Rolling Bearing Fault Detection in the Initial Stage of Degradation Based upon Optimized NLM and TKEO

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During the operation of rolling bearings, vibration signals contain abundant state information, which exhibits strong nonstationarity and nonlinearity. It is always arduous to detect the initial damage point during the lifetime. Non-local means (NLM) algorithm can suppress noise and highlight the components of the fault impact, but the problem lies in the determination of parameters which directly affect the result. In this paper, we proposed a signal processing method combined NLM optimized by Fruit fly Optimization Algorithm (FOA) and Teager Kaiser energy operator (TKEO) to detect the initial stage degradation of bearings. First of all, the proposed optimal NLM algorithm is used to denoise the bearing vibration signals which are gathered in the initial stage of bearing degradation. Then, the TKEO algorithm is applied to suppress the non-impulsive components and the periodic impulsive characteristics of the denoised signals are enhanced simultaneously. Furthermore, the analysis of the frequency components in the Teager energy spectrum is conducted to detect whether the bearings are abnormal or not. Experimental and comparative analyses are presented to validate the proposed method in the end.

1. INTRODUCTION

Rolling bearing is one of the most widely used rotating components at present. It plays an important role as “mechanical joints” in electromechanical equipment and weapon equipment. Unfortunately, rolling bearing is usually vulnerable due to the disadvantageous operation environment, so it is important to find out the hidden damage in it.1 Condition Based Maintenance (CBM) is a kind of popular maintenance method in recent years. This method can detect abnormalities and figure out whether there is tendency to malfunction according to the real-time state monitoring data so as to take further maintenance and preventive measures.2 If the damage of the rolling bearing can be detected as soon as possible, there will be enough time to work out reasonable maintenance program to further ensure the safe and reliable operation of the equipment.

The vibration signal of the rolling bearing contains abundant state information, which shows strong non-stationary and non-linear characteristics. And it is influenced by the complex vibration transmission path, serious noise disturbance, the coupling of multi-vibrational source excitation and response and other factors.3 Especially in the early stage of bearing degradation, the shock signal caused by structural damage is difficult to detect.4 Fast Kurtogram (FK) method processes signals through a pass-band filter, which is simple and convenient to be applied in vibration signal denoising.5 However, it should be realized that FK has a limited range of possible centre frequencies particularly when the bandwidth is wide.6 Meanwhile, there is a limitation to the accuracy improvement of extracting transient characteristics from noisy signals and recognizing machinery fault with the kurtogram method.7 As a new denoising method, non-local means (NLM) algorithm has the advantages of simple calculation, no iteration and positive performance. Therefore, it has gradually become a hotspot research topic in image processing8 and biomedical.9 However, this algorithm is still in its infancy in the processing of one-dimensional vibration signals. Combining NLM with Empirical Mode Decomposition (EMD), Mien et al.10 firstly applied NLM in the field of vibration signals and the bearing fault diagnosis was realized. Lv et al.11 diagnosed rolling bearing fault successfully by fast NLM algorithm with the envelope spectrum analysis. Zhu et al.12 combined NLM and Local Mean