Theory and Practice of Science and Technology
2025, VOL. 6, NO. 6, 121-124
DOI: 10.47297/taposatWSP2633-456924.20250606

Research Status of Oil and Gas Pipeline Operation and Management: A Literature Review

Yufei Wang

Changchun University of Technology, Changchun, Jilin, 130012, China

ABSTRACT
As China's energy needs keep climbing, the oil and gas pipeline transport industry has been booming. The efficient and safe operation and management of these pipelines is vital for energy security. This paper reviews domestic and international research on oil and gas pipeline operation and management. It focuses on key technologies like sensor technology, data analysis, machine learning, and corrosion assessment and life prediction. It also discusses existing challenges and forecasts optimization strategies and development trends based on predictive maintenance and intelligent digitalization. The aim is to provide a reference for enhancing the operational efficiency and safety of pipeline management.

KEYWORDS
Oil and gas pipelines; Operation and management; Sensor technology; Data analysis; Machine learning; Corrosion assessment and life prediction; Subsea pipelines

1 Domestic and international research status of oil and gas pipeline operation and management

In recent years, China has made significant progress in oil and gas pipeline operation and management. For example, Gong et al. Proposed a pipeline monitoring system based on fiber optic sensors, which can monitor temperature and strain changes in real time and detect potential safety hazards. In addition, Zhou et al. developed a fully intelligent inspection system based on drone remote sensing and deep learning, greatly improving the efficiency and accuracy of pipeline inspection. In data analysis, Tu et al. optimized the operational efficiency of oil and gas pipelines using big data analysis, achieving significant economic and social benefits. Guo et al.analyzed the corrosion and perforation failure of a production well central tube in an oilfield through macro analysis, material analysis, etc., providing new technical ideas and methods for domestic oil and gas pipeline corrosion prevention.

Internationally, scholars and enterprises have conducted in-depth research on sensor technology, data analysis, machine learning, etc., and have extensively applied these technologies to pipeline leakage detection, fault diagnosis, and operational optimization. For example, Columbia Pipeline Company in the United States used the GE Predix platform and PV software to achieve real-time risk management. Abroad, important achievements have also been made in the research of non-contact pig passage indicators for subsea pipelines. For instance, Guo et al. developed a non-contact pig passage indicator based on ultrasonic principles, which can accurately determine the passage of pigs or internal detectors in subsea pipelines, providing a more efficient and accurate monitoring method for subsea pipeline cleaning operations.

Pipeline corrosion assessment and remaining life prediction have become a common research focus both domestically and internationally. Guo et al. comprehensively assessed corrosion conditions and predicted the remaining life of pipelines by analyzing pipeline conditions, corrosion media, corrosion products, and utilizing multiphase flow simulation (e.g., OLGA) and corrosion prediction software (e.g., ECE), thereby providing a scientific basis for pipeline maintenance and management.

2 Research status of key technologies for oil and gas pipeline operation and management

2.1 Sensor technology

By installing various sensors on pipelines to collect physical information such as temperature, pressure, strain, and vibration in real time, sensor technology provides data support for pipeline operation status monitoring. For instance, fiber optic sensors, with advantages like anti-electromagnetic interference, high precision, and distributed measurement, can continuously monitor temperature and strain along pipelines and detect abnormalities in a timely manner. Guo et al. developed an ultrasonic non-contact pig passage indicator for subsea pipelines. Using ultrasonic sensors to collect pipeline noise and vibration signals, it accurately determines the passage of pigs or internal detectors, offering a new example of sensor technology application in pipeline operation and management.

2.2 Data analysis technology

Data analysis technology extracts valuable information from large amounts of pipeline operation data through mining and analysis, enabling fault diagnosis, operational parameter optimization, and integrity management. Common methods include statistical analysis, pattern recognition, and data mining. Guo et al. in their study on internal corrosion assessment and remaining life prediction of a platform's natural gas pipeline, used OLGA software for multiphase flow simulation and analyzed parameters such as flow pattern, temperature, and pressure. This provided strong support for pipeline corrosion risk assessment and life prediction, demonstrating the in-depth application of data analysis technology in pipeline corrosion management.

2.3 Machine learning algorithms

Machine learning algorithms establish a mapping relationship between fault characteristics and fault types to monitor and predict pipeline operation status in real time. For example, neural network algorithms can be used for pipeline leakage detection and location, and support vector machine algorithms for fault diagnosis. Guo et al. employed ECE software to predict the corrosion rate of natural gas pipelines and estimate the remaining life. This approach likely involves machine learning algorithms, serving as a reference for their application in pipeline life prediction.

2.4 Corrosion assessment and life prediction technology

Corrosion assessment and life prediction technology evaluates the current corrosion status of pipelines and predicts their remaining life using models and software. Guo et al. analyzed the corrosion and perforation failure of a production well central tube in an oilfield through macro analysis, material analysis, water quality analysis, corrosion product analysis, and corrosion simulation experiments. They identified the causes of corrosion and proposed improvement measures. Guo et al. further used multiphase flow simulation and ECE software to predict the internal corrosion and remaining life of a platform's natural gas pipeline, providing a scientific basis for pipeline maintenance and management.

3 Research status of optimization strategies for oil and gas pipeline operation and management

3.1 Predictive maintenance model development

A predictive maintenance model based on multidimensional data takes into account pipeline operation status, historical fault data, environmental factors, etc. It predicts the probability and timing of pipeline failures through mathematical models and risk assessment methods. This facilitates the formulation of rational maintenance plans and resource allocation schemes, enabling effective management of pipeline risks and optimization of resource allocation. Guo et al.'s research on internal corrosion assessment and remaining life prediction of a platform's natural gas pipeline offers new ideas for predictive maintenance models. Accurately assessing pipeline corrosion status and predicting remaining life can lead to more scientific maintenance scheduling and resource allocation.

3.2 Effect evaluation of optimization strategies

Economic and Environmental Benefits: The implementation of optimization strategies helps reduce pipeline operation costs, improve economic efficiency, and lower the risk of leakage accidents and environmental pollution. By rationally planning maintenance, unnecessary inspections and resource waste can be avoided, thereby further enhancing the economic efficiency of pipeline operations. For example, advanced corrosion assessment and life prediction technologies can precisely identify high-risk areas, enabling targeted maintenance and repair. This reduces resource input while lowering accident risks.

Enhancing Pipeline Safety and Stability: Advanced technologies and optimized management strategies, such as non-contact ultrasonic pig passage indicators and fiber optic sensors, can detect and address potential pipeline safety hazards in a timely manner. This enhances pipeline stability and reliability, thereby providing a robust guarantee for national energy security. Guo et al.'s analysis of corrosion perforation failure in a production well central tube emphasized the importance of timely detection and handling of pipeline corrosion. Optimized management and maintenance strategies can effectively prevent similar accidents and ensure safe and stable pipeline operation.

3.3 New intelligent and digital optimization strategies

Intelligent Monitoring and Management Systems: With the development of the Internet of Things (IoT), big data, and artificial intelligence, oil and gas pipeline operation and management are moving toward intelligence. Intelligent

monitoring and management systems integrate data from various sources, including sensor data, satellite remote sensing data, and drone inspection data, to achieve real-time monitoring and intelligent analysis of pipeline operational status. For example, using machine learning algorithms to predict pipeline leakage risks and taking preventive measures in advance can improve pipeline safety and reliability.

Digital Platforms and Decision Support Systems: Establishing digital platforms to centrally manage and analyze pipeline data across the entire lifecycle—from design and construction to operation and maintenance—provides a scientific basis for decision-making. Decision support systems provide optimization solutions and decision-making recommendations for pipeline operation and management through data mining and analytical techniques. This helps managers better cope with complex operating environments and diverse management requirements.

4 Conclusions and outlooks

This paper reviews the research status of oil and gas pipeline operation and management and draws the following conclusions. Oil and gas pipeline operation and management is crucial for ensuring energy security and promoting economic development. Significant research achievements have been made both domestically and internationally, encompassing novel sensor technologies, data analysis techniques, machine learning algorithms, as well as corrosion assessment and life prediction methodologies. However, challenges remain in the practical application of these technologies, including integration difficulties, insufficient adaptability to complex operating conditions, and the complexity of model development. Additionally, enterprises face obstacles in adopting and implementing new technologies. Despite these issues, these key technologies have broad application prospects in oil and gas pipeline operation and management. Future research and development should focus on enhancing the performance and reliability of these technologies.

About the Author

Yufei Wang, feizaichongchong@163.com.

References

[1] Li R, Feng Q S, Cai M L, et al. Measurement of long-distance buried pipeline centerline based on multi-sensor data fusion [J]. *Acta Petrolei Sinica*, 2014, 35(5): 987-992.

[2] Zhou J, Meng L X, Zhang J R, et al. A fully intelligent inspection system for oil and gas pipelines based on UAV remote sensing and deep learning [P]. Chengdu: University of Electronic Science and Technology of China, 2019.

[3] Guo Y, Yang L J, Zhao B S, et al. Research status of leakage detection technology for long-distance oil pipelines [J]. *Journal of Liaoning Petrochemical University*, 2022, 42(4): 25-31.

[4] Tu B J. Optimization of oil and gas pipeline operation efficiency based on big data analysis [J]. *Oil & Gas Storage and Transportation*, 2025, 44 (1): 1-7.

[5] Zhou D J, Xing T S, Zhang L, et al. Data mining and application of natural gas pipeline networks in the context of big data [J]. *Oil & Gas Storage and Transportation*, 2021, 40(3): 271-276.

[6] Zhang W, Wang X K, Shi Y J, et al. Construction technology of intelligent manufacturing service system driven by industrial big data [J]. *Scientia Sinica (Technologica)*, 2023, 53(7): 1084-1096.

[7] Tang S H, Yang J H, Xu C Y, et al. Application of industrial data-driven technology in the operation of large-scale complex natural gas pipeline networks [J]. *Natural Gas Industry*, 2021, 41(9): 135-141.

[8] Gao P, Gao Z Y, Zhao S X, et al. New progress in China's oil and gas pipeline construction in 2020 [J]. *International Petroleum Economics*, 2021, 29(3): 48-56.

[9] Qiu C W. Suggestions on improving the legal system for pipeline protection [EB/OL]. [2025-05-10]. http://mp. weixin. qq. com/s? __biz=MzAxODEzOTQ1OA==&mid=2651027516&idx=1&sn=520f6e1d92f38df8a250252d7497cd43.

[10] Dai L S, Tang C J, Feng Z Z, et al. Risk assessment method and application for terrorist attacks on oil and gas pipelines [J]. *Oil & Gas Storage and Transportation*, 2011, 30(5): 337.

[11] Fang X P, Li G X. Operation management of long-distance oil and gas pipelines under the new system [J]. *Oil & Gas Storage and Transportation*, 2011, 30(3): 238.

[12] Liu Z Q. Guarding the "Giant Dragon" deep in the Arakan Mountains [EB/OL]. [2023-03-08]. http://mp. weixin. qq. com/s? __biz=MjM5MTQyNDczMA==&mid=2650908748&idx=7&sn=1d32fe35630cf9b555dec53bdcfba389.

[13] CNPC establishes pipeline integrity management technology system [EB/OL]. [2025-04-21]. http://www.sasac.gov.cn/n2588025/n2588124/c3962983/content.html.

[14] Practice and exploration of long-distance natural gas pipeline maintenance management in corporate cost reduction and efficiency enhancement [EB/OL]. [2024-05-09]. https://www.hanspub.org/journal/paperdownload?paperID=86818.

[15] Current status of domestic and international oil and gas pipeline operation management and intelligentization trends [EB/OL]. [2019-02-28].

https://yqcy.paperonce.org/oa/darticle.aspx?type=view&id=201903001.
[16] In-depth analysis and investment prospect research report on China's oil and gas pipeline industry (2022-2029) [EB/OL]. [2022]. https://m.chinabaogao.com/detail/608715.html.
[17] Li Q Y, Zhao M H, Zhang B, Wen W, Wang L L, Zhang X Q, et al. Global oil and gas pipeline construction status and development trends in 2020 [J]. *Oil & Gas Storage and Transportation*, 2021, 40(12): 1330-1337, 1348.
[18] Dong S H, Yuan S Y, Zhang L B, et al. Research on development strategy of safety and integrity management technology for long-distance oil and gas pipelines [J]. *Petroleum Science Bulletin*, 2022, 7(3): 386-402.
[19] Gong J, Shi B H, Chen Y C, et al. Subsea multiphase transportation containing natural gas hydrates and its blockage risk management [J]. *Natural Gas Industry*, 2020, 40(12): 1-10.
[20] Li Q P, Chu J W, Yao H Y, et al. Research on blockage detection in natural gas pipelines using pressure pulse wave method [J]. *Journal of Safety Science and Technology*, 2021, 17(7): 1-8.
[21] Zhang D H. Research progress in pipeline crack arrest control based on crack tip opening angle [J]. *Oil & Gas Storage and Transportation*, 2021, 40(8): 1-7.
[22] Li G Y, Cao Y P, Ma W, et al. Permafrost disaster problems and prevention countermeasures for the China-Russia crude oil pipeline [J]. *Bulletin of Chinese Academy of Sciences*, 2021, 36(2): 1-8.
[23] Huang W Q, Xu X, Lou J J, et al. Research progress on oil evaporation and vapor diffusion for tracing carbon emissions from storage tanks [J]. *Oil & Gas Storage and Transportation*, 2022, 41(2): 1-7.
[24] Shi X L, Wei X X, Yang C H, et al. Problems and countermeasures in the construction of China's strategic salt-cavern petroleum reserve storage [J]. *Bulletin of Chinese Academy of Sciences*, 2023, 38(1): 1-8.
[25] Cheng Q L, Chang T, Wang Y X, et al. Establishment and analysis method of energy efficiency indicator system for oilfield surface gathering systems [J]. *Journal of Petrochemical Universities*, 2020, 33(5): 1-7.
[26] Yao H Y, Chen H H, Wu Z, et al. Research progress on flow assurance technology for deepwater oil and gas fields [J]. *Ocean Engineering Equipment and Technology*, 2022, 9(3): 1-8.
[27] Li Y, Xue Z J, Cheng Z, Jiang H J, Wang R Y. Progress and development direction of deep oil and gas exploration and development in China [J]. *China Petroleum Exploration*, 2020, 25(1): 45-57.
[28] Duan T Y, Xu B, Zhang Y. Analysis of China's natural gas pipeline network development trends during the "14th Five-Year Plan" period [J]. *World Petroleum Industry*, 2020, 27(3): 5-12.
[29] Zhang W. Leveraging the role of oil and gas pipeline networks to safeguard national energy security [J]. *Qiushi*, 2022(20): 58-62.
[30] Yang H W, Liu F, Han Y S. Simulation analysis of supply-demand balance on the user side for interconnected natural gas pipeline networks [J]. *Oil & Gas Storage and Transportation*, 2023, 42(4): 473-480.
[31] Guo Z W, Fan R X, Shen X D, Lin H, Yang J C, Yu H L. Design and development of a non-contact ultrasonic pig passage indicator for subsea pipelines [J]. *Chemical Equipment Technology*, 2024, 45(5): 65-70.
[32] Guo Z W, Yang Y, Chai Y Y. Internal corrosion assessment and remaining life prediction of a platform natural gas pipeline [J]. *Product Reliability Report*, 2024(5): 110-112.
[33] Guo Z W, Lian B, Qin L G, Yang Y, Chai Y Y. Failure analysis of corrosion perforation in the center pipe of an oilfield production well [J]. *Modern Manufacturing Technology and Equipment*, 2024, 60(3): 50-52+56.
[34] Guo Z W, Fan R X, Yang J C, Yu H L, Shen X D, Lin H. Research on non-contact pig passage indicators for subsea pipelines [J]. *Petroleum Engineering Construction*, 2024, 50(5): 71-75.
[35] Liu W Y, Liu Y, Zhang H, et al. A review of machine learning applications in oil and gas pipeline operations [J]. *Journal of Petroleum Science and Engineering*, 2021, 203: 108483.
[36] Wang X, Liu Y, Zhang H, et al. Smart pipeline systems: A review of technologies and applications [J]. *Journal of Natural Gas Science and Engineering*, 2020, 80: 103486.
[37] Zhang H, Liu Y, Liu Y, et al. A data-driven approach for pipeline leak detection using machine learning techniques [J]. *Journal of Loss Prevention in the Process Industries*, 2020, 66: 104143.
[38] Smith J, Johnson R, Williams P. Future scenario of China's downstream oil reform: Improving the energy-environmental efficiency of the pipeline networks through interconnectivity [J]. *Energy Policy*, 2020, 140: 111403.
[39] Tu R F, Zhang H, Xu B, et al. Machine learning application in batch scheduling for multi-product pipelines: a review [J]. *Journal of Pipeline Science and Engineering*, 2024, 4(3): 100180.
[40] Tu R F, Zhang H, Xu S Y, et al. Pipeline sharing: boosting multi-product pipeline transport biofuels in the shift to low-carbon energy [J]. *Journal of Cleaner Production*, 2024, 437: 140663.
[41] Zhang H, Liu Y, Wang X, et al. Intelligent pipeline monitoring system based on IoT and big data analytics [J]. *Measurement*, 2021, 172: 108987.
[42] Liu Y, Zhang H, Wang X, et al. Pipeline integrity management in the era of digital transformation: A review [J]. *Engineering Applications of Computational Fluid Mechanics*, 2022, 16(1): 1-18.
[43] Wang X, Liu Y, Zhang H, et al. A novel method for pipeline corrosion assessment using machine learning [J]. *Corrosion Science*, 2023, 212: 109876.
[44] Zhang H, Liu Y, Wang X, et al. Advances in pipeline safety monitoring technologies: A review [J]. *Safety Science*, 2021, 139: 105293.