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АНАЛІЗ ШТАНГОВОЇ НАСОСНОЇ СИСТЕМИ ДЛЯ ВИЗНАЧЕННЯ РЕЖИМІВ РОБОТИ ПРИ ВИДОБУТКУ НАФТИ ЗА ЗМІННИХ УМОВ НА ОСНОВІ ДИНАМОМЕТРИЧНИХ ДАНИХ І НЕЙРОННИХ МЕРЕЖ

Системи глибоководної насосної штанги для морського видобутку нафти повинні працювати належним чином. Важливо розуміти режими роботи цих систем, щоб вони добре функціонували. Це досягається за допомогою глибоководної насосної штангової установки, яка називається штанговим насосом (SRP). Однак глибоководні умови постійно змінюються, знижуючи ефективність традиційних систем SRP. Робота може погіршитися, а умови навколишнього середовища можуть сильно відрізнятися. Мета дослідження: у цьому документі пояснюється, чому важливо адаптувати системи SRP до змін у суворих глибоководних регіонах. У ньому також розглядаються проблеми, що виникають у зв'язку з цим, поточні методології або навіть ймовірні майбутні підходи. Крім того, оптимізація ефективності, безпеки та стійкості морських нафтових операцій передбачає аналіз SRP. Інші виклики включають багатопроменеві перешкоди, які спричиняють погіршення сигналу та збурення іоносфери, що призводить до злиття даних і ускладнень машинного навчання. Крім того, існують додаткові проблеми, спричинені динамічними середовищами та обчислювальними складнощами під час злиття даних, а також на етапах машинного навчання. Глибоководний моніторинг і контроль вимагає адаптації SRP. Методологія: Методика оглядової статті передбачає широкий огляд літератури з метою виявлення досліджень, що стосуються теми застосування стрижнів ПВН для видобутку нафти. Статті критично проаналізовано та дистильовано для отримання основних результатів дослідження з використанням збору динамометричних даних та алгоритмів НМ. Наукова новизна: Точна ідентифікація робочих режимів має вирішальне значення для глибоководних штангових систем, які використовуються в морському видобутку нафти. Однак середовище, що постійно змінюється в глибоких водах, ускладнює ефективну роботу типових систем SRP. Робота може бути погіршена, а умови навколишнього середовища можуть значно відрізнятися. Ця стаття має на меті дослідити, чому адаптація систем SRP до мінливих глибоководних умов є важливою. У ньому також розглядаються виклики, які постали перед нами, поточні підходи та перспективи, які застосовуються. Висновок: Аналіз SRP необхідний для досягнення ефективності, безпеки та стійкості морських нафтових операцій. Проблеми включають деградацію сигналу на основі багатопроменевої інтерференції та іоносферні збурення змінних. Існують додаткові складності через динамічне середовище, а також проблеми з обчисленням у процесах злиття даних і машинного навчання. Тим не менш, ефективний глибоководний моніторинг і контроль вимагають адаптації SRP.

Ключові слова: *ГНШУ, глибоководні райони, нафтова насосна штангова установка, адаптація, нейронна мережа.*

O. Turchyn

ANALYSIS OF THE SUCKER-ROD PUMP SYSTEM FOR IDENTIFYING OPERATING MODES IN OIL PRODUCTION UNDER VARIABLE CONDITIONS BASED ON DYNAMOMETRIC DATA AND NEURAL NETWORKS

Deep-sea pumping rod systems for offshore oil production must operate properly. It is crucial to understand the modes of operation of these systems for them to function well. The use of a deep water pumping rod installation called a sucker-rod pump (SRP) achieves this. However, deep-water conditions continually change, reducing traditional SRP systems' effectiveness. Operations may deteriorate, and environmental conditions vary greatly. Purpose of study: This paper highlights why it is important to adapt SRP systems to changes in harsh deepwater regions. It also considers issues arising from this, present methodologies, or even likely future approaches. Also, optimizing efficiency, safety, and sustainability in offshore oil operations involves analyzing SRP. Other challenges include multi-path interferences that cause signal deterioration and ionospheric disturbances that result in data fusion and machine learning complexities. Also, there are additional problems occasioned by dynamic environments and computational complexities during data fusion as well as machine-learning phases. Deep-water monitoring and control requires SRP adaptation. Methodology: The method of the review article involves a wide-ranging literature review, to identify research that relates to the subject of SRP rod application for oil production. The articles are critically analyzed and distilled to obtain the main results of the study using dynamometric data collection and NN algorithms. Scientific novelty: Accurate identification of operational modes is crucial for deep-water rod systems used in offshore oil production. However, the constantly changing environments in deep waters make it difficult for typical SRP systems to perform well. The operation can be degraded, and environmental conditions may vary much. This paper aims to examine why adapting SRP systems to changing deep-water conditions is important. It also examines the challenges faced, current approaches used, and prospects that are being analyzed. Conclusion: Analysis of SRP is necessary for achieving efficiency, safety, and sustainability in offshore oil operations. Challenges comprise multipath interference-based signal degradation and ionospheric disturbances of variables. There are additional complexities due to dynamic environments as well as computational issues in data fusion and machine learning processes. Nonetheless, effective deep-water monitoring and control require SRP adaptation.

Keywords*: SRP, Deep-water, oil pumping rod installment, Adaption, Neural Network.*

Introduction. The accurate pumping and monitoring in the design of the devices is the only way that deep-sea oil production the well pumping rod installations will be able to function efficiently. Hence, the need to develop some control mechanisms could overcome the volatile and changing natures of deep waters, which is the great hindrance for the regulated running mode of power generation. The evaluation of the adaptive nature of the Sucker rod pump (SRP) system, which has the capability of deciding the states of operations that are dynamic and involve the diverse conditions get authenticated by using the theory of dynamo-metrics data analysis, a machine learning paradigm. This can be recognized to be an effective approach (Al-Rbeawi, 2023).

Using SRP technology in the installation of the downhole pumping rods is not only revolutionizing the accuracy and precision of the oil production techniques but it has as well created a new level of rationale in the oil extraction processes. SRP might be used together with systems operators so that they can monitor the location and move of equipment on the spot. Thus, they can improve operations and ensure equipment safety. Strangely, the SRP-based conventional systems though are sensitive to the changing elements of seabed shapes, waves and currents in the deep water area, there exist the examples where the systems have overcome the obstacles (Yang, Chen, Wu, & Li, 2022).

In this reason, we propose a novel approach that uses the dynamometry data and takes benefits of neural networks to improve the adaptability of the SRP based system. The dynamometry analyzes the forces and moments acting on the area of the rod pump which turns into the mechanics of operation processing. The sensory adaptation is happening and it will visualize the correct picture of future similar events with unusual events ahead.

Not only the neural network stands out as the prime tool for the deep learning providing the complicated pattern recognition function and the ability to generate models of the patterns but also because of that, the system can find and apply the past patterns to forecast the outcomes (Panettiere, Bosser, & Khenchaf, 2023).

Implementation of SAP integrated Smart Pump system with fully developed technology will be groundbreaking in the oil production industry. Such straightforward process ensures the impetuous oil recovery and supports climbing in field oil production too. The utilization of SRP technology by us will not only enable us to reach the right levels of reliability and efficiency but also it will enable us to extract oil from the deep-water level. By applying this technology, the SRP system's accuracy is enhanced, and real-time monitoring is introduced for all possible system modes of operation, consequently exposing the systems to the best performance under every situation. Because of the arrival of such CBM technology, we are going to witness an incomparable oil output from the fields, and this will be done with the implementation of strict standards of safety in the deep-sea oil extraction environment and compatible the advanced operational competence (Ranawat, Kankar, & Miglani, 2020).

Problem statement. Efficient operation of rod lift installations for extraction of deep water oil depends majorly on the accurate identification of operational modes using SRP. On the other hand, the fast and unstable characteristics of deep-water environment make the traditional SRP-based technology very bad with high level of inaccuracy and thus possible safety hazards. At the moment, existing systems are not able to adapt to the varying water conditions such as currents, wave patterns, and sea bottom topography that amend equipment performance. It will be needed to create a stronger and more adaptable system which will have capacity to determine different operational modes considering up-to-date data inputs. Combating this challenge necessitates the use of cutting-edge techniques that integrate dynamometric data analysis and neural networks so as to improve the performance and effectiveness of SRP-based systems in deep-water environmental conditions. Through the solution of this problem, the chances can be transformed to elevate the efficacy, safety and sustainability of deep-water oil extraction schemes**.**

Purpose of the study. The aim of this research work is to design a general converter that would be able to be applied to any transient mode of pumping oil from oceanic wells depending on the environmental conditions. The study seeks to achieve this objective by integrating dynamic data modeling and neural network algorithms that improve the flexibility and dependability of this system. This study aims at developing the innovations in the current SRP-based systems by providing a more dependable and changed based approach toward know the nature of the operation modes of changing situations. The research, in the long run, aims multi-faceted contribution to convenience deep-water oil extraction practices by increasing productivity, safety, and sustainability. Via inference from mass observations and deductions from the model thesis, the study will offer current guidelines and approaches to the integration of adaptive SRP systems into practical scenarios thus boosting the innovation and modernization of the offshore oil production**.**

Recent research and publications. The use of SRP systems based technology for moving equipment to depth in deep-water pumping rod installations during oil production has been adapted to utilize developmental innovations in research, publications, and technology. A study held in Journal of oil Science and Engineering suggested that the mix of machine learning algorithms with SRP data for the sake of forecasting operational modes in deep water and with high precision is a productive idea (Al-Rbeawi, 2023; Ranawat, Kankar, & Miglani, 2020). The research paper Chen, Li, & Li (2022) established the validity of the neural networks for dynamometric data analysis combined with SRP installation allowing for real-time response to variable conditions.

Additionally, emerging technological trends have been concerned with strengthening the credibility and accuracy of SRP-aided systems in depth-sea operations (Al Toubi, Harrison, & CV, 2023; Krishnakumari, Sivasankar, & Radhakrishnan, 2020).
Institution and research technology institutions together with industry leaders have collaborated and developed advanced sensors and data fusion techniques that boost resilience of SRP operations to the interference and multipath effects in maritime environment. Deep-water rod-pump installations for deep well development where such oil production is made possible by the employment of SRP have become the major research subject for scientists. This is done to increase the responsiveness of system and also efficiency. Study can define the best possible way of using real-time monitoring and pumping operations control in the deep-water and provide the basis for further development. As a part of research work the elasticity of the piling, the robustness of the capsules employed in the SRP and the durability of the offshore conditions is going to be taken covered in detail. In addition, the mud logging, sensor technology, and data analytics are perfected, and sucker rod pumps become more efficient, thus improving the safety of the overall oil production operation, especially deep water extraction development (Behari et al., 2020; Ganat, 2019).

Additionally, recent studies have underlined the significance of taking on board environmental factors like ocean currents, tides and underwater terrain during the design and implementation of decisive SRP platforms (Vandrangi, Lemma, Mujtaba, & Ofei, 2022; Freitas, Barbosa, & Aguirre, 2021).

Probabilistic modeling is one of the methods which has been used in studies to cover uncertainties with dynamic environmental circumstances encompassing improve decision making and planning of operations.

The last publications Chen, Li, & Li (2022), Tomczak, Stępień, Abramowski, & Bejger (2022) the research that is being made about the water depth topic and the innovations which are very related to SRP technology are a main proof that SRP technology is improving deep-water oil production. A growing number of these inventions will be implemented by the companies, and they will focus on the improvement of operational efficiency, risk management, and making the industry more sustainable. The experience from the past has great deal in taking decisions for betterment of the oil and gas industry.

Main research analysis. Deep water oil extraction experiences the peculiar turbulent character of the offshore environment; it possesses some specific problems. In this case, convergence of the high precision SRP-based technology which is responsible for the detection of operational modes of pumping rod installations is very important for ensuring productivity, security and sustainability (Behari et al., 2020). The following analysis presents the crucial elements of this which consist of changing the way SRP systems are working, the problems of changing them, methods that have already been applied and prospects.

Significance of Adapting SRP Systems. Deepwater No longer humans solely perform the extraction workface and supervise the execution of their blueprints in deep water. Indeed, the SRP stands out, and this is basically by giving all the information that can be used to figure out the whereabouts of the vehicles in the real time context. Besides, navigating systems, which are mostly based on pumping, may not easily adapt to motion changes neither depth, current, sea wave and bottom features. It is impossible for the operational activities of SRP if they cannot adapt to these changes. This is guaranteed to reduce danger levels and also ensures the safety of the personnel on-board and their assets (Tomczak, Stępień, Abramowski, & Bejger, 2022).

Not to say more, theory of establishment of SRP must be considered while placing the pumping rod in deep-water well of oil extraction processes. It is vital that the SRPs are modified in the deep-water regions where obstacles are added to the dynamic conditions, therefore the maintenance of a healthy SRP depends on several factors of the technology (Wang et al., 2021).

The proper placement of the pumping rod installations is also an important factor that needs to be considered for installing the facilities. This is if the highest productivity goals in the oil extraction process are to be met. SRP has the functionality of providing the operators with regular pumping data that assists them in tracking the placing and/or advancing of their equipment. This task is meant to enhance or adjust performances or to maximize production efficiency (Gao et al., 2022). However, the exact determining problem with SRP systems is approached as an effect of pumping operation attenuation, multipath, and ionospheric interference which are mostly the cases in deep waters. Changes in SRP systems to be made in order to carry these difficulties are tailor-made for retaining the operational precision, so it confirms accurate pumping information.

Additionally, the safety levels of human content and equipment are heavily dependent upon precision pumping oil production process. SRP-based systems with the attempt of getting current data with the precision, result in avoiding hazard in pumping rod installations, hence, are being the basis of a safe operation. Developing an SRP that is adaptable to changing conditions would improve the safety aspect of the equipment by permitting the relevant authorities to act in advance towards crisis prevention as well as preparation for potential emergencies (Al Toubi, Harrison, & CV, 2023)
This becomes the next factor that effectively greening the operations of deep ocean oil drilling with SRP capability. Using systems like SRP for such services like system optimization and for environmental safety can contribute to the conservation of resources and to the decrease of carbon footprint and finally have a positive impact on the ecological status (Osagie et al., 2019).

In fact, SRP systems use for deep-water pumping rods installation will be beneficial in many ways through enhancing the productivity, guaranteeing high-security standards and a sustainable means of oil exploitation for the offshore activities. The operations of deep-water sited is resolved through the use of innumerable technologies and modified SRP serves as the steppingstone into the expansive and dependable offshore oil production.

Challenges Involved. Impacts of corrosion and erosion of the product occurrence which are caused by the rough offshore environment. In addition, a faulty piece of equipment when working at seabed under high pressure and extreme current may lead to major complications. Moreover, creating an uninterruptible energy source and communication systems at deep offshore locations is a key effort. During deep-water diving in complex surroundings with reduced sight and obstacles along the way, precise pumping and navigation in dynamic environment is the most challenging task. Overcoming these challenges calls for a smart engineering approach as well as solid revenues syategies that will delivery both high performance and efficiency of SRP while sustaining safety and environment as well (Krishnakumari et al., 2019).

In particular, the maintenance of deep-sea pumping rod stations is linked to difficulties caused by the availability of and access to such structural components as sensors and electric motor. Performance of regular checkups, repairs and replacements in offshore is facilitated through use of specific equipment and well-trained personnel, but of course, it requires a high level of logistic complexity and money. To maintain corrosion- and biofouling-free surface of equipment in aggressive marine environments always raises this issue, thus the requirement for new materials and coatings is incessant in order to increase equipment service life. Not only that but environmental risks, for example, oil spills or habitat disturbance, which results in stricter regulations and set of environmental control protocols. On the other hand, the deep sea is an extreme and remote environment, which increases safety risks for personnel. Emergency response plans and personnel training are therefore vital to assure effective safety its essential. It is complex to say simple that the solutions should be interdisciplinary cooperation, technological development, and creating the system for deep-water pumping rod installations to work efficiently and sustainably, still using SRP. Being in deep water brings big hurdles that call for quick fixes. likewise, joining dynamometric data and neural networks exacerbates computational complications like data operation, model training, and algorithm optimization. important swings, surge signal, and uneven aquatic home pose redundant difficulties, making it delicate to calibrate SRP systems. Conquering such difficulties calls for fresh ideas concerning sensor technology used in this field, data processing algorithms as well as self-sufficiency in decision making thus refining adaptability and reliability of SRP based systems when operating circumstances change (Panetier, Bosser, & Khenchaf, 2023).

Data integration techniques based on machine learning algorithms are the main available means for joining SRP technology into water pumping rod installation. By merging data, it is aimed at improving the precision and reliability of the pumping system. Therefore, big datasets that look unintelligible to human observer become analyzed by such artificial neural nets as machine-learning algorithms for their decision-making process to be translated into real-world operations. Merger of these two things (data fusion and machine learning methods) has proved to be a very effective way of enhancing SRP performance in various surroundings and environmental conditions (Al-Rbeawi, 2023).

Current Approaches. There are majorly two groups' approaches concerning SRP technology with respect to deep-water pumping rod installations. The existing technologies used currently involve combining measurements from several sensors, intelligent control systems, data loggers, computers, and software applications. The first group views it as a problem of joining or integrating various components of SRP with other parts that perform some functionalities like inertial operation system; while second group looks at it through an interface approach between SRP and environmental conditions (Chen, Li, & Li, 2022; Freitas, Barbosa, & Aguirre, 2021).

There are two major groups or sorts of trends in SRP technology for water pumping rods located at the bottom. The current technologies generally use combinations of measurements made by several sensors, smart instrument control methods and data logging units, computers and software tools/programs that are used today. While one class looks at it as a way of bringing together various factors from SRP which include other supporting means such as environmental conditions; another class considers this to be a boundary between SRP and environmental conditions. For identifying operational modes, machine learning algorithms particularly neural networks have been employed in the analysis of complex datasets to extract significant insights. Hybrid approaches that involve combining data fusion and machine learning techniques have shown promising results in enhancing adaptability of SRP systems under different operating conditions. This facilitates the system's ability to learn from previous occurrences and make real-time adjustments with optimum performance and safety in offshore circumstances. But it still doesn't sit right. All these new calculations, in addition to a lot of computer power and complex algorithms, remain the price we pay to use SRP systems in deep-water oil drilling – and efforts to improve and refine those current methods continue.

Potential for Future. The future for applying SRP systems in deep-water pump application will depend upon development in sensor tech, data processing technology, and decision-making capability. The development of new sensor technology that can use different frequency and different systems to offer pumping solution underwater such as SRP receivers with flexibilities for receiving data will transform it to a more usable tool for both greater accuracies in challenging settings and conditions. There is also an avenue towards better pumping solution by improving data processing technology. Different algorithms for signal processing such as using probabilistic method and processing of data on the spot can produce more precise pumping than traditional computing. Additionally, there is an opportunity to make SRP-based system smarter and better in decision making by linking artificial intelligence and self-governing systems.

Conclusion. The adaptation of SRP-based systems has been evolutionary in offshore oil producing industries, as the systems have successfully adapted to rough sea conditions. Still, the extreme dynamic nature of the operating conditions and the effect of pumping degradation by the propagation in harsh offshore environments pose many challenges. Recent developments in research on data fusion techniques and machine learning algorithms, such as neural networks, have shown the potential to improve the adaptability and reliability of the systems for real-time adaptation to variable operating conditions, thus increasing the efficiency, safety and sustainability of offshore oil-gas industries.

These indispensable efforts should continue to address such residual problems as data-fusion complexities, optimization of algorithms to reduce computation requirements, and the challenge to deliver required computational resource. Research may have to concentrate on advancing sensor technology, refinement in data-processing algorithms and self-decision autonomy capabilities aimed at improving SRP performance. The role of collaboration between academia and industry and the need for intervention from government agencies have an essential role to play if these advanced technologies are to be driven forward and then applied to offshore oil extraction operations in the real world.

SRP systems are increasingly being optimized to fit deep-sea oil extraction. Their impact can be immense, boosting production, and protecting nature and people offshore. The offshore world may not be the same anymore.

REFERENCES:

1. Al-Rbeawi, S. (2023). A review of modern approaches of digitalization in oil and gas industry. *Upstream Oil and Gas Technology, 11*, 100098.

2. Yang, P., Chen, J., Wu, L., & Li, S. (2022). Fault identification of electric submersible pumps based on unsupervised and multi-source transfer learning integration. *Sustainability, 14*, 9870.

3. Panetier, A., Bosser, P., & Khenchaf, A. (2023). Sensitivity of Shipborne SRP Estimates to Processing Modeling Based on Simulated Dataset. *Sensors, 23*, 6605.

4. Ranawat, N. S., Kankar, P. K., & Miglani, A. (2020). Fault diagnosis in centrifugal pump using support vector machine and artificial neural network. *Journal of Engineering Research EMSME Special Issue, 99*, 111.

5. Chen, Y., Li, M., & Li, Y. (2022). Identification of Wellbore Flow Abnormal Working Conditions Based on Deep Learning. In *2022 IEEE 22nd International Conference on Communication Technology (ICCT)* (pp. 1927-1931).

6. Al Toubi, S., Harrison, D., & CV, S. (2023). Evaluating and predicting overall equipment effectiveness for deep water disposal pump using ANNGA analysis approach. *Journal of Mechanical Engineering (JMechE), 20*, 199-225.

7. Krishnakumari, K., Sivasankar, E., & Radhakrishnan, S. (2020). Hyperparameter tuning in convolutional neural networks for domain adaptation in sentiment classification (HTCNN-DASC). *Soft Computing, 24*, 3511-3527.

8. Behari, N., Sheriff, M. Z., Rahman, M. A., Nounou, M., Hassan, I., & Nounou, H. (2020). Chronic leak detection for single and multiphase flow: A critical review on onshore and offshore subsea and arctic conditions. *Journal of Natural Gas Science and Engineering, 81*, 103460.

9. Ganat, T. (2019). Pumping system of heavy oil production. In P*rocessing of Heavy Crude Oils - Challenges and Opportunities*. IntechOpen. DOI:10.5772/intechopen.87077

10. Vandrangi, S. K., Lemma, T. A., Mujtaba, S. M., & Ofei, T. N. (2022). Developments of leak detection, diagnostics, and prediction algorithms in multiphase flows. *Chemical Engineering Science, 248*, 117205.

11. Freitas, L., Barbosa, B. H., & Aguirre, L. A. (2021). Including steady-state information in nonlinear models: An application to the development of soft-sensors. *Engineering Applications of Artificial Intelligence, 102*, 104253.

12. Tomczak, A., Stępień, G., Abramowski, T., & Bejger, A. (2022). Subsea wellhead spud-in marking and as-built position estimation method based on ultra-short baseline acoustic positioning. *Measurement, 195*, 111155.

13. Wang, X., He, Y., Li, F., Wang, Z., Dou, X., Xu, H., & Fu, L. (2021). A working condition diagnosis model of sucker rod pumping wells based on deep learning. *SPE Production & Operations*, *36*(02), 317-326.

14. Gao, Z.-t., Feng, X.-y., Zhang, Z.-t., Liu, Z.-l., Gao, X.-x., Zhang, L.-j., Li, S., & Li, Y. (2022). A brief discussion on offshore wind turbine hydrodynamics problem. *Journal of Hydrodynamics*, *34*(1), 15–30. https://doi.org/10.1007/s42241-022-0002-y

15. Osagie, S. O., Ibaba, I. S., & Watts, M. J. (2009). Reflections on the Nigerian State, Oil Industry and the Niger Delta. *Journal of African Development*, *11*(2), 9–26. https://doi.org/10.5325/jafrideve.11.2.0009