High-Resolution Envelope Analysis Using Sparse Semi-Parametric Spectral Estimators

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Spectral analysis of vibration signals plays a crucial role in the majority of existing condition monitoring schemes. A commonly employed spectral analysis tool for vibration-based diagnosis of machine defects is envelope analysis. The envelope of a vibration signal allows for a straightforward analysis of the modulations present in a signal. It is thus often used for the early detection of modulating fault signatures as typically introduced by gear or bearing faults. The squared envelope spectrum employs the Discrete Fourier Transform or DFT for generating the amplitude modulation spectrum containing information about the dominant modulating frequencies. While the DFT is an easy-to-interpret non-parametric spectral estimator with low computational complexity and no model assumptions, it does suffer from leakage effects reducing the frequency resolution for low-frequency or closely spaced peaks. However, such peaks are often encountered in large, complex industrial machinery as they typically consist of many different subcomponents that can rotate at slow speeds. This work investigates the potential of using sparse semi-parametric spectral estimators as an alternative to the DFT for envelope analysis. This type of spectral estimators offers a reduction in leakage effects in exchange for a higher computational complexity. This work investigates the performance of the iterative adaptive approach and sparse iterative covariance-based estimator for high-resolution envelope analysis. These two methods are examined on both simulated and experimental vibration data and compared to the DFT with regard to characteristic frequency tracking.