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Editorial

Special Issue: Intelligent Control and Maintenance of Fluid Component and System

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1. Introduction

Fluid components and systems are major components of modern mechanical equipment and have been widely used in various fields such as engineering machinery, rotating machinery, and hydraulic machinery. Modern mechanical equipment is developing towards a more specialized, large-scale, complex, high-speed, integrated, and intelligent direction, posing higher requirements for the accuracy, efficiency, reliability, and intelligence of fluid components and systems. This has put forward higher requirements for intelligent control and maintenance methods for fluid components and systems in various industries. Based on this, various innovations, advanced health assessment methods, and intelligent control strategies are essential. For example, the innovative improvement of the structure of pumps, valves, and jet systems would mean an increase in their efficiency and quality.

This Special Issue on "Special Issue: Intelligent Control and Maintenance of Fluid Component and System" collects 10 papers for publication, ranging from studies of flow characteristics and structural optimization in pumps, valves, and jet systems to research on fault feature extraction, diagnosis and health assessment methods for hydraulic pumps and steel surfaces, to intelligent control and decision-making of hydraulic systems.

The Special Issue is available online at the following link: https://www.mdpi.com/journal/processes/special_issues/fluid_component.

The contributions are summarized in four parts as follows:

2. Intelligent Control and Maintenance in Pumps

As general-purpose fluid machinery, pumps are increasingly widely used in many fields relevant to the national economy, and their performance requirements are also increasing. It is therefore significant to conduct health status assessment and prediction for pumps. At the same time, the complexity of application scenarios and working conditions bring various challenges to health status assessment and typical fault diagnosis.

In terms of pump structure optimization, Li et al. [1] developed an energy-recovery-type recessed multiple-acting pump that integrates a high-pressure pump, energy recovery devices, and a booster pump. A mathematical model of the port plate was established, and its internal flow field characteristics were researched. The optimal operating speed and output flow rate of the pump were calculated via a numerical method combined with an experimental approach. The volume was reduced by more than 40%, effectively alleviating the problems of low integration and efficiency in the reverse osmosis desalination system.

Li et al. [2] conducted visual testing for the motion and flow of a reciprocating pump valve, as well as computational fluid dynamics (CFD) analysis on a wing-guided bevel discharge valve in a horizontal quintuple single-acting reciprocating pump. The results indicate that the duration of valve closure is approximately twice that predicted by U-Adolph, and the maximum displacement is consistent with the U-Adolph prediction. The flow state, pressure, and velocity characteristics of the discharge valve opening were studied through CFD analysis. Based on the above research methods, a novel type of horizontal quintuple single-acting reciprocating pump was developed.

In terms of pump health assessment, Zhang et al. [3] developed a practical method for predicting remaining useful life of gear pumps. The depth sparse autoencoder, support vector machine, unsupervised manner, principal component analysis, multi-layer bidirectional long-short-term memory network, and other methods were applied. Comparative experiments show that the average absolute error of the proposed method was reduced by 2.53, and the normalized mean square error was reduced by 0.36, reflecting the practicability and accuracy of the method.

Li et al. [4] utilized wavelet packet decomposition and amplitude feature extraction, combining the traditional LSTM algorithm with a VAE algorithm, and proposed a health indicator structure and health status evaluation method for hydraulic pumps based on LSTM-VAE, which evaluates the health of four states of gear pumps. Comparative experiments indicate that the proposed method outperforms traditional methods in three aspects.

3. Intelligent Control and Maintenance in Nozzles

Water jet technology has a wide range of applications due to advantages such as high efficiency and environmental protection. The nozzle is the core component of a high-pressure water jet, and an excellent nozzle structure can improve the energy conversion efficiency of the water jet and achieve outstanding spraying performance.

In the study of [5], Chen et al. designed five nozzles with different outlet shapes and researched the influences of nozzle shape on various state parameters of the water jet through water jet experiments and numerical simulations. The results demonstrate that the five designed nozzles are superior to traditional circular nozzles in terms of flow coefficient and effective impact area under different inlet pressures and target distances.

Chen et al. [6] proposed a multi-objective collaborative optimization method based on the maximum velocity of the X-axis and the effective extension distance of the Y-axis as evaluation indicators for water jet performance. BP (back propagation) neural networks and genetic algorithms were introduced to optimize the key structural parameters of the nozzle, and the optimal structural parameters of the nozzle were obtained as follows: $\theta = 42.5512^\circ$, $1/d = 2.5608$, $\gamma = 12.431^\circ$. Erosion experiments indicated that the optimized nozzle has significantly improved water jet performance and punching depth, providing new ideas for the design and optimization of coal breaking and punching nozzles.

4. Intelligent Control and Maintenance in Hydraulic Systems

Hydraulic control systems are widely used in marine, aerospace, and construction machinery, and intelligent development is the main direction of industrial development. The intelligent control and decision-making of hydraulic systems has become a hot topic.

In the research of [7], Zhou et al. proposed a hydraulic cylinder position control method based on input and output pressures in a multi-coupled field, providing a new method and the possibility for automatic adjustment of hydraulic supports in intelligent mining processes without displacement sensors. The experiments reveal that this method can also control errors within a very small range under high voltage, proving the effectiveness of the simulation model.

Gao et al. [8] discussed the development of control strategies for high speed on/off valves (HSVs), and reviewed the research results on discrete voltage and pulse control in single HSVs and coding control in parallel HSVs. The advantages and disadvantages of different control strategies and their application ranges were analyzed and compared, and their development trend is predicted from multiple aspects.

5. Intelligent Control and Maintenance in Industrial Production

With the development of industrial production towards greater integration and intelligence, effective health assessment for fluid components of industrial production, can avoid performance issues caused by processing.

In the discussion of [9], Liu et al. put forward an improved Yolov5 to solve the problem of poor real-time diagnosis and prediction of steel surface faults. The results indicate that the improved Yolov5 can efficiently and accurately diagnose the typical faults of steel surfaces.

Wang et al. [10] proposed a lightweight Yolov4 target detection network based on the fusion of EfficientNet-B0 and the ECA mechanism to improve the accuracy of garbage classification. Compared with the original model, the proposed model not only improves the detection accuracy but also reduces the parameters of the network model, greatly reducing the size of the model. The results demonstrate that the size of the model is only 48 MB, with an mAP of 91.09%. The improved small target recognition method enhances the effectiveness and robustness of the algorithm.

6. Conclusions

In this Special Issue, 10 papers are published, covering the intelligent control and maintenance of pumps, nozzles, hydraulic control systems, and industrial production. We believe that intelligent control and maintenance methods for fluid components and systems will continue to improve in terms of accuracy, timeliness, and intelligence in the future.

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