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”JJCAB1#7 - A multi order synchro-squeezing transform approach for instantaneous angular speed estimation”

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Under non-stationary conditions, estimating the Instantaneous Angular Speed (IAS) of rotating machines from vibration measurements is a practical way for encoder-free condition monitoring. The Phase Demodulation (PD) and the Multi Order Probabilistic Approach (MOPA) are arguably the most popular techniques used in this context. Although they both offer a straightforward approach to determine accurately the IAS of a rotating machine, they still present some limitations that can hinder the estimation accuracy and its overall reliability. On the one hand, PD relies on the presence of a single harmonic with a high signal-to-noise ratio (SNR) for the full duration of the measured vibration signal, which is sometimes not satisfied and, consequently, limiting its applicability for a generic speed estimation scheme. On the other hand, MOPA determines the IAS via probability density functions that are constructed from the Time-Frequency Representation (TFR) of the signal followed by an a priori continuity concept that degrades the estimation resolution due to Gaussian smoothing. In this paper, we propose a novel Multi Order Synchro-squeezing Transform (MOST) approach for estimating the IAS in low SNR conditions without compromising the angular resolution. Therefore, it addresses the limitations of PD and MOPA by providing a more accurate method for estimating the IAS under non-stationary conditions. Firstly, the proposed method provides a preliminary estimation of the instantaneous speed for frequency reallocation in the signal's TFR; then it defines a normalized threshold to preserve the corresponding energy in the TFR at each bin of time. Secondly, the probability density functions are constructed using multiple harmonics, benefitting from the repetitive profile of the IAS. Finally, an automatic setting is proposed to keep the useful information of given harmonics and neglect the noisy ones. The proposed method is thoroughly investigated by assessing its performance on a vibration signal of a turbojet engine.

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