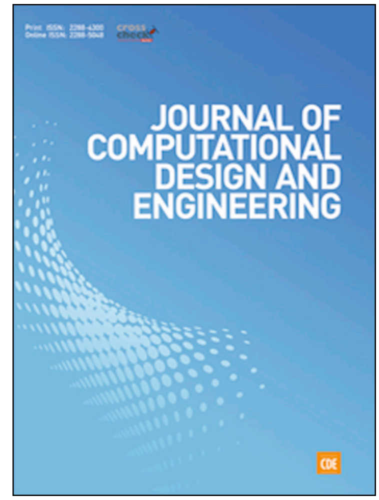
Accepted Manuscript



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PII: S2288-4300(17)30019-2
DOI: http://dx.doi.org/10.1016/j.jcde.2017.05.002
Reference: JCDE 94

To appear in: *Journal of Computational Design and Engineering*

Received Date: 25 February 2017
Revised Date: 15 May 2017
Accepted Date: 17 May 2017

Please cite this article as: S. Tyagi, S.K. Panigrahi, An improved envelope detection method using Particle Swarm Optimisation for rolling element bearing fault diagnosis, *Journal of Computational Design and Engineering* (2017), doi: http://dx.doi.org/10.1016/j.jcde.2017.05.002

Journal of Computational Design and Engineering

An improved envelope detection method using Particle Swarm Optimisation for rolling element bearing fault diagnosis

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Received 00 000, 0000; received in revised form 00 000, 0000; Accepted 00 000, 0000

Abstract

Traditionally Envelope Detection (ED) is implemented for detection of rolling element bearing faults by extracting the envelope of band-passed vibration signal and thereafter taking its Fourier transform. The performance of ED is highly sensitive to the envelope window (i.e. central frequency and bandwidth of the passband). This paper employs Particle Swarm Optimisation (PSO) to select the most optimum envelope window to band pass the vibration signals emanating from rotating driveline that was run in normal and with faults induced rolling element bearings. The envelopes of band-passed signals were extracted with the help of Hilbert Transform. The performance of ED whose envelope window was optimized by PSO to identify various commonly occurring bearing faults such as bearing with Outer Race Fault (ORF), Inner Race Fault (IRF) and Rolling Element Fault (REF) were checked under varying load conditions. The performance of 'ED enhanced by PSO' was also checked with increase in the severity of defect. It was shown that the improved ED method is successfully able to identify all types of bearing faults under different load conditions. It was shown that the by selecting envelope window by PSO makes ED especially useful to identify bearing faults at the incipient stage of defect. It was also shown by presenting comparative performance that by optimizing the envelope window by PSO the performance of ED gets significantly enhanced in comparison to the traditional ED method for bearing fault diagnosis.

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Keywords: Envelope Detection (ED); Particle Swarm Optimisation (PSO); Hilbert Transform; rolling element bearing; Fault Diagnosis; High Frequency Resonant Technique (HFRT)

1. Introduction

Rolling element bearings or ball/roller bearings are most common machine component of any rotating machinery used in industry. Rolling element bearings endure heavy loads under industrial operating conditions and structural faults, such as wear, pitting, or spall may occur after a long period of running [1]. A defect in bearing if remain undetected would cause its break down and may ultimately cause catastrophic failure of the machinery. Therefore early detection of bearing defects is most important for effective condition monitoring of industrial plant.

Changes in vibration signals are often an indication that fault is developing in machinery. Measuring the vibration of machine with the help of accelerometer mounted on the bearing housing and monitoring changes in characteristic defect frequency is an established method for machinery fault assessment. However, it is difficult to identify the bearing defect frequency in vibration spectrum as common bearing defects are pits or spalls located at outer race, inner race and on the rolling element. These defects generate a series of impacts as rolling element passes over the defect due to the metal to metal contact. The resultant vibrations in time domain are sharp peaky bursts. It is difficult to identify the defect frequency in spectrum as these impact vibrations distributes their energy over wide range of frequencies; the bearing's characteristic defect frequency contains low energy [2] and hence it get masked by broadband noise and other low frequency effects.

Simple frequency domain or time domain analysis of raw vibration signal is unable to detect the ball bearing faults [3]. Various researchers have tried to solve this problem using wide range of techniques such as spectral kurtosis [4], improving the SNR by use of adaptive noise cancelling technique [5]. Wavelets have also been used for bearing fault diagnosis due to its ability of generating multi resolution analysis [6–8]. However, Envelope Detection (ED) also known as High Frequency Resonant Technique (HFRT) has been used most successfully for bearing fault detection over the years because the envelope signals provide much more diagnostic insight than the raw signals [9]. A reviews of Envelope Detection have been presented by Randall and Antony [1] and McFadden and Smith [10]. Every time a rotating elements passes over the defect on mating element, a pulse of short duration is generated that excites the resonances. This excitation happens periodically at the characteristic frequency that is related to the location of the defect. The resultant vibration is and amplitude modulated signal with resonant frequency as the carrier frequency whose amplitude is modulated at the characteristic defect frequency. By demodulating at one of these resonances, a signal indicative of the bearing condition can be obtained.

The ED technique involved bandpassing the vibration signal while keeping the central frequency of passband at one of the resonance and using the filter of bandwidth equal to 3 to 4 times the highest characteristic defect frequency of the bearing [10].

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Peer review under responsibility of Society for Computational Design and Engineering.