A Fault Diagnosis Approach for Rolling Bearing Based on Wavelet Packet Decomposition and GMM-HMM

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Considering frequency domain energy distribution differences of bearing vibration signal in the different failure modes, a rolling bearing fault pattern recognition method is proposed based on orthogonal wavelet packet decomposition and Gaussian Mixture Model-Hidden Markov Model (GMM-HMM). The orthogonal three-layer wavelet packet decomposition is used to obtain wavelet packet decomposition coefficients from low frequency to high frequency. Rolling bearing raw vibration signals are firstly decomposed into the wavelet signals of different frequency bands, then different frequency band signals are reconstructed respectively to extract energy features, which form feature vectors as the model input of GMM-HMM. A large number of samples are trained to get model parameters for different bearing faults, then several groups of test data are adopted to verify GMM-HMMs so different fault types of rolling bearings are recognized. By calculating the current state appearance probability of monitoring data in GMM-HMMs, different failure patterns are recognized and evaluated from the maximum probability. Similarly, we establish GMM-HMMs for different grade fault samples and evaluated the performance degradation state. Test results show that the proposed fault diagnosis approach can identify accurately the fault pattern of rolling bearings and evaluate performance degradation of bearings.

1. INTRODUCTION

Safe and reliable operation of the mechanical equipment has aroused wide attention and great interest of researchers in recent years, so we usually carry on condition monitoring, fault diagnosis of early stages, and failure identification and prediction to ensure safe and reliable operation of the mechanical equipment. Rolling bearings are key components of rotating machinery; the fault and failure of rolling bearings can cause abnormal vibration and noise, even direct destruction for mechanical equipment, and affect safe and reliable operation. According to statistics, among the rotating machinery about 30% of mechanical failures are associated with rolling bearing damages.1 The diagnosis technology on rolling bearing fault has always been a hot spot for many research scholars. Xia Ruixia applied time domain analysis method to feature vector extraction of rolling bearing vibration signal and developed fault diagnosis technology for rolling bearings.2 Huang Zhonghua proposed a fault diagnosis method of rolling bearings with Hilbert transformation considering the modulation feature of vibration signal.3 In order to solve the application problem of traditional resonance demodulation technique, which is seriously impacted by the low signal to noise ratio of rolling bearing original vibration and the choice of filter parameters depending on manipulator’s subjective experience, Zhou Zhi presented the method of combining adaptive noise reduction with adaptive resonance demodulation.4 These studies have made some progress, but they still fail to break through these disadvantages of time domain analysis, which has lower frequency resolution at high frequencies and has poor temporal resolution at low frequencies.5 Wavelet analysis is a localized method of time frequency analysis, and it can gradually make the signal refined on multi-scale by the telescopic pan operations and ultimately achieve time segments at high frequency and frequency segments at low frequency, which can automatically adapt to the requirements of frequency signal analysis.6