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Optimization of Fault Elimination Method for Hydraulic Cylinder of Construction Machinery Based on Feature Clustering and Wavelet Analysis

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Abstract: At present, with the rapid development of China's economy, the construction industry, transportation industry and other fields have also made continuous progress. In these aspects, the traditional structure of mechanical hydraulic cylinder can no longer meet the growing needs of people. Therefore, it is of great significance to research and design new efficient and reliable hydraulic system. In this paper, by analyzing the structure and working principle of several common hydraulic cylinders in construction machinery, and combining with the methods of fault diagnosis and elimination, a fusion device based on wavelet and clustering algorithm is proposed. In the process of processing the input signal of fusion fusion device, the wavelet transform method is used. The clustering technology is used to extract each rod variable after collecting different feature sets as the sample training quadrate curve to achieve fault location. The simulation experiment conducted by Matlab software verifies that the wavelet adaptive analysis method has excellent denoising effect in processing fault removal, can clearly locate the fault location, and efficiently process the fault location.

1. Introduction

With the development of the times, people have higher and higher requirements for the use of mechanical hydraulic cylinders. At present, due to the rapid rise of China's construction industry and the dominance of foreign enterprises in the domestic market. Therefore, China's engineering construction field is also facing enormous pressure and challenges. On the one hand, the construction environment is complex; on the other hand, the rapid economic growth and continuous improvement of people's living standards in China have brought more and more problems under the

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influence of uncertain factors, more acute contradictions, increased potential safety hazards and many other reasons, which lead to various failures of hydraulic cylinders of construction machinery during operation, posing a threat to people's lives and properties and causing serious harm [1-2].

At present, there are many researches on the analysis and classification of fusion features at home and abroad. There are mainly the following kinds. Foreign scholars have proposed many algorithms based on machine structure, mechanical characteristics and other aspects after comprehensively considering various factors. These methods are summarized by using mathematical theory to draw conclusions, and genetic algorithm is used to solve discrete combination equations to obtain high accuracy and easy to realize automatic control problems, but this method can only solve local extremum [3-4]. Domestic scholars have studied the kinematics characteristics of hydraulic cylinder and its relationship with force transmission, resistance and speed. Some scholars used fluid coupling model to analyze the pressure distribution and variation of piston rod under different working conditions. Other scholars use wavelet transform (PWM) method to establish mathematical modal equations. According to this theory, the correlation function expression between the two variables is derived, in which the motion parameters of each hydraulic cylinder in the system are relatively consistent with the actual situation, and the relatively stable motion under point or nonlinear constraints cannot meet the requirements of high-precision engineering [5-6]. Therefore, based on feature clustering and wavelet analysis, this paper studies the method of fault elimination for hydraulic cylinders of construction machinery.

In this paper, the fault diagnosis of hydraulic cylinders of construction machinery is studied. First, the application of feature set theory and methods based on wavelet analysis algorithm and clustering technology in hydraulic systems is described. The traditional failure modes are summarized. Then, a hybrid tree classification method combining mathematical modeling and signal processing characteristics is proposed to solve the above problems. Finally, experiments verify that the model can be applied to traditional PID control and fuzzy logic control systems to achieve the optimization goal of high-precision PID controller parameter tuning process.

2. Discussion on the Optimization of Fault Elimination Method for Hydraulic Cylinder of Construction Machinery Based on Feature Clustering and Wavelet Analysis

2.1. Functions of Hydraulic Cylinders of Construction Machinery

The function of the hydraulic cylinder of construction machinery is mainly to do work on the piston rod, so that it can produce pressure oil, and realize energy conversion through the pump. In the working process, due to the complex structure of the hydraulic cylinder itself, unstable movement speed and other reasons, it has a large pressure difference within a certain range. When the load changes, it will lead to the increase of the internal pressure of the system, as well as the increase of the pipe resistance and liquid flow loss. There may also be a problem that the sealing of the connection between the pipe and the valve body is not good. The basic function of the hydraulic cylinder is to input the oil into the wavelet network and magnify it to obtain the ideal liquid pressure [7-8]. By adjusting the valve and controlling the fluid flow, the pressure difference in the hydraulic chamber can be controlled; The pump has stable pressure, low viscosity and large flow resistance under normal working conditions. When the system is in a high-pressure working environment or under heavy load, large fluctuations will occur. Change the shape of the throttle (reduce overflow) and adjust the pump speed, thus reducing the oil temperature and pressure. The hydraulic system of construction machinery consists of two parts, pressure control valve and flow control valve. In the pressure control circuit, different functions are realized by changing the input and output variables.

When the pump enters, a certain amount of liquid flow will be generated to drive the piston rod. When the oil pressure is reduced to a certain extent, it will suck air from the high-pressure suction port and send it to the oil storage chamber through the pipeline. Then the energy will be absorbed by the reservoir and supplied to the hydraulic cylinder for use. Schematic diagram 1 of hydraulic system of construction machinery is shown in the pressure control circuit. During the movement of the actuating mechanism of construction machinery, it will be affected by various forces, friction and inertia, which all affect the piston rod. Therefore, we can adjust them to form a whole and maintain stable operation by selecting appropriate pressure control valves to achieve the desired goal [9-10]. Figure 1 is the technical framework of troubleshooting.

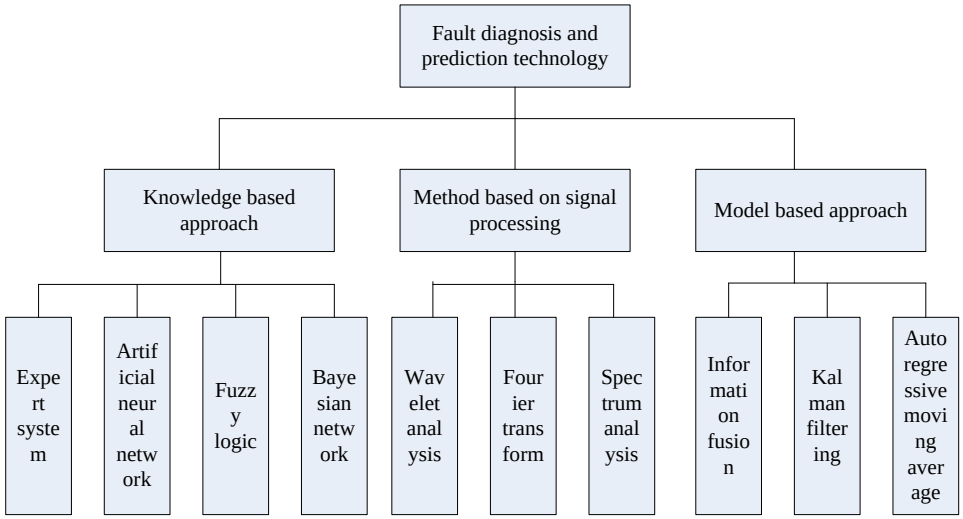


Figure 1. Troubleshooting technology

2.2. Failure of Hydraulic Cylinder of Construction Machinery

The working principle of the hydraulic cylinder is that when the throttle valve is filled with oil, the piston rod will move by controlling and regulating the flow, otherwise the pressure will be closed. However, in the actual engineering application process, there are many factors that will lead to a certain degree of leakage. For example, problems such as large throttling loss and low volumetric efficiency will affect system performance, service life and reliability. Another reason is that the hydraulic cylinder leaks due to the high flow speed of high-pressure liquid, which causes the oil to enter the pipeline under fault condition. In practical engineering, there are many hydraulic cylinders with unreasonable design, resulting in too fast flow rate or too high pressure of hydraulic oil during operation. When the system generates large flow and pressure difference, it will lead to the collision between the piston and other parts and damage the whole mechanism. There are also some reasons that the leakage point is not eliminated in time or the leakage point is not treated, which will also cause the whole mechanism to malfunction, or even paralysis [11-12]. After the analysis and diagnosis of the causes of the system damage, there are a lot of small bubbles in the hydraulic cylinder, and these bubbles will produce friction when moving. When the piston rod touches the large and thin glass, it will form a great resistance. Leakage caused by high or low pressure in the pump chamber is one of the common fault types, followed by damage to the piston ring and overheating of the valve element. If the seal ring is not tight or there are bad wear marks such as air leakage and overflow, hydraulic oil may leak.

2.3. Feature Clustering and Wavelet Analysis Algorithm

The method based on feature clustering and wavelet analysis is a widely used algorithm at present. It refines the original data, and then establishes the correlation matrix between characteristic attribute vectors with specific meaning, property or structure information through wavelet functions [13-14]. This method can take the original sample set as the basic unknown. Through feature point clustering and wavelet analysis algorithm, the network structure obtained has certain similarity, and can be transformed into each other under different conditions. The feature pair dissimilation problem can be recognized by binary or ternary pattern. When a variable has multiple types, it is decomposed into several subfunctions to represent it. Otherwise, it is processed in binary or ternary mode. If there are multiple constraints between two variables, wavelet algorithm cannot be combined to analyze and calculate them; otherwise it will lead to wrong results. Figure 2 is the structure diagram of wavelet analysis.

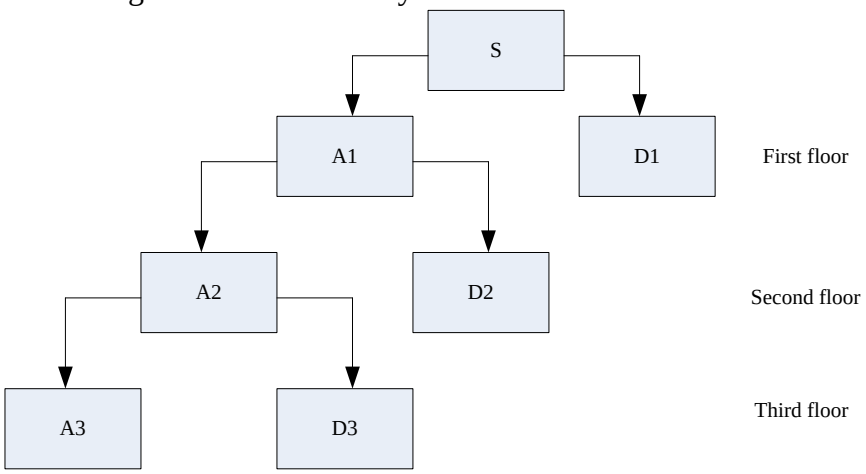


Figure 2. Wavelet analysis structure diagram

First, the input variables are preliminarily screened, and then the final objective function is determined as the characteristic value according to the clustering index obtained after classification and the similarity between different categories. Finally, it is matched [15-16]. Some meaningful or important information is extracted from the signal, which can be used to explain the cause of the fault, identify the possibility of the event and have different degrees of influence on other useful signals. On the contrary, wavelet strongly reflects those features that have great value, can be widely used in the field of data processing, are widely used, have low probability, but are not easy to lose and have low error rate. Given a basic function v (t), let:

$$\psi_{a,b}(t)=\frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right) \tag{1}$$

Where a and b are constants, and a>0. Obviously, va (t) is obtained after the basic function v (t) is shifted first and then expanded. If a and b change constantly, we can get a family of functions va (t). Given the square integrable signal f (t), that is, f (t) eL (R), the wavelet transform of f (t) is defined as:

$$Wf(a,b)=\frac{1}{\sqrt{a}}\int f(t)\psi\left(\frac{t-b}{a}\right)dt \tag{2}$$

In the formula, a, b and t are continuous variables, so the formula is also called continuous wavelet transform. The wavelet transform Wf (a, b) of signal f (t) is a function of a and b, α Is the scale factor and b is the translation factor [17].

3. Experimental Process of Optimization of Fault Elimination Method for Hydraulic Cylinder of Construction Machinery Based on Feature Clustering and Wavelet Analysis

3.1. Optimization Model of Fault Elimination Method for Hydraulic Cylinder of Construction Machinery Based on Feature Clustering and Wavelet Analysis

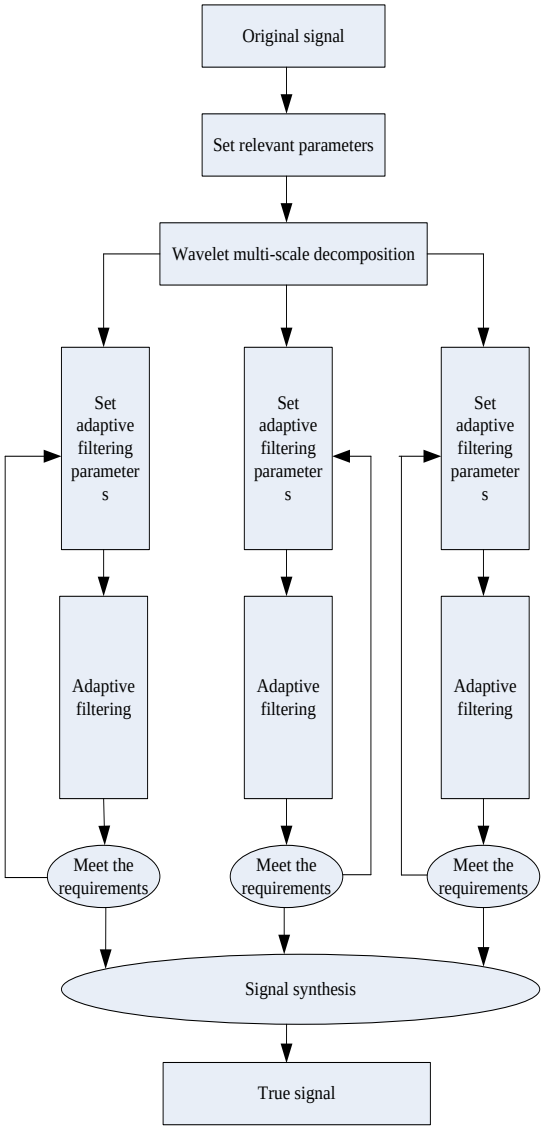


Figure 3. Flowchart of troubleshooting based on wavelet analysis

The troubleshooting method for hydraulic cylinders of construction machinery based on feature clustering and wavelet analysis (as shown in Figure 3) is a comprehensive diagnosis technology combining fuzzy reasoning and pattern recognition, which is based on fuzzy mathematics and gray theory, and uses nonlinear mapping method to model low rank sample sets. The input variables can

be converted into output values through the nonlinear mapping method, and the high-frequency data can be processed using the feature tree algorithm. When there are problems involving feature points and noise, the wavelet analysis method can be used, that is, the high-resolution pattern can be extracted first as the model training sample. When troubleshooting the hydraulic cylinder of construction machinery based on the method of feature clustering and wavelet analysis, several mathematical tools such as wavelet function method, least square fitting method and minimum construction tree are used according to the fault diagnosis theory, and binary function and unitary linear regression method are used to process the sample data. Using the multivariate statistical model, it is easy to get the following conclusions: when the input variable is a stationary random process signal and an autocorrelation feature, its corresponding eigenvector is a second-order moment, while when the input variable is a non-stationary random process signal, it is a non-negative value.

3.2. Model Performance Test Based on Feature Clustering and Wavelet Analysis for Optimization of Troubleshooting Method of Hydraulic Cylinder of Construction Machinery

In the cluster analysis, through the detection of wavelet transform and Fourier distribution, a fault removal method based on rough set theory is obtained. In the test, we should first improve the clustering algorithm, and then apply the wavelet analysis method to the actual situation. Before the experiment, use the computer to establish a clustering function, and then use the mathematical software MATLAB to simulate the function to get the results. Then we can draw a conclusion. First, use the Matlab software to write a program to achieve initialization, and collect the data for fuzzy inference. Then use MATLAB toolbox to complete model testing, simulation experiments and statistical atlas analysis to verify whether the results are correct. Then select appropriate samples on the database file, optimize and adjust the input parameters, and obtain the final results to meet the actual application needs. If the sample data changes, the appropriate parameters and variables should be re selected. However, due to the large number of samples and the large difference between different types of samples, multiple iterations are required.

4. Experimental Analysis on Optimization of Fault Elimination Method for Hydraulic Cylinder of Construction Machinery Based on Feature Clustering and Wavelet Analysis

4.1. Model Performance Test Analysis Based on Feature Clustering and Wavelet Analysis for Optimization of Troubleshooting Method of Hydraulic Cylinder of Construction Machinery

Table 1 shows the model performance test data optimized for troubleshooting methods of hydraulic cylinders of construction machinery.

Table 1. Model performance test of mechanical hydraulic cylinder troubleshooting method optimization

Inspection parameters	The original noise signal	Hard threshold method	Soft threshold method	Adaptive method
Noise-signal ratio	23.137	24.214	21.231	25.261
Root-mean-square error	0.0524	0.0625	0.0572	0.0725
Peak error	0.543	0.537	0.673	0.532

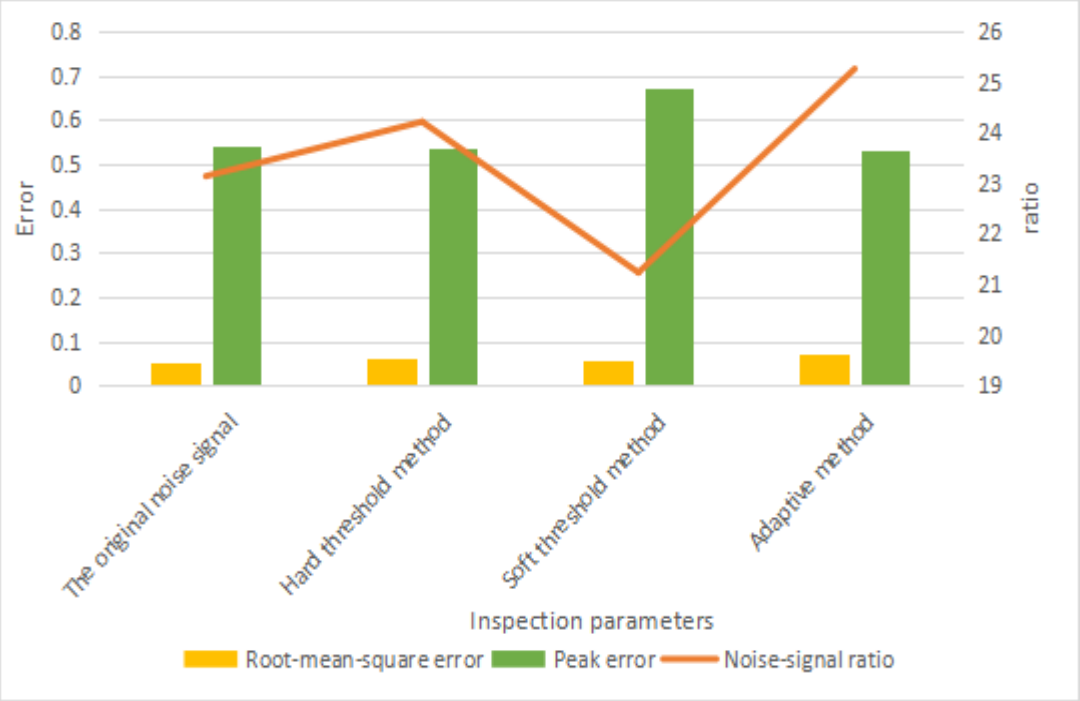


Figure 4. Wavet filter transform performance detection

Through the analysis of the motion parameters and performance of the hydraulic cylinder of construction machinery, the method of wavelet analysis is used to eliminate the faults based on clustering and wavelet functions. Through the collection of data, the correlation model is established with the feature vector as the input variable. Select 10 representative indicators in the sample set, because the feature extraction process is randomly generated. Therefore, it is necessary to select wavelet analysis indicators with appropriate quantity, good quality, strong distribution uniformity, high accuracy, high reliability and low representation of overall characteristics for troubleshooting. It can be seen from Figure 4 that the wavelet adaptive analysis method has excellent denoising effect in processing and troubleshooting, and can clearly locate the fault location and efficiently process the fault location.

5. Conclusion

In this paper, the hydraulic cylinder of construction machinery is taken as the research object, and its fault types are analyzed using wavelet transform, iterative entropy and other methods. According to the basic principle and characteristics of feature clustering method, a fuzzy recognition network based on wavelet multi-scale model is proposed on the basis of traditional PID algorithm. The mass flow matrix of each unit is obtained through verification calculation. On this basis, based on the equation, the failure probability and position vector expression of fault locator are given. Finally, combined with the actual case, it is concluded that there is a certain relationship between the pressure distribution in goaf and the time change from multiple angles and aspects.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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