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A new strategy of using a time-varying structure element for mathematical morphological filtering

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Abstract: This paper presents a novel signal processing scheme, namely time-varying morphological filtering (TMF), for rolling element bearing fault detection. In contrast with the multiscale morphological filtering (MMF) method, the structure element (SE) used in TMF is no longer fixed. It adjusts adaptively according to the extreme points of a signal so that the raw signal can be fit more accurately. In addition, the MMF needs to execute morphological operations multiple times, whereas the TMF can finish the filtering in one time operation. Consequently, TMF has a significant advantage in terms of computation efficiency. Experimental vibration signals collected from a bearing test rig are employed to evaluate the effectiveness of TMF. The results show that the proposed method can extract fault features of defective rolling element bearings with high computational efficiency. Moreover, five SEs are compared for TMF. The results show that the Dolph-Chebyshev SE performs best.

Keywords: morphological filtering, multiscale filtering, time-varying filtering, structure element, rolling element bearing, fault diagnosis

1. Introduction

Mathematical morphological filtering is a nonlinear filtering method that has been widely applied in machinery fault detection in recent years [1-18]. In contrast to the joint time-frequency domain signal analysis methods, such as wavelet transform and Hilbert-Huang transform, mathematical morphological filtering provides an alternative means of extracting impulse features purely based on time domain signals.

The main idea of morphology filter can be described as follows: it first selects a data set called a structure element (SE). Then, morphological operations are performed between the raw signal and selected SE to modify the geometric shape of the raw signal for the purpose of removing noise and extracting useful information.

At the early stage of the morphological filtering study, a single-scale analysis with a fixed length of SE was utilized. However, the single-scale analysis may suffer from the lack of completeness in the extracted impulsive features [7]. Later,

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