Cyclo-non-stationary analysis for bearing fault identification based on instantaneous angular speed estimation

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Problem statement

The Instantaneous Angular Speed (IAS) is one of the most important parameters to measure alongside mechanical vibration for vibration condition monitoring as an indicator of the health of the machine. However, the speed measurement is sensitive to disturbances like loss of samples or artifacts [2]. Alternatively, the IAS can be extracted directly from the vibration signal, being this the most difficult situation. Due to the multi-component nature of the signals where different families of harmonics may coexist. The interaction between the orders and the structural resonances of the machine, and the low Signal to Noise Ratio (SNR) where noise comprises any component in the signal which is not of direct interest for the analysis [3]. Nevertheless, the acquisition of vibration signals is non-destructive but not necessarily non-invasive, because, to implementing it is mandatory to stop the machine. An alternative entirely non-invasive approach is to use acoustic signal, due to the sensors offer a non-contact measurement [4]. Nonetheless, acoustic signals are more susceptible to environmental noise than vibration ones, making necessary to utilize signal preprocessing techniques that reduce the undesirable interferences and improve the low signal-to-noise ratio (SNR)[5].

Objectives

- To extend the vibration based methods for instantaneous angular speed estimation to acoustic signals.

- To highlight and identify a bearing fault signal from a measurement under varying speed, grounded on the cyclo-stationary theory.

Approach

For the first objective, as we will deal with low SNR in acoustic signals, our approach must be stochastic. For such reason, the starting point will be parametric methods based on Bayesian inference, but those methods usually assume stationarity, a condition that is not fulfilled by vibration nor acoustic signals under varying speed. Consequently, an extension to the non-stationary case should be proposed.
It will also be studied the relationship between the stationarity of a signal and the eigenvalues of its autocorrelation and spectral correlation matrices, to establish a link between the variation of the IAS and the stationarity of a signal of a rotating machine. With a robust indicator developed from the above-mentioned relationship, we should be able to formulate an IAS extraction algorithm able to distinguish the orders from other components such as, resonances, or external interferences.
The second objective has been widely studied in the state-of-the-art for the constant speed scenario, and an extension to the varying speed case is recently proportioned in [6]. Consequently, for this objective, our approach will be to implement, to evaluate and to adapt different state-of-the-art techniques, to be able to deal with low SNR, and variable speed as to be expected in industrial environments.

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