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Application of EMD method to friction signal processing

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Abstract

Due to measurement limitation, the measured friction signal often contains noise and other force components such as elastic forces. Traditional Fourier-based analysis methods are not suitable to process nonlinear and non-stationary signal. In this paper, the combination of median filter and empirical mode decomposition (EMD) method is used to analyze the measured friction signal. Median filter is a nonlinear process useful in reducing random noise, while EMD method has offered a powerful method for nonlinear and non-stationary data processing. The background noise and the noise arising from the measurement system in the measured friction signal are removed using median filter first. Then the other force components except the real friction force can be extracted from the measured friction signal using the EMD method. The residue after extracting can be taken as a relatively clean and real friction force. This method is compared with the traditional Fourier-based methods and wavelet decomposition method. The comparison results both in time domain and in Hilbert spectrum can show the superiority of the EMD method in dealing with the problem of friction signal processing.

Keywords: EMD method; Median filter; Nonlinear and non-stationary; Traditional Fourier-based analysis; Wavelet decomposition; Hilbert spectrum

1. Introduction

In the system with friction contact, the measured friction signal often contains noise and other force components. With friction model becoming more and more complex, the identification of friction parameters also becomes more difficult [1,2]. And most of these identification work is done in the hypothesis of clean data or data with relatively little noise [3,4]. With the test data contaminated by noise and other force components badly, the parameter identification work even can be corrupted. Thus, it is very much necessary to develop a method to extract real friction force from the measured signal.

Many de-noising theory and methods have been developed to eliminate these noise [5,6]. Among them, median filter is often used to remove noise. Median filtering is a nonlinear process useful in reducing random noise. In many different kinds of digital signal processing, median filtering follows this basic prescription. It consists of sliding a window of an odd number of elements along the signal, replacing the center sample by the median of the samples in the window. In particular, the median is hardly affected by one or two discrepant

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values among the signals in the window. Consequently, median filtering is very effective at removing various kinds of noise by ignoring it. However, in friction measurement other force components, such as elastic forces, often are included into the friction force data. These components often cannot be removed from measured

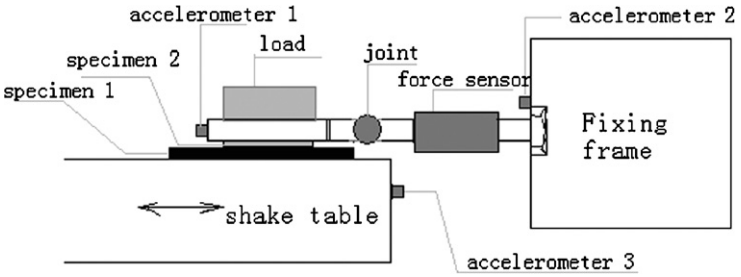

Fig. 1. Test apparatus.

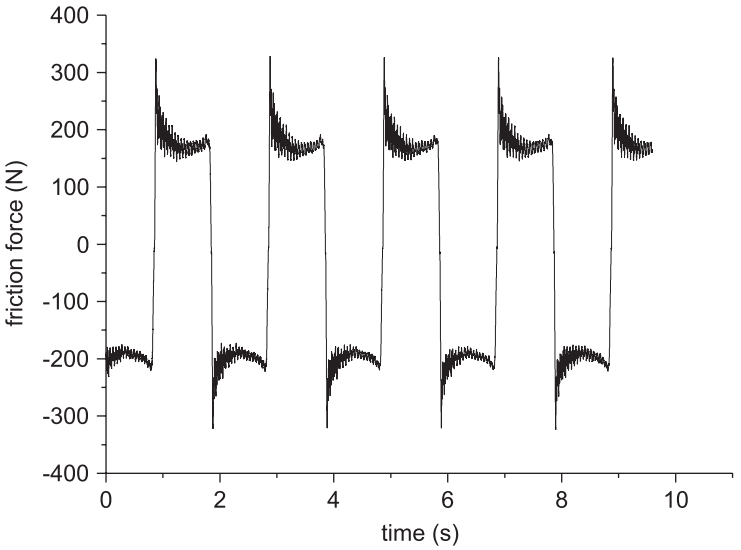

Fig. 2. Measured time-domain friction signal (shake table moved in sinusoidal wave. The amplitude is 20 mm, and the frequency is 0.5 Hz).

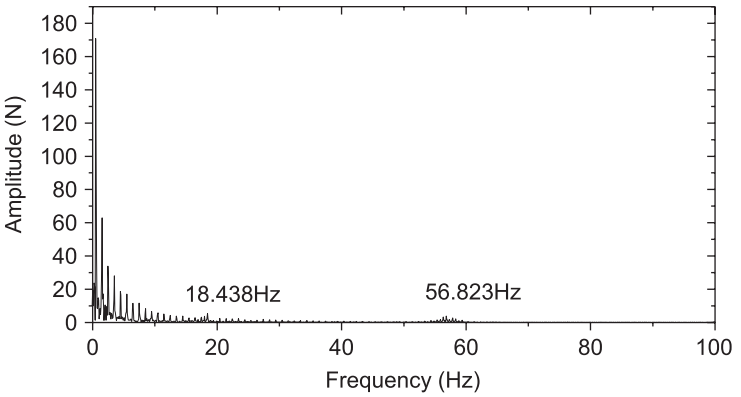

Fig. 3. The spectrum of measured friction signal (18.438 and 56.823 Hz are detected).