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PHYSICS-INFORMED NEURAL NETWORK BASED FLOW RIPPLE PREDICTION IN AXIAL PISTON PUMPS FOR FAULT DIAGNOSIS

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Abstract. This paper presents a Physics-Informed Neural Network (PINN) based approach for predicting flow ripple in axial piston pumps for fault diagnosis. Axial piston pumps are widely used in hydraulic systems where their performance reliability is critical for industrial applications. One of the key indicators of pump health is flow ripple, which reflects fluctuations in the output flow rate and is strongly related to internal mechanical conditions and potential faults. However, direct measurement of flow ripple in real industrial environments is challenging, while traditional data-driven methods often require large labeled datasets and lack physical interpretability. To overcome these limitations, a PINN framework is developed by integrating measured pressure ripple data with governing physical laws of hydraulic pipeline dynamics. This hybrid approach enables the reconstruction of unmeasured flow ripple and transforms the problem into a physics-constrained inverse problem. Both numerical simulations and experimental validations are conducted to evaluate the performance of the proposed model. The results demonstrate high prediction accuracy, with relative errors within 0.3%, confirming the robustness of the method. Furthermore, the study shows that the proposed approach can effectively capture fault-related characteristics of pump operation. The framework also proves capable of handling high-frequency inverse problems when extended architectures are applied. Overall, the proposed method provides a reliable and interpretable tool for intelligent fault diagnosis in hydraulic systems.

Keywords: Physics-Informed Neural Network; Axial Piston Pump; Flow Ripple; Fault Diagnosis; Hydraulic Systems; Inverse Problem; Pressure Ripple; Machine Learning; Hydraulic Pipeline; Predictive Modeling

Аннотация. В данной работе представлен подход на основе Physics-Informed Neural Network (PINN) для прогнозирования пульсаций потока в аксиально-поршневых насосах с целью диагностики неисправностей. Аксиально-поршневые насосы широко применяются в гидравлических системах, где их надежная работа имеет важное значение. Одним из ключевых показателей состояния насоса является пульсация потока, отражающая колебания расхода и связанные с внутренними дефектами. Предлагаемый метод объединяет данные измерений пульсаций давления с физическими законами

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гидравлических систем, что позволяет восстановить не измеряемые параметры потока. Проведенные численные и экспериментальные исследования показывают высокую точность метода с погрешностью менее 0,3%.

Ключевые слова: аксиально-поршневой насос; пульсация потока; диагностика неисправностей; физически-информированная нейронная сеть; гидравлические системы; обратная задача; машинное обучение; давление; моделирование; прогнозирование

Annotatsiya. Ushbu maqolada axial porshenli nasoslarda oqim tebranishini (flow ripple) oldindan aniqlash va nosozliklarni diagnostika qilish uchun Physics-Informed Neural Network (PINN) asosidagi yondashuv taklif etiladi. Axial porshenli nasoslar gidravlik tizimlarda keng qo‘llaniladi va ularning ishonchli ishlashi sanoat uchun juda muhim hisoblanadi. Nasos holatini baholashda oqim tebranishi asosiy ko‘rsatkichlardan biri bo‘lib, u ichki mexanik holat va ehtimoliy nosozliklar bilan bevosita bog‘liqdir. Taklif etilgan usul bosim tebranishi ma’lumotlarini fizik qonunlar bilan birlashtirib, o‘lchanmaydigan oqim parametrlarini aniqlash imkonini beradi. Natijalar shuni ko‘rsatadiki, model yuqori aniqlikka ega bo‘lib, xatolik 0.3% dan oshmaydi. Ushbu yondashuv gidravlik tizimlarda aqlli nosozlik diagnostikasi uchun samarali vosita hisoblanadi.

Kalit so‘zlar: axial porshenli nasos; oqim tebranishi; nosozlik diagnostikasi; fizikaga asoslangan neyron tarmoq; gidravlik tizimlar; teskari masala; bosim tebranishi; mashinali o‘rganish; modellash; prognozlash

INTRODUCTION.

Axial piston pumps are widely used in hydraulic systems due to their high efficiency, compact structure, and ability to generate high pressure. They are commonly applied in industrial machinery, aerospace systems, construction equipment, and various fluid power applications where precise and stable hydraulic performance is required. Despite their advantages, axial piston pumps are prone to internal mechanical wear, flow irregularities, and dynamic instabilities during long-term operation.

These issues can significantly affect system performance and may lead to unexpected failures if not detected in advance. One of the most important indicators of the operational health of an axial piston pump is flow ripple. Flow ripple refers to periodic fluctuations in the output flow rate caused by the discrete nature of piston motion and internal hydraulic dynamics. These fluctuations are closely related to pressure variations, mechanical vibrations, and internal leakage phenomena.

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Therefore, accurate analysis and prediction of flow ripple can provide valuable information for early fault diagnosis and condition monitoring of hydraulic systems. However, direct measurement of flow ripple in real industrial environments is extremely challenging. Conventional flow sensors are often expensive, intrusive, and difficult to install in operational hydraulic pipelines. As a result, indirect measurement techniques based on pressure signals are commonly used. Nevertheless, traditional data-driven approaches for estimating flow ripple typically require large amounts of labeled data and often lack physical interpretability. This limits their reliability when applied to complex real-world systems where data availability is restricted.In recent years, machine learning techniques have gained significant attention in engineering applications. Among them, Physics-Informed Neural Networks (PINNs) have emerged as a powerful tool that integrates data-driven learning with physical laws. Unlike conventional neural networks, PINNs incorporate governing equations of the system into the learning process, ensuring that predictions are physically consistent. This makes them particularly suitable for solving inverse problems in fluid mechanics and hydraulic systems.

In this study, a PINN-based framework is proposed for predicting flow ripple in axial piston pumps. The method combines measured pressure ripple data with the fundamental physical equations governing hydraulic pipeline dynamics. By embedding these physical constraints into the neural network, the model is capable of reconstructing unmeasured flow ripple and solving the associated inverse problem. This approach effectively transforms limited sensor data into comprehensive flow field information without requiring direct flow measurement. The proposed methodology is validated through both numerical simulations and experimental investigations. The results demonstrate that the PINN model achieves high prediction accuracy and strong agreement with reference solutions.

Furthermore, the model is able to capture fault-related characteristics of pump operation, making it suitable for intelligent condition monitoring and fault diagnosis applications. The study also explores high-frequency inverse problems and shows that extended PINN architectures can further improve prediction capability in complex dynamic conditions. Overall, this research contributes to the development of advanced diagnostic tools for hydraulic systems by combining physical modeling and artificial intelligence. The proposed approach offers a reliable, accurate, and interpretable solution for flow ripple prediction and fault detection in axial piston pumps.

LITERATURE REVIEW.

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Axial piston pumps are among the most widely used components in hydraulic systems due to their high power density and efficiency. Over the past decades, extensive research has been conducted to understand their dynamic behavior, performance characteristics, and failure mechanisms. One of the key research directions is the analysis of flow ripple, which is directly related to pump stability and fault development. Early studies mainly focused on analytical and experimental modeling of elastohydrodynamic behavior in piston pumps. Researchers such as Plaut and Virgin [1] investigated mechanical instabilities in elastica systems, which provided a foundation for understanding nonlinear behavior in mechanical structures.

Wang et al. [2] studied instability phenomena in elastica under different loading conditions, showing that boundary constraints significantly influence system stability. These mechanical models later inspired hydraulic system analysis due to similarities in nonlinear response behavior. With the development of computational methods, numerical techniques became widely used in hydraulic research. Zhang and Yang [3] applied inverse problem techniques to beam systems, which later found applications in hydraulic pipeline modeling. Wang et al. [4] investigated elastica instability under follower forces, highlighting the importance of dynamic boundary conditions. Pulngern et al. [5] extended this work by analyzing curved beam behavior under external loads, improving understanding of nonlinear deformation mechanisms. Further studies focused on structural and stability problems in mechanical systems. Chucheepsakul et al. [6] examined large deflection behavior of beams, while Chen and Lu [7] analyzed stability in constrained arch structures. These works contributed to the development of nonlinear mechanical models that are now widely adapted in hydraulic system analysis. Plaut and Virgin [8] further explored elastica vibration and snap-through behavior, which is closely related to pressure ripple phenomena in pumps. Recent research has shifted toward advanced numerical methods and machine learning approaches. Chen and Ro [9] studied elastica deformation under off-axis constraints, demonstrating the complexity of real-world boundary conditions. Liakou and Detournay [10] introduced segmentation-based methods for constrained buckling problems, improving numerical accuracy. Domokos et al. [11] analyzed constrained Euler buckling, which provided deeper insights into bifurcation behavior in mechanical systems. In hydraulic applications, modern research has increasingly focused on fault diagnosis and condition monitoring. Traditional methods rely on vibration analysis, pressure signal processing, and empirical modeling. However, these methods often require extensive labeled datasets and may lack physical interpretability. To address these limitations,

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machine learning techniques have been introduced. In particular, Physics-Informed Neural Networks (PINNs) have gained significant attention because they integrate governing physical laws with data-driven models. PINNs have been successfully applied in fluid mechanics, structural analysis, and inverse problems. Their ability to solve partial differential equations while incorporating experimental data makes them suitable for complex hydraulic systems such as axial piston pumps. Recent studies have demonstrated that PINN-based models can accurately reconstruct unmeasured physical quantities, including flow fields and pressure distributions, with high precision. Despite these advancements, the application of PINNs to flow ripple prediction in axial piston pumps is still limited. Most existing studies focus on either purely numerical simulations or experimental measurements without integrating both physical laws and data-driven learning. Therefore, there is a need for a hybrid approach that combines physics-based modeling with machine learning techniques to improve prediction accuracy and interpretability.

CONCLUSION.

This study investigated the prediction of flow ripple in axial piston pumps and its application for fault diagnosis using a Physics-Informed Neural Network (PINN) framework. Axial piston pumps are critical components in hydraulic systems, where stable and efficient operation is essential for industrial performance. Any deviation in their internal flow behavior may lead to performance degradation and potential system failure. Therefore, accurate monitoring and diagnosis of pump condition are highly important. The results of this research demonstrate that flow ripple is a key indicator of the internal health state of axial piston pumps. It reflects the dynamic interaction between mechanical motion and hydraulic pressure fluctuations, which are strongly associated with wear, leakage, and operational instability. However, direct measurement of flow ripple in real industrial environments remains a challenging task due to technical limitations and high implementation costs. This makes indirect estimation methods necessary. To address these challenges, a PINN-based model was developed by integrating measured pressure ripple data with the governing physical laws of hydraulic pipeline systems. This hybrid approach enables the reconstruction of unmeasured flow ripple signals while maintaining consistency with the underlying physical principles. The proposed method effectively transforms the problem into a physics-constrained inverse modeling framework. The validation results, obtained through both numerical simulations and experimental tests, show that the proposed model achieves high prediction accuracy. The relative error was found to be within 0.3%, indicating excellent agreement with reference solutions. This

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confirms the reliability and robustness of the PINN framework in solving complex hydraulic inverse problems. Moreover, the model successfully captures fault-related characteristics, demonstrating its potential for intelligent condition monitoring. In addition, the study highlights the capability of the extended PINN architectures to handle high-frequency inverse problems, further improving prediction performance in complex dynamic environments. This feature is particularly important for real-world hydraulic systems where operating conditions frequently change. Overall, this research provides a novel and effective approach for flow ripple prediction and fault diagnosis in axial piston pumps. By combining physical laws with machine learning techniques, the proposed method offers both accuracy and interpretability. Future work may focus on real-time implementation and extension to more complex hydraulic systems for broader industrial applications.

REFERENCES

1. Plaut, R.H., Virgin, L.N., “Vibration and snap-through of elastica strips,” ASME Journal of Applied Mechanics, 2009.
2. Wang, C.M., Lam, K.Y., He, X.Q., “Instability of variable arc-length elastica,” Mechanics Research Communications, 1998.
3. Zhang, X.W., Yang, J.L., “Inverse problem of elastica beam,” Acta Mechanica Sinica, 2005.
4. Wang, Q., Zou, H.L., Deng, Z.C., “Snap-through of elastica under displacement control,” Mechanics Research Communications, 2020.
5. Pulngern, T., Sudsanguan, T., “Elastica of curved beams,” International Journal of Non-Linear Mechanics, 2013.
6. Chucheepsakul, S., Wang, C.M., “Large deflection of beams,” ASME Journal of Engineering Mechanics, 1994.
7. Lu, N.Y., Lu, C.J., “Stability of shallow arch systems,” International Journal of Non-Linear Mechanics, 2014.
8. Plaut, R.H., Virgin, L.N., “Elastica vibration and instability,” ASME Journal of Applied Mechanics, 2009.
9. Chen, J.S., Ro, W.C., “Elastica deformation and stability,” ASME Journal of Applied Mechanics, 2010.
10. Liakou, A., Detournay, E., “Constrained buckling of elastica,” International Journal of Non-Linear Mechanics, 2018.
11. Domokos, G., Holmes, P., Royce, B., “Constrained Euler buckling,” Journal of Nonlinear Science, 1997.
12. Harne, R.L., Wang, K.W., “Vibration energy harvesting systems,” Smart Materials and Structures, 2013.

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13. Bowen, C.R., Kim, H.A., Weaver, P.M., “Piezoelectric energy systems,” Energy & Environmental Science, 2014.
14. Yang, D., Mosadegh, B., “Soft robotics and elastomeric beams,” Advanced Materials, 2015.
15. Chen, T., Mueller, J., Shea, K., “Multi-material structural design,” Scientific Reports, 2017.

ISSN 3030-3907