Monitoring Hydraulic System Fault Based on Motor Current Signal and Wavelet Transform

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ABSTRACT

Fault diagnosis of a hydraulic system is not easy because most components of a hydraulic system are mounted internally and vibration signal is difficult to be obtained. An efficient method to detect the load fluctuation in a hydraulic system is the motor current signature analysis (MCSA). Motor current signal is the input source signal of hydraulic system and can be easily accessed, which make motor current become ideal information source for fault diagnosis. In this paper, a hydraulic system (with coupling misalignment fault) has been studied. In order to replace the conventional signal processing method by MCSA, wavelet also be used for fault feature extraction from motor current. Experimental results show that the method is available.

INTRODUCTION

Hydraulic system plays an important role in modern industry. Any defect in hydraulic system will lead to equipment failure and resulting in a loss of production. It is difficult to diagnosis on hydraulic system using traditional diagnosis method, because mechanical, electrical, hydraulic and control subsystems have strong interact and coupling in a hydraulic system. A number of methods have been applied
in order to diagnose faults in hydraulic system[1-3]. Among various methods, motor current signature analysis (MCSA) has proven to be a highly valuable predictive maintenance method. Mechanical system faults related to bearings, gears, couplers and alignment all can be analyzed through the use of motor current spectrum[4].

According to MCSA theories, when there is a load fluctuation on motor shaft, a change in rotation speed occurs thus changing the per unit slip, which subsequently causes magnetic field anomaly thus changing the mutual and self-inductance of motor [5]. For fault conditions, the frequency spectrum of motor stator current spectrum will be different from normal condition.

In fact, in the measurement of motor current, both the measuring system and the electromagnetic environment inevitably introduce noise in the measured current signals. Moreover, traditional MCSA method is simply the process by FFT in the frequency domain and main component of current signal FFT spectrum is industrial frequency of motor current, it proved difficult to analyze most other frequencies.

In order to analyze the motor current better, this paper use wavelet transform for feature extraction of motor current. It aimed at applying wavelet transform with better denoising effect and lead good results to multi-resolution extractions.

WAVELET TRANSFORM

Wavelet transform has being widely used in problems of pattern recognition, signal processing, images analysis, information compression and signal denoising. Wavelet transform is praised as a “mathematical microscope” in signal processing, because of the possibility of analyzing the signal simultaneously in time and frequency spaces [6].

The continuous wavelet transform of a finite energy signal \( x(t) \) with the analyzing wavelet \( \Psi(t) \) is the convolution of \( x(t) \) with a scaled and conjugated wavelet:

\[
W(\alpha,b) = \alpha^{-\frac{1}{2}} \int_{-\infty}^{\infty} x(t) \Psi^* \left( \frac{t-b}{\alpha} \right) dt
\]  

The wavelet coefficient \( W(\alpha,b) \) measures the similarity between the signal \( x(t) \) and the analyzing wavelet \( \Psi(t) \) at different scales as defined by the parameter \( \alpha \), and different time positions as defined by the parameter \( b \). The factor \( \alpha - 1/2 \) is used for energy preservation. Equation (1) indicates that the wavelet analysis is a time-frequency analysis. For the analysis of the signal \( x(t) \), one can assemble the wavelet coefficients into a scaleogram of the signal. A set of wavelets will decompose signal without gaps or overlap. As a mathematical tool, wavelets can be used to extract information from many different kinds of data. That is why the wavelet transform has had a great acceptance for analyzing fault signals.
It has been found that different wavelet function $\Psi(t)$ will lead to different analysis results when processing engineering signal by wavelet analysis. In order to get the multi-scale characteristics of engineering signal as precisely as possible, it's necessary to select an appropriate wavelet function at first. In this paper, Daubechies wavelets (Db9) were selected as wavelet function.

EXPERIMENT AND ANALYSIS

The experiment data was obtained from a hydraulic testing platform, as shown in Figure.1

![Figure 1. Hydraulic testing platform.](image)

The hydraulic platform is composed of a fuel tank, an AC motor, a hydraulic oil gear pump, a relief valve, a directional valve and a hydraulic motor. A computer controlled magnetic powder brake simulated loading system was developed for experiments. The hydraulic platform can simulate different types of working conditions. Current and voltage signals of AC motor stator are measured through sensors located on platform. Signals measured from sensors are transmitted to a data-acquisition card and then sampled at a rate of 2560 samples/s. In this paper, working pressure of hydraulic is set a 3 MPa, operating speed of motor is 1460 r/min.

To simulate a misalignment failure in this hydraulic platform, the shaft axis of gear pump is located artificially misaligned with shaft axis of motor. In order to analyze the motor current signal, a Fast Fourier Transform (FFT) is performed. FFT is a mathematical operation designed to extract the frequency information from the time domain and transform it into the frequency domain. The frequency spectrum of motor current signal is shown in Figure.2
From Figure.2, we can find that the main component of current signal’s frequency spectrum is industrial frequency of motor current (50Hz). Industrial frequency is so obvious that it cover up other frequency components.

In order to extract characteristic components from current signal, wavelet transformation analysis was carried on, and the result is shown in Figure.3.

![Figure 2. Frequency spectrum of motor current signal.](image)

![Figure 3. Wavelet decomposition results of motor current signal.](image)

In order to analyze the wavelet decomposition results in frequency domain, Fast Fourier Transform (FFT) was performed. The frequency spectrums of wavelet decomposition are shown in Figure.4.
Based on the respective analysis of each wavelet decomposition results, we can find that \(d_5\) is rotational frequency of motor (25Hz), \(d_4\) is industrial frequency of motor current (50Hz), \(d_3\) is second harmonic frequency (100Hz). There are four characteristic spectrum lines in \(d_2\) (150Hz, 200Hz, 250Hz and 300Hz respectively) and three characteristic spectrum lines in \(d_1\) (350Hz, 450Hz, and 550Hz respectively), these spectrum lines are all multiple-frequency harmonics industrial frequency (50Hz). These multiple-frequency in frequency domain are by-product of rotating flux components, misalignment failure result in a change to the vibration spectrum and lead to airgap eccentricity in motor, and rotating flux waves is produced in stator phase windings, and corresponding currents are induced in three phases. In this way, misalignment failure can be detected via current monitoring.

![Figure 4. The frequency spectrum of wavelet decomposition results.](image)

**CONCLUSION**

This article was concerned to study MCSA and wavelets as an analytical method to detect faults in hydraulic system. Wavelet method is used to decompose motor current signals into different frequency components with different wavelet scales, and then FFT analysis is applied to analyze decomposed components in frequency domain. The experimental results shown that the proposed method works well in
diagnosis of hydraulic system. It can extract fault features of current signal and convenient for accurate diagnosis.

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