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Gear fault diagnosis using active noise cancellation and adaptive wavelet transform

D.P. Jena, Sudarsan Sahoo, S.N. Panigrahi *

Sense & Process (SnP) Laboratory, School of Mechanical Sciences, Indian Institute of Technology Bhubaneswar, Bhubaneswar 751013, India

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ABSTRACT

Acoustic signal from a gear mesh with faulty gears is in general non-stationary and noisy in nature. Present work demonstrates improvement of Signal to Noise Ratio (SNR) by using an active noise cancellation (ANC) method for removing the noise. The active noise cancellation technique is designed with the help of a Finite Impulse Response (FIR) based Least Mean Square (LMS) adaptive filter. The acoustic signal from the healthy gear mesh has been used as the reference signal in the adaptive filter. Inadequacy of the continuous wavelet transform to provide good time–frequency information to identify and localize the defect has been removed by processing the denoised signal using an adaptive wavelet technique. The adaptive wavelet is designed from the signal pattern and used as mother wavelet in the continuous wavelet transform (CWT). The CWT coefficients so generated are compared with the standard wavelet based scalograms and are shown to be apposite in analyzing the acoustic signal. A synthetic signal is simulated to conceptualize and evaluate the effectiveness of the proposed method. Synthetic signal analysis also offers vital clues about the suitability of the ANC as a denoising tool, where the error signal is the denoised signal. The experimental validation of the proposed method is presented using a customized gear drive test setup by introducing gears with seeded defects in one or more of their teeth. Measurement of the angles between two or more damaged teeth with a high level of accuracy is shown to be possible using the proposed algorithm. Experiments reveal that acoustic signal analysis can be used as a suitable contactless alternative for precise gear defect identification and gear health monitoring.

1. Introduction

Every dynamic mechanical system generates sound pressure which carries its dynamic signature predominantly. However, the acoustic signature gets corrupted with peripheral noise, including noise from any defective components of the same system. So this challenge still draws the attention from researchers to establish an appropriate technique to identify and measure the defect of a rotating system using acoustic signal. Gear is one of the major component in rotating system and hence gear defect identification and measurement using acoustic signal is the focus of the present work.

Gear fault diagnosis using acoustic emission (AE) has been widely appreciated by many researchers [1]. Frequency domain analysis has been well recognized in machine condition monitoring such as gear and bearing faults. However, the time–frequency analysis, specifically, continuous wavelet transform has been implemented for fault analysis in detail [2]. One can find quite a few reports on various signal processing techniques, defect types and defect scenarios of gears by many researchers [3,4]. Wu et al. (2009) have reported the effectiveness of discrete wavelet transform (DWT) in detecting the abnormal transient signals in terms of the data quantity and energy difference, which helps in indicating the presence of the

* Corresponding author. Tel.: +91 674 2306 271; fax: +91 674 2301 337.
E-mail address: psatyan@iitbbs.ac.in (S.N. Panigrahi).

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gear fault [5]. Zhu et al. (2009) have analyzed transient vibration signals of automotive gearbox using continuous wavelet transform (CWT) and K–S test for fault diagnosis [6]. Ma et al. (2012) have conceptualized the analytical model of gear tooth failure and investigated experimentally and reported the double impulse phenomena in case of multiple teeth failure in gears [7]. Many investigators have demonstrated the importance of the appropriate wavelet function selection in CWT for fault diagnosis [8,9]. From literature study, it is concluded that wavelet

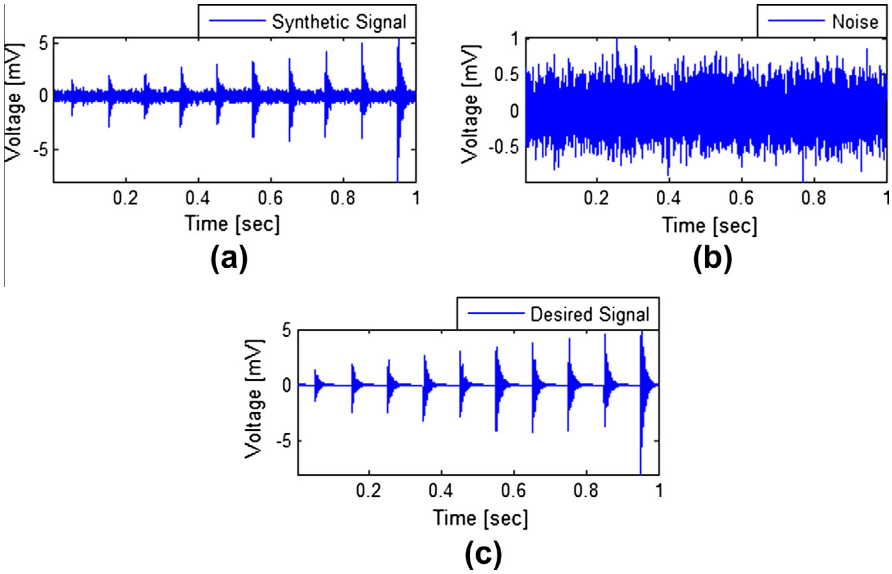

Fig. 1. Synthetic signal used for the performance analysis of the proposed method; (a) synthetic signal $X(n)$, (b) reference Gaussian signal $G(n)$ and (c) desired signal $x(n)$.

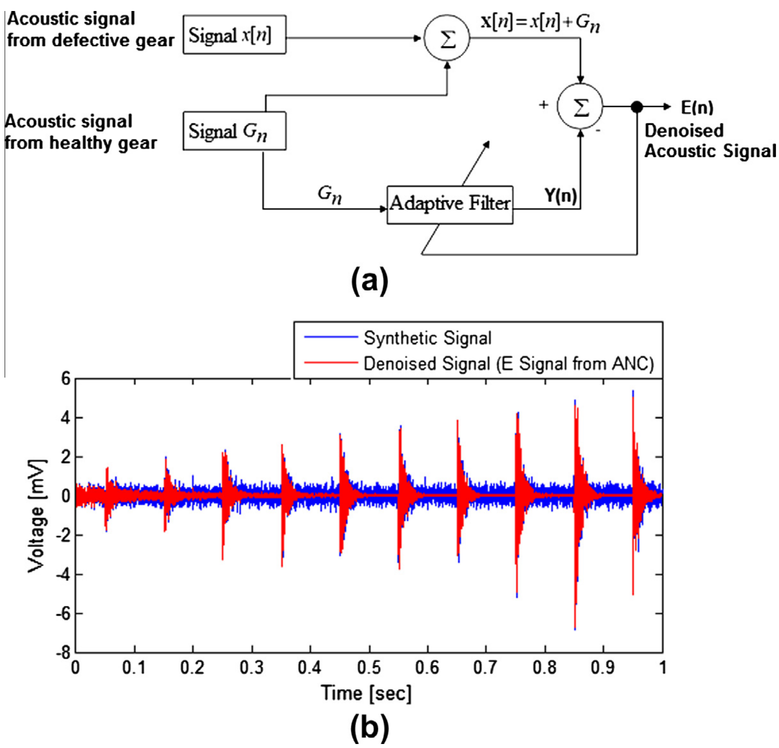

Fig. 2. Active noise cancellation of synthetic signal $X(n)$; (a) schematic of active noise cancellation and (b) error signal $E(n)$ (denoised signal) from ANC overlapped with synthetic signal $X(n)$.