Mechanical Systems and Signal Processing 25 (2011) 803–811

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

journal homepage: www.elsevier.com/locate/jnlabr/ymssp

The combined use of order tracking techniques for enhanced Fourier analysis of order components

K.S. Wang*, P.S. Heyns

Dynamic Systems Group, Department of Mechanical and Aeronautical Engineering, University of Pretoria, Pretoria 0002, South Africa

ARTICLE INFO

Article history:
Received 2 April 2009
Received in revised form
30 July 2010
Accepted 11 October 2010
Available online 16 October 2010

Keywords:
Computed order tracking (COT)
Fourier analysis
Order tracking (OT)
Rotating machinery
Vold–Kalman filtering and computed order tracking (VKC-OT)
Vold–Kalman filter-based order tracking (VKF-OT)

ABSTRACT

Order tracking is one of the most important vibration analysis techniques for diagnosing faults in rotating machinery. It can be performed in many different ways, each of these with distinct advantages and disadvantages. However, in the end the analyst will often use Fourier analysis to transform the data from a time series to frequency or order spectra. It is therefore surprising that the study of the Fourier analysis of order-tracked systems seems to have been largely ignored in the literature. This paper considers the frequently used Vold–Kalman filter-based order tracking and computed order tracking techniques. The main pros and cons of each technique for Fourier analysis are discussed and the sequential use of Vold–Kalman filtering and computed order tracking is proposed as a novel idea to enhance the results of Fourier analysis for determining the order components. The advantages of the combined use of these order tracking techniques are demonstrated numerically on an SDOF rotor simulation model. Finally, the approach is also demonstrated on experimental data from a real rotating machine.

1. Introduction

Order tracking (OT) is one of the most important vibration analysis techniques for diagnosing faults in rotating machinery. The main advantage of OT over other vibration analysis techniques lies in the analysis of non-stationary noise and vibration, which vary in frequency with the rotation of a reference shaft or shafts. Order domain analysis relates the vibration signal to the rotating speed of the shaft, instead of to an absolute frequency base. In this way, the vibration components that are proportional to multiples of the running speed can easily be identified. OT can be performed in many different ways, each of these with distinct advantages and disadvantages.

Among the OT techniques, two approaches are frequently employed. The first is angle domain sampling-based order tracking (AD-OT) or computed order tracking (COT). Various papers discussing the theory and implementation of this approach are available (see for example the work by Fyfe and Munck [1]). The significance of AD-OT or COT is that the re-sampled data have the same properties as stationary frequency data, but the data still need to be processed further by Fourier analysis in terms of uniform angular intervals, instead of uniform time intervals. The re-sampling process is performed, however, subject to artificial assumptions for re-sampling the data, therefore unavoidable errors are introduced. Although COT has some limitations due to the re-sampling and the Fourier analysis process, it remains a very useful tool for analyzing rotating machinery signals in industry, as has indeed been demonstrated by authors such as Eggers et al. [2].

Another approach is what is called waveform reconstruction OT, a typical example of which is Vold–Kalman filter-based order tracking (VKF-OT). This approach to OT can overcome many of the limitations of other OT techniques, such as allowing

* Corresponding author. Tel.: +27 12 4203724; fax: +27 12 3625087.
E-mail address: keshengwang@gmail.com (K.S. Wang).

0888-3270/$ - see front matter
doi:10.1016/j.ymssp.2010.10.005