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Weak fault feature extraction of rolling bearing based on cyclic Wiener filter and envelope spectrum

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ABSTRACT

In vibration analysis, weak fault feature extraction under strong background noise is of great importance. A method based on cyclic Wiener filter and envelope spectrum analysis is proposed. Cyclic Wiener filter exploits the spectral coherence theory induced by the second-order cyclostationary signal. The original signal is duplicated and shifted in the frequency domain by amounts corresponding to the cyclic frequencies. The noise component is optimally filtered by a filter-bank. The filtered signal is analyzed by performing envelope spectrum. In the envelope spectrum, characteristic frequencies are quite clear. Then the most impactive part is effectively extracted for further fault diagnosis. The effectiveness of the method is demonstrated on both simulated signal and actual data from rolling bearing accelerated life test.

1. Introduction

As a vital part of rotating machinery, rolling element bearings play a very important role in the whole system. Any defect in the bearing, no matter how light it is, will cause a series of faults of connected components. It is necessary to extract fault characteristics of the bearing as early as possible. However it is not an easy task. Early fault is weak, and fault information is usually corrupted by strong background noise. Parameters of rolling bearing are periodically time-varying, especially for those under failure situation, which implies second-order cyclostationarity [1–3]. It has been demonstrated that cyclostationarity provides powerful tools for analyzing vibration signals captured on rotating machinery for noise control or fault diagnosis purposes [4–6]. Therefore, study based on cyclostationary characteristics of rolling bearing is more close to the fault essence and provides an easier access to weak fault feature extraction.

Cyclic Wiener filter exploits the spectral coherence theory induced by the second-order cyclostationary signal [7–9]. It requires the prior knowledge of the cyclic frequencies of the signal to analyze. The original signal is duplicated and shifted in the frequency domain by amounts corresponding to the cyclic frequencies. The noise component is optimally filtered by a filter-bank. The difference from traditional adaptive filter is that in the cyclic Wiener filter, all the weight vectors of filter-bank are synchronously adjusted, not just one of them.

When fault occurs in the rolling bearing, it will interact with other rolling element surfaces, which makes the vibration signals present the feature of amplitude modulation. Envelope analysis is a well-known method to extract bearing defect frequency components [10–12]. Hilbert transform can be efficiently used to perform envelope analysis. While, the weak fault information is always buried under strong background noise, it is better to filter the signal prior to the Hilbert transform.

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