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Virtual prototype and experimental research on gear multi-fault diagnosis using wavelet-autoregressive model and principal component analysis method

Zhixiong Li [a,b], Xinping Yan [a,b,*], Chengqing Yuan [a,b], Zhongxiao Peng [c], Li Li [d]

[a] Reliability Engineering Institute, School of Energy and Power Engineering, Wuhan University of Technology, Wuhan 430063, China
[b] Key Laboratory of Marine Power Engineering and Technology (Ministry of Transportation), Wuhan University of Technology, Wuhan 430063, China
[c] School of Engineering & Physical Sciences, James Cook University, Townsville, Qld. 4811, Australia
[d] Hubei Key Laboratory of Hydroelectric Machinery Design & Maintenance, China Three Gorges University, Yichang 443002, China

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ABSTRACT

Gear systems are an essential element widely used in a variety of industrial applications. Since approximately 80% of the breakdowns in transmission machinery are caused by gear failure, the efficiency of early fault detection and accurate fault diagnosis are therefore critical to normal machinery operations. Reviewed literature indicates that only limited research has considered the gear multi-fault diagnosis, especially for single, coupled distributed and localized faults. Through virtual prototype simulation analysis and experimental study, a novel method for gear multi-fault diagnosis has been presented in this paper. This new method was developed based on the integration of Wavelet transform (WT) technique, Autoregressive (AR) model and Principal Component Analysis (PCA) for fault detection. The WT method was used in the study as the de-noising technique for processing raw vibration signals. Compared with the noise removing method based on the time synchronous average (TSA), the WT technique can be performed directly on the raw vibration signals without the need to calculate any ensemble average of the tested gear vibration signals. More importantly, the WT can deal with coupled faults of a gear pair in one operation while the TSA must be carried out several times for multiple fault detection. The analysis results of the virtual prototype simulation prove that the proposed method is a more time efficient and effective way to detect coupled fault than TSA, and the fault classification rate is superior to the TSA based approaches. In the experimental tests, the proposed method was compared with the Mahalanobis distance approach. However, the latter turns out to be inefficient for the gear multi-fault diagnosis. Its defect detection rate is below 60%, which is much less than that of the proposed method. Furthermore, the ability of the AR model to cope with localized as well as distributed gear faults is verified by both the virtual prototype simulation and experimental studies.

1. Introduction

As a key component of rotating machinery, gears are mostly subjected to progressive deterioration due to severe working conditions [1]. The condition of a gear will directly affect the normal running of the machine or even the entire

* Corresponding author at: Reliability Engineering Institute, School of Energy and Power Engineering, Wuhan University of Technology, Wuhan 430063, China. Tel.: +86 13667123462.
E-mail address: lzx___520@163.com (X. Yan).

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