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The Pipe Pressure Signal Mutation Detection Based on the WPEMD-WTM Method

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Abstract: For pressure characteristics of the signal mutation when fluid pipeline is blocked, the method which connects wavelet packet preprocessing, empirical mode decomposition (EMD) and wavelet transform modulus maxima(WTM) is presented for pressure signal singularity detection, and the validity and accuracy of the proposed approach is verified through experiment data, this research will lay foundation for fluid pipeline blockage prediction.

Keywords Wavelet Packet; EMD; Mutation detection; pipeline

INTRODUCTION

In the field of automatic control, signal of the singular point or mutation point is one of the important characteristics of signal, often contains important information. If fault happens in the system, for example, then the output signal mutation of the fault characteristics will occur. Therefore, fault diagnose can be made through detecting feature signal mutation points. Mathematically, if the function is discontinuous at some point or a derivative is discontinuous, so this point is the representation of signal singularity functions[Wang, 2011]. Singular point generally can be divided into two types. First type of singular point refers to the signal that at some time the amplitude or frequency mutation happens, causing the signal discontinuity. The second type is that amplitude or frequency of mutation does not occur, the signal is smooth, but the first order differential mutation happens and is discontinuous. When pipe blockage happened, the pressure signal mutations happen, according to waveform analysis for the pipeline pressure signal, it is shown that amplitude development of the pressure signal is rapid, the pressure signal mutation belongs to the first type of singular point.

THE SINGULARITY DETECTION BASED ON WPEMD-WTM METHOD

[Cai et al., 2008]point out that singularity of function can be used to quantitatively described with Lipschitz index. Along with the increase of the decomposition scale, wavelet transform extremum will converge to the signal singularity, Lipschitz index of the signal singularity point will determine the speed of attenuation. In addition, when the edge of the noise and signal is under multi-scale continuous wavelet transform, their extrema have different performance. The wavelet transform extremum of noise edge decays quickly with the increase of scale, while wavelet transform the extremum of signal edge will increase or remain the same with the increase of scale. Then, the continuous wavelet transform can used to accurately isolate signal edge features from the noise background, so the signal mutation can be detected. Therefore wavelet transform modulus maxima method can be used to detect signal singularity. Wavelet transform modulus maxima happen in the place that signal mutation appears, the bigger the signal mutation, the greater its wavelet transform modulus maxima, the time that signal mutation point happens can be obtained by modulus maxima detection[Liu et al., 2009].

In Hilbert Huang transform (HHT), empirical mode decomposition (EMD) method is used to decompose the signal into a series of intrinsic mode function (IMF) component from high frequency to low frequency; the different IMF component contains different characteristics of signal. Empirical mode decomposition (EMD) is put forward by Huang, which is based on the assumption that any complex signal can be decomposed into intrinsic mode function (IMF) that is finite and has a certain physical definition. According to the characteristics of the signal, the EMD method can adaptively decompose signal into a series of different IMF from high to low frequency. The method directly obtain basis function from the signal itself, thus has the adaptability [Semion, 2010].

However, HHT method also has shortages. The first high frequency IMF component obtained by the

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EMD decomposition may be covered with a very wide frequency range, is not strictly a single mode signal, modal aliasing phenomenon exists. In the low frequency area false IMFs component may produce. In view of this, the Wavelet Packet Transform (WPT)is introduced in this article as a means of pretreatment, and is used preprocess for HHT signal. First the signal is decomposed into several narrow band signals, and then EMD decomposition is made to the narrowband signals, respectively obtained IMF components should also be narrow band.

The advantage of wavelet packet fine decomposition is used only to decompose the signal, and other processing isn't done, let the EMD deal with follow-up work completely. Then the advantages of conventional HHT is not only retained, but all the signal characteristic information is perfectly preserved, and modal aliasing phenomenon during EMD process is overcomed[Dorostghol et al., 2010].

Therefore for pressure signal mutation point detection problem from coal slurry pipeline, wavelet packet preprocessing will be firstly made for pressure signal in this paper, then the EMD decomposition will be made, in the end combined with the wavelet transform modulus maxima method, which is called WPEMD-WTM for signal mutation detection. The flow chart is shown in Fig.1.

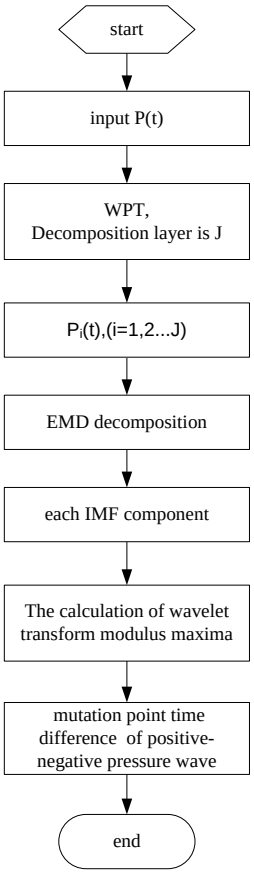

Fig.1 The time difference detection of positive-negative pressure wave

SIMULATION EXPERIMENT OF PIPELINE PRESSURE SIGNAL MUTATION DETECTION BASED ON WPEMD-WTM METHOD

In order to validate the effectiveness of WPEMD-WTM mutation point detection method proposed in this paper, the experimental data from fluid pipeline is used to verify the mutation point detection method. In the experiments, the degree of blockage can be divided into three levels, in this paper let level I block as an example, test data of a period of time is selected and the negative pressure signal is used. using wavelet transform modulus maxima method is directly used for mutation detection, the simulation results are shown in Fig.2.Then the method combined wavelet transform with the EMD and without wavelet packet preprocessing is used[Leh-Sung,2012],the simulation results are shown in Fig.3.

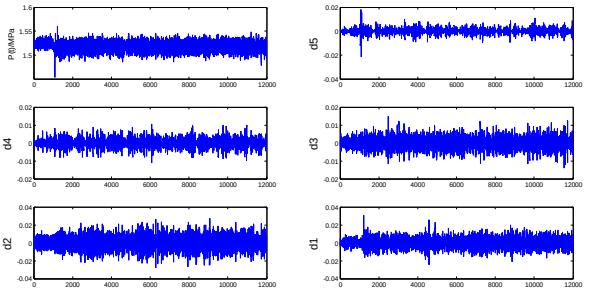

Fig.2 Detection results of the mutation with wavelet transform modulus maxima method

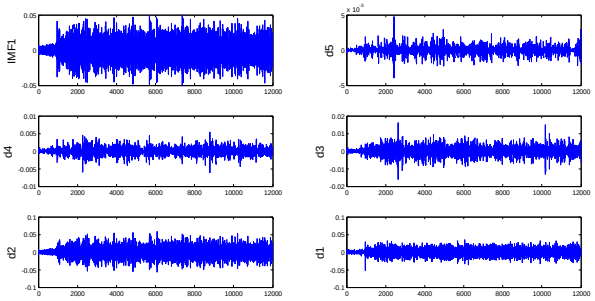

Fig.3 Detection results of the mutation without wavelet packet preprocessing

It is shown in the Fig.2 that mutation moment can be seen only in d5 layer and its characteristics are not obvious. From the Fig.3, it can be seen that the mutation point isn't detected.

In the new algorithm proposed in this paper three layer wavelet packet decomposition is made firstly, as shown in Fig.4. c1 includes rich characteristics of original signal, so the EMD decomposition is then made, which includes the first three IMFs of c1, as shown in Fig.5. Finally wavelet transform modulus maxima is done for the IMF1 component, the simulation results are shown in Fig.6.

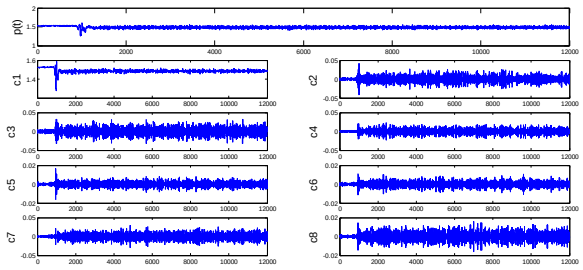

Fig.4 3 layer wavelet packet decomposition

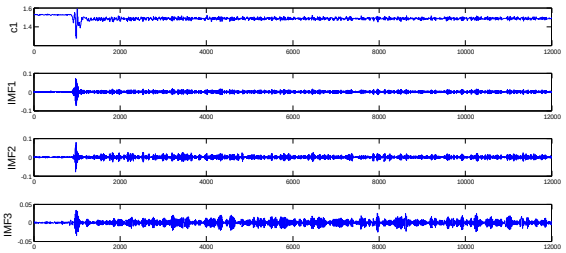

Fig.5 The first three IMFs of c1 after EMD decomposition

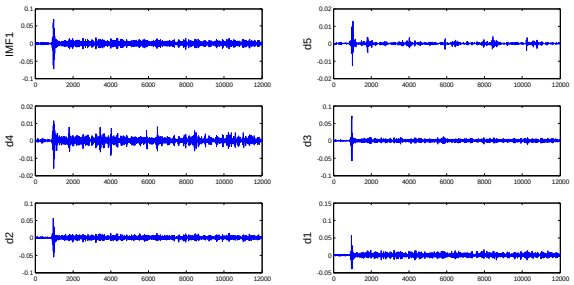

Fig.6 Mutation detection results with method proposed in this paper

As can be seen from the Fig.6, d1, d2, d3, and d5 layer in the wavelet decomposition, compared with the wavelet modulus maxima, the mutation information is very obvious.

CONCLUSION

Because of the complexity increase in modern control system, fault diagnosis requirements are increasing as well. Some fault diagnosis can be done by detecting mutation point. Through simulation the effectiveness and accuracy of the detection method proposed in this paper has been verified, which is based on the wavelet packet pretreatment combined EMD and wavelet transform modulus maxima (WPEMD-WTM), and will lay the foundation for the analysis of fault diagnosis.

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