Expert Systems with Applications 37 (2010) 4568–4579

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Application of mother wavelet functions for automatic gear and bearing fault diagnosis

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ARTICLE INFO

Keywords:
Condition monitoring
Fault detection and diagnosis
Feature extraction
Mother wavelet
Daubechies 44 (db44)
Gear
Bearing
Vibration signal
Fourth central moments

ABSTRACT

This paper introduces an automatic feature extraction system for gear and bearing fault diagnosis using wavelet-based signal processing. Vibration signals recorded from two experimental set-ups were processed for gears and bearing conditions. Four statistical features were selected: standard deviation, variance, kurtosis, and fourth central moment of continuous wavelet coefficients of synchronized vibration signals (CWC-SVS). In this research, the mother wavelet selection is broadly discussed. 324 mother wavelet candidates were studied, and results show that Daubechies 44 (db44) has the most similar shape across both gear and bearing vibration signals. Next, an automatic feature extraction algorithm is introduced for gear and bearing defects. It also shows that the fourth central moment of CWC-SVS is a proper feature for both bearing and gear failure diagnosis. Standard deviation and variance of CWC-SVS demonstrated more appropriate outcome for bearings than gears. Kurtosis of CWC-SVS illustrated the acceptable performance for gears only. Results also show that although db44 is the most similar mother wavelet function across the vibration signals, it is not the proper function for all wavelet-based processing.

1. Introduction

Gears and bearings are important machine components in condition monitoring. In condition monitoring between vibration (Boulahbal, Golnaraghi, & Ismail, 1999; Dalpiaz, Rivola, & Rubini, 2000) and acoustic measures (Apostoloudia, Douka, Hadjileontiadis, Rekanos, & Trochidis, 2007; Lin, 2001), vibration signals have shown satisfactory results and are applicable in noisy industrial factories. Intelligent vibration monitoring is on-going research for automatic fault detection and diagnosis of mechanical systems, particularly to identify the incipient failures because of the complexity of the vibration signals.

To inspect raw vibration signals, a wide variety of techniques have been introduced that may be categorized into two main groups: classic signal processing (McFadden & Smith, 1984) and intelligent systems (Paya, Esat, & Badi, 1997). To make mention of a few, FFT (Kar & Mohanty, 2006), Wigner–Ville distribution (Baydar & Ball, 2001; Zou & Chen, 2004), wavelet (Newland, 1994; Wang & Gao, 2003), Hilbert–Huang transform (Peng & Chu, 2004), blind source separation (Tse, Zhang, & Wang, 2006), statistical signal analysis (Jardine, Lin, & Benjevic, 2006), and their combinations (Fan & Zuo, 2006; Farina, Lucas, & Doncarli, 2008) are classic signal processing methods. ANN-based (Paya et al., 1997). GA-based (Samanta, 2004), FL-based (Saravanan, Cholairajan, & Ramachandran, 2009), various similar classifiers (Saravanan, Kumar Siddabattuni, and Ramachandran (2008)), expert systems (Ebersbach & Peng, 2008), and combined algorithms (Rafiee, Tse, Harifi, & Sadeghi, 2009; Wu, Hsu, & Wu, 2009) could be classified as intelligent systems. Currently, industrial applications of intelligent monitoring systems have been increased by the progress of intelligent systems.

One of the most significant issues in intelligent monitoring is related to feature extraction. This research mainly focuses on finding applicable features for bearing and gear fault detection and diagnosis. Wavelet transform (WT), capable of processing stationary and non-stationary signals in time and frequency domains simultaneously, was used for feature extraction (Daubechies, 1991). Despite the amount of previous research on wavelet transform, the selection of the mother wavelet function, which is a significant topic in signal analysis, is open to question. WT can be mainly divided into discrete and continuous forms. The former is faster with lower CPU time, but continuous forms are more efficient since there is good resolution throughout the signals.

The dominant contributions to optimum mother wavelet selection can be found in literature (e.g. Ahuja, Lertrattanapanich,

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doi:10.1016/j.eswa.2009.12.051

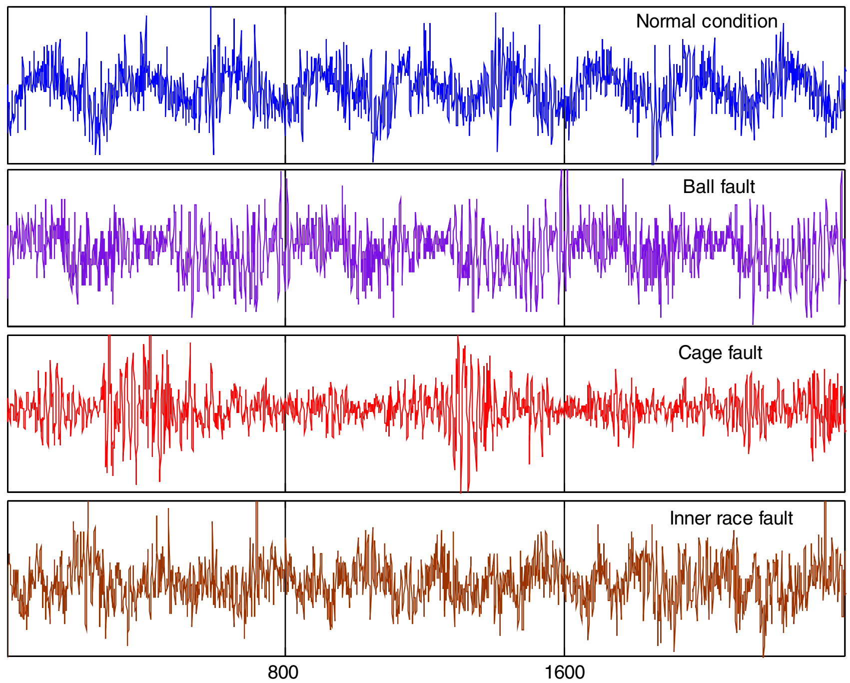

Fig. 1. Three segmented signals recorded in four bearing conditions (*X*-axis: number of datapoints–time, *Y*-axis: amplitude).

& Bose, 2005; Brechet, Lucas, Doncarli, & Farina, 2007; Flanders, 2002; Singh & Tiwari, 2006; Tse, Yang, & Tam, 2004). Although application of Daubechies wavelets (db) has been referred to in several papers, low-order db (db1–db20) (Wu & Liu, 2007) are generally used, and the application of high-order db is rare (Antonino-Daviu, Riera-Guasp, Folch, & Palomares, 2006). In this research, we have focused on 324 candidate mother functions from different families to understand their behaviors for gear and bearing fault diagnosis. Then, a wavelet-based automatic feature extraction system, applicable for intelligent systems (Rafiee, Arvani, Harifi, & Sadeghi, 2007), is presented for gears and bearings faults.

2. Developed algorithm

The research follows these steps:

(1) For gear defects, raw vibration signals were recorded from a motorcycle gearbox in four conditions including: normal gearbox (NG), broken-tooth gear (BT), slight-worn gear

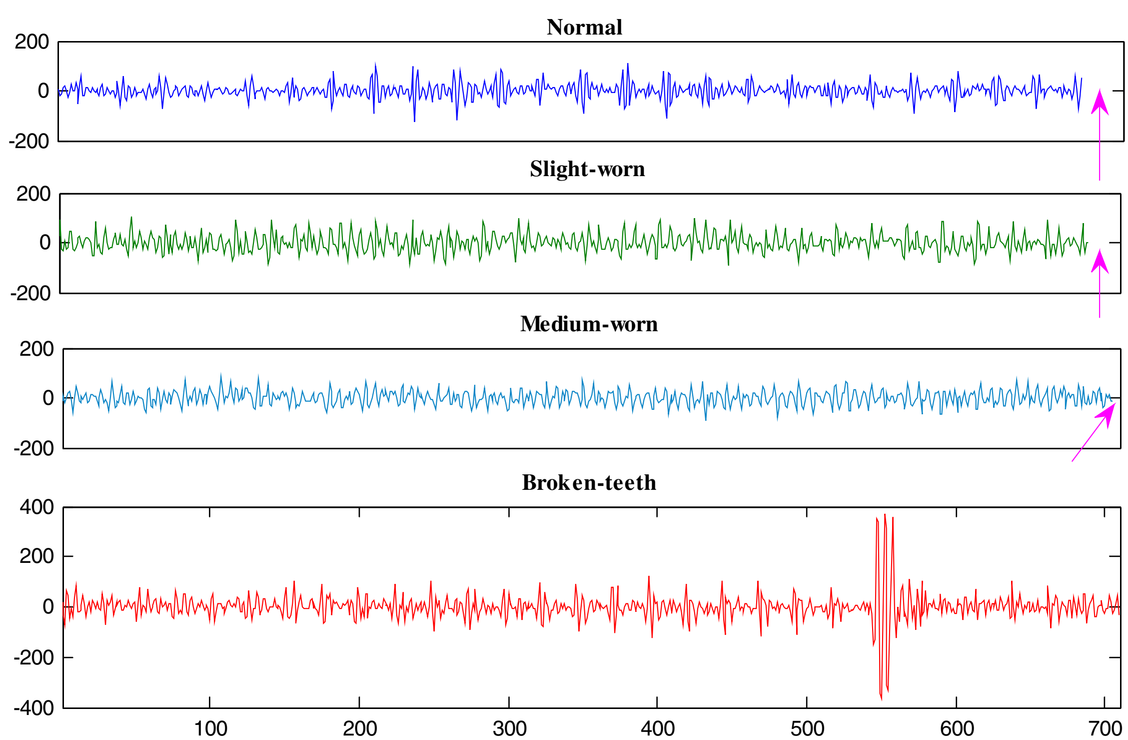

Fig. 2. Non-synchronous gearbox vibrations in one sample signal (*X*-axis: number of samples–time, *Y*-axis: amplitude).