buckling

Subsea pipeline buckling mitigation strategies use a variety of techniques to protect the pipes' integrity and stability. In order to resist external pressure and avoid buckling, these precautions include the application of sophisticated pipeline design techniques, such as pipe diameter, wall thickness, and material property optimization. Furthermore, lateral movement and the chance of buckling are lessened by erecting pipeline supports along the pipeline's path, such as concrete mattresses, sleepers, or anchors.

The early detection of potential buckling through continuous monitoring with technologies such as strain gauges and acoustic sensors allows for prompt intervention through modifications to operational parameters or even active measures like injecting buoyant materials or applying controlled internal pressure to counteract external forces and maintain pipeline stability.

Results and Discussion

What Factors Influence Propagation Buckling the Most?

Participants were asked to identify the factors that influence propagation buckling in subsea pipelines in the West Africa fields. The question contained a list of answers regarding the following variables that affect propagation buckling in subsea pipelines: high temperature, seabed conditions, external pressure, and installation methods. The reply to this question indicates that the majority of participants chose both external pressure and high temperature as the primary causes of propagation buckling in subsea pipelines, with 15 (83.3%) choosing external pressure and 11 (61.1□) choosing high temperature.No, participants identified installation methods and seabed conditions as the primary factors contributing to propagation buckling in subsea pipelines (see Figure 1)

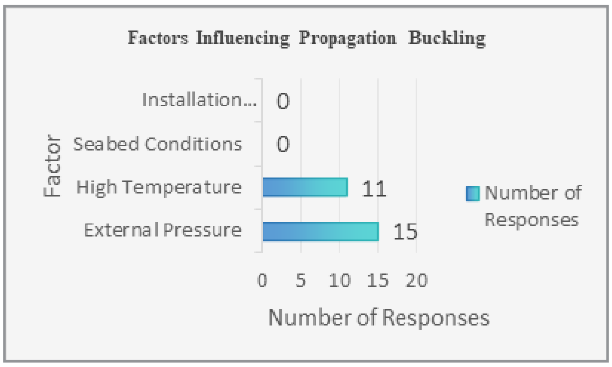

Figure 1: Factors Influencing Propagation Buckling the Most

What mitigation strategies do you consider most effective in preventing propagation buckling in subsea pipelines?
The question requested participants to choose the best mitigation strategies to prevent propagation buckling of subsea pipelines in the West Africa fields. The question featured multiple choice answers, and the participant was requested to select all that applied, such as pipeline design optimization, material selection, protective coatings, installation techniques, regular monitoring and maintenance, and buckle arrestors.

According to the results, the majority of participants identified more than one mitigation strategy that they feel will prevent propagation buckling in subsea pipelines. There were 13 (72.2%) responses for pipeline design optimization, no responses for material selection, 2 (11.1%) for protective coatings, no responses for installation techniques, no responses for regular monitoring and maintenance, and 16 responses (88.9%) on buckle arrestors (see Figure 2).

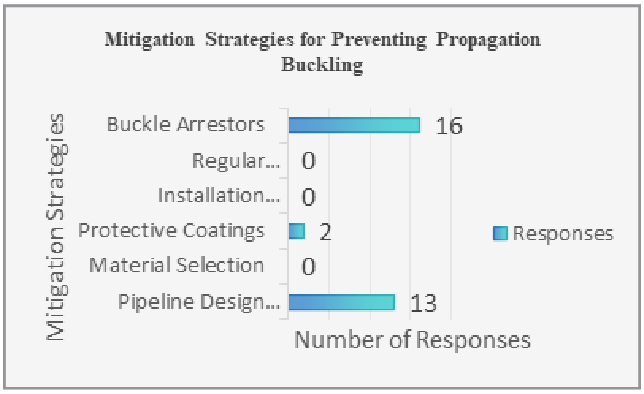

Figure 2: Mitigation strategies in preventing propagation buckling in subsea pipelines.

What type(s) of buckle arrestors have been used in the subsea oil and gas field you are familiar with?
The question asked participants to choose the type of buckle arrestors in the subsea oil and gas field they are familiar with. The question featured multiple choice answers, and the participants were requested to select all that applied, such as Slip-on arrestor, Integral arrestor, Spiral arrestor and Clamped arrestor.

According to the result, the majority of participants identified they are familiar with more than one buckle arrestor type that has been used in the West Africa fields. There were 12 (66.7%) responses for integral arrestors, 9 (50%) for clamped arrestors, and no responses for slip-on arrestors or spiral arrestors. However, 1 person (5.6%) indicated that they are familiar with thick wall pipe joint arrestors. Another person answered that they were familiar with concrete mattresses, which received 1 (5.6%) response (see Figure 3)

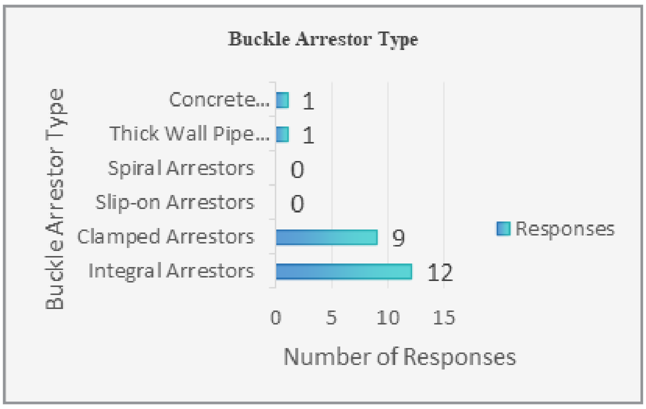

Figure 3: Participants Familiarity with Buckle Arrestor Type(s)

What economic factors affect the decision to utilize buckle arrestor in the West African oil and gas fields?
The question asked participants to identify the factors that affect the decision to utilize buckle arrestors in the West Africa oil and gas fields. Initial capital expenditure, Cost-Benefit Analysis and Return on Investment (ROI), Maintenance Costs and Operational Efficiency, Financial Constraints and Budgetary Limitations were among the multiple-choice answers on the topic. Participants were asked to select all that applicable. Initial capital expenditure received 8 (44.4%) response, Cost-Benefit Analysis and Return on Investment (ROI) had 10 (55.6%) responses, these financial algorithms are used to assess if installing buckle arrestors in subsea pipelines is feasible and profitable, particularly in challenging areas like the West Africa oil and gas fields.

Stakeholders can use these approaches to assess whether utilizing buckle arrestor is more advantageous than it is expensive. Maintenance Costs and Operational Efficiency had no response and Financial Constraints and Budgetary Limitations also had 8 (44.4%) responses (see Figure 4).

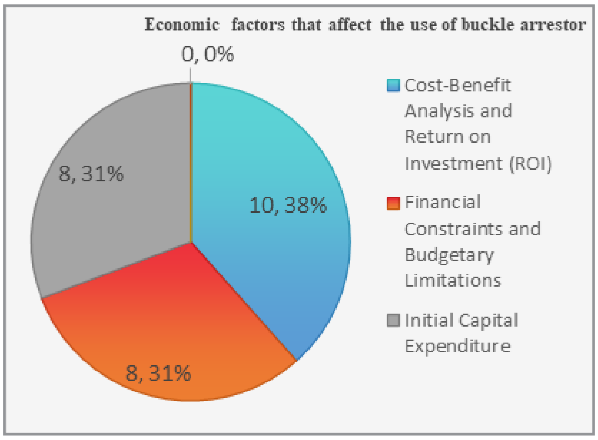

Figure 4: Economic factors that affect the utilization of buckle arrestors in the West Africa oil and gas fields.

What are the core challenges related to the use of buckle arrestors in the oil and gas fields in West Africa?

This question was given to allow participants to identify the challenges associated with the usage of buckle arrestors in West African oil and gas fields. The question featured multiple-choice options, and participants were instructed to select all that were applicable. The question included multiple-choice answers such as high cost, installation difficulty, logistics & supply chain issues, and compatibility with existing infrastructure. High cost received 16 (88.9%) responses, Installation difficulty received 1 (5.6%) response, Logistics & Supply Chain Issues received 2 (11.1%) responses, and Compatibility with Existing Infrastructure received 3 (16.7%) responses from the participants (see Figure 5)

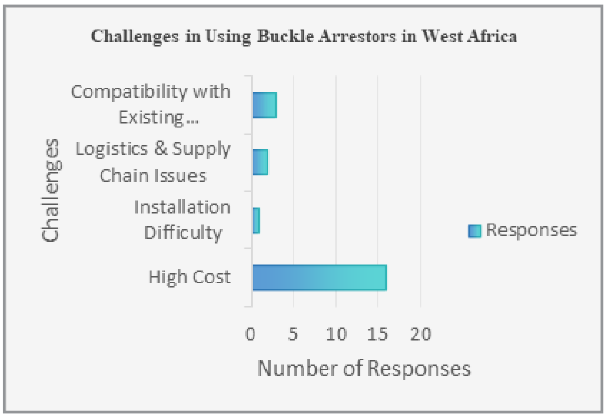

Figure 5: Challenges In Using Buckle Arrestors In West Africa Oil and Gas Fields.

In the subsea pipeline project you have worked on, how often have buckle arrestors been installed or used?

Participants were asked how frequently buckle arrestors were utilized or installed in the subsea pipeline projects they have worked on. Frequently in Deep-Water Projects, Occasionally, When Required by Regulations or Contracts, Rarely, Due to Budget Constraints, and Regularly for Projects in Harsh Environments were among the multiple-choice answers on the topic. Participants were asked to select all that applicable. Frequently in Deep-Water Projects received no response, Rarely, Due to Budget Constraints had 11 (61.1%) responses, Occasionally, When Required by Regulations or Contracts received 6 (33.3%) responses, and Regularly for Projects in Harsh Environments received just 1 (5.6%) (see Figure 6).

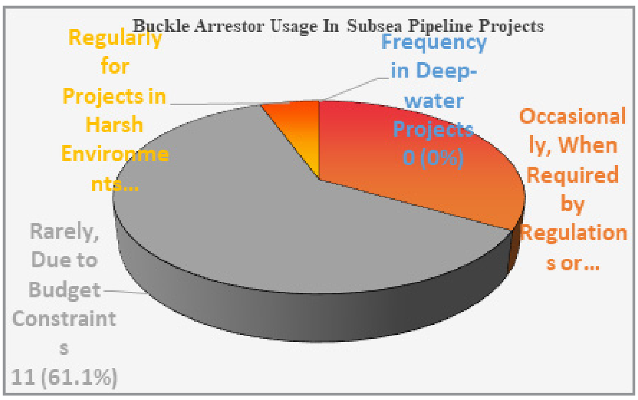

Figure 6: Usage Of Buckle Arrestor In Subsea Pipeline Projects.

What type(s) of buckle arrestors do you recommend for future installations in the West Africa subsea pipeline projects? This topic was posed to elicit participants' opinions on the appropriate types of buckle arrestors for future subsea pipeline installations in West Africa. The issue seeks to determine the most effective and frequently recommended buckling arrestor types for maintaining pipeline integrity. The question had multiple choice answers, and participants were instructed to select all that were relevant. The multiple-choice answers to the question were Clamp-On Buckle Arrestors, Integral Buckle Arrestors, Reinforced Concrete Coated Buckle Arrestors, and Segmented Buckle Arrestors. According to the data obtained from participants, Clamp-On Buckle Arrestors received 10 (55.6%) responses, Integral Buckle Arrestors 13 (72.2%) responses, Reinforced Concrete-Coated Buckle Arrestors had no response, Segmented Buckle Arrestors also got no response. However, one participant commented that thick wall pipe joints arrestors can also be recommended for future installations in the West Africa subsea pipeline projects (see Figure 7).

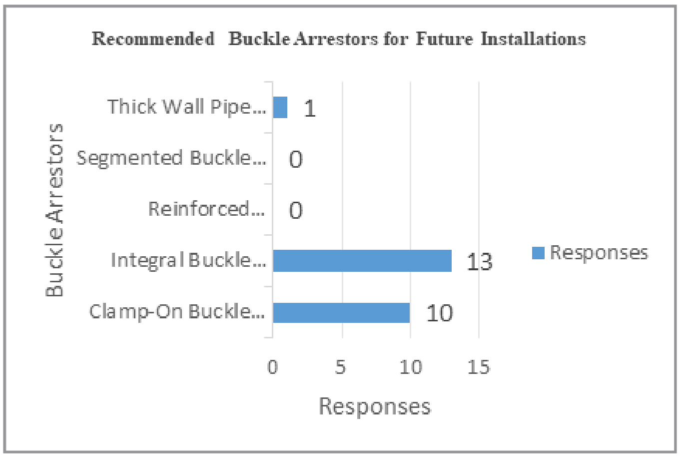

Figure 7: Recommended buckle arrestor types

Recommendation

Working with industry stakeholders to develop more efficient and cost-effective buckling arrestor solutions is encouraged. These collaborative efforts can result in novel solutions customized to the specific problems of West African subsea fields, thereby lowering total operational costs.Trenching and carefully positioning buoyancy modules at key pipeline locations are two ways to overcome financial limitations in subsea projects.By offering additional support, these actions can lessen the need for and expense of putting buckle arrestors in particular locations. Make investments in materials with improved durability that can tolerate high external pressures and frequent temperature cycling.

Conclusion

The study emphasizes choosing buckle arrestors that can withstand high pressures, temperatures, and corrosion while remaining cost-effective. Recommendations highlights the use of integral and clamp buckle arrestors and autonomous robotics for installation of buckle arrestors and sustainability in subsea pipeline operations. Overall, the focus is on improving buckle arrestor technology to optimize performance and long-term reliability.

References

1. Andrew, C. P., Martin, J. H. (1975). Buckle propagation in submarine pipelines. Nature, 254, 46-48.
2. Ji-Hui, N., Si-Wei, L., Jian-Hong, W., Wei, H. (2021). Line-element formulation for upheaval buckling analysis of buried subsea pipelines due to thermal expansion, 17(2), 210-220.
3. Oyeneyin, B. M. (2011). Challenges of deepwater developments. Advanced Materials Research, 367, 367-373.
4. DNV. (2007). Recommended practice DNV-RP-F110: Global buckling of submarine pipelines—Structural design due to high temperature/high pressure. Det Norske Veritas. https://shaghool.ir/Files/GLOBAL-BUCKLING-OF-SUBMARINE-PIPELINE-RP-F110.pdf
5. Toscano, R. G., Gonzalez, M., Dvorkin, E. N. (2003). Validation of a finite element model that simulates the behavior of steel pipes under external pressure. The Journal of Pipeline Integrity, 2, 74-78.
6. Toscano, R. G., Gonzalez, M., Dvorkin, E. N. (2003). Experimental validation of a finite element model that simulates the collapse and post-collapse behavior of steel pipes. In K.-J. Bathe (Ed.), Proceedings of the Second MIT Conference on Computational Fluid and Solid Mechanics (pp. 74-78). Elsevier.
7. Toscano, R. G., Timms, C., Dvorkin, E. N., DeGeer, D. (2003). Determination of the collapse and propagation pressure of ultra-deepwater pipelines. In Proceedings of the International Conference on Offshore Mechanics and Arctic Engineering (OMAE), Cancun, Mexico.
8. Toscano, R. G., Mantovano, L., Dvorkin, E. N. (2004). On the numerical calculation of collapse and collapse propagation pressure of steel deep-water pipelines under external pressure and bending: Experimental verification of the finite element results. In Proceedings of the 4th International Conference on Pipeline Technology (pp. 1417-1428), Ostend, Belgium.
9. Hassan, K., & Mahmoud, A. (2020). Propagation buckling of subsea pipelines in subsea pipe-in-pipe systems. In IntechOpen. https://www.intechopen.com/chapters/66767

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