Vibration based Diagnosis of Rolling element bearings —Diagnosis based on HMMs

1 Background and objective

As crucial components, rolling bearing serve in all kinds of rotating mechanical systems, e.g., wind turbine, aerospace, transportation etc. Therefore the diagnosis of bearing and guarantee of its normal performance are very important for the industrial operation[1]. The vibration signal of faulty bearing will appear the repetitive transient pulses contaminated with additive noise. The transient pulse is often due to faulty point passing through the load zone, which is followed by the oscillations with decaying low-frequency specified by the excited structural resonances. Whereas, the additive noise comes from a variety of interfering sources, such as, channel effects or device defects, system tremor, environmental interference, etc[2]. Due to the structure of the bearing and additive noise inference, this kind of repetitive pattern tend to stochastic and non-stationary, especially, in high frequency range dominantly, which bring difficulties to analyze. Therefore recognizing that kind of transient from non-stationary signals needs helps from stochastic models. Statistical methodology for identifying periodicities in time series can provide meaningful information about the underlying physical process. The objective of this thesis is to present an integrated auto-diagnostic framework that includes detection, identification, and characterization, which is based on one kind stochastic model.

2 Measurement and modelling

The bearing vibration is a complex process that often contains uncertainty and randomness. The short-time spectral-analysis method is a good measuring tool to quantify the properties of the non-stationary signal. It is performed mainly by successively placing windows over the signal, and then the spectral-analysis method is applied to window signal to produce a detailed representation of the spectral properties of the non-stationary signal. In which, the signal in one window is considered to be stationary. The spectral feature vector has proved extremely useful to extract the time-frequency information, which can be attributed both to the theoretical basis of spectral-analysis techniques developed, as well as to the completeness representation of the signal information[3]. Therefore, the short-time spectral-analysis method will be used as the first measurement tool for the vibration signal, and transfer the time domain signal into a sequence of time-frequency features. After obtain these features, we need to deal with them through one stochastic model. The reason for selecting stochastic model is the non-stationary phenomenon may undermine the foundational assumption of the deterministic models, whereas stochastic models, based on probabilistic statements, are able to cope with such complexity and flexibility. Hidden Markov model (HMM)[4-6] is a statistics-based time series analysis model, which can reveal the transition regularity of the state hidden in the observation samples. In the modelling, we often call this short-time spectral vector as observation. Each observation has one corresponding hidden state indicating its character. We can model the time-frequency spectral vector sequence in terms of Markov chain that describes the ways one state changes to another. The basic theoretical strength of the HMM is that it combines modeling of stationary stochastic processes (for the short-time spectra) and the temporal relationship among the processes (via a Markov chain) together in a well-defined probability space.

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