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Sparse signal decomposition method based on multi-scale chirplet and its application to the fault diagnosis of gearboxes

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ABSTRACT

Based on the chirplet path pursuit and the sparse signal decomposition method, a new sparse signal decomposition method based on multi-scale chirplet is proposed and applied to the decomposition of vibration signals from gearboxes in fault diagnosis. An over-complete dictionary with multi-scale chirplets as its atoms is constructed using the method. Because of the multi-scale character, this method is superior to the traditional sparse signal decomposition method wherein only a single scale is adopted, and is more applicable to the decomposition of non-stationary signals with multi-components whose frequencies are time-varying. When there are faults in a gearbox, the vibration signals collected are usually AM–FM signals with multiple components whose frequencies vary with the rotational speed of the shaft. The meshing frequency and modulating frequency, which vary with time, can be derived by the proposed method and can be used in gearbox fault diagnosis under time-varying shaft-rotation speed conditions, where the traditional signal processing methods are always blocked. Both simulations and experiments validate the effectiveness of the proposed method.

1. Introduction

When there is a fault in gearboxes, amplitude modulation and frequency modulation will usually emerge simultaneously. The meshing frequency and its harmonics are usually modulated by the frequency of the shaft rotation speed and its harmonics [1]. Although manufacturing errors, improper assembly, and so on can also cause periodic disturbances in the meshing signal's amplitude and frequency and can introduce sidebands when the gear is in good condition, the amplitude of the sidebands is usually small and difficult to detect in the noise. With the development of fault, the energy of meshing signals and sidebands will increase simultaneously; if the sidebands are detected in the signals, serious faults in the gearbox are indicated. When the shaft rotation speed is time-varying, the modulating frequency and carrier frequency will both vary and, in that case, it is difficult to recognize the sidebands and to diagnose the gear faults based on the spectra of vibration signals.

Wavelet transform [2] and EMD [3] are the two methods most commonly used in the diagnosis of gearbox faults. Wavelet transform, which uses variable window functions, is always regarded as "a mathematic microscope" but, because of the Heisenberg in-equation [2], it is impossible to have high resolutions of time and frequency simultaneously [4]. What's more, the scales of wavelet transform relate only to signals' sample rate, rather than to the signals themselves. Therefore, wavelet transform is not a self-adaptive signal decomposition method essentially [5–7]. In the EMD method,

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