Gearbox Damage Diagnosis using Wavelet Transform Technique

Mohamed S. El-morsy

Department of Mechanical Design, Helwan University, Cairo, P.O box 11718, Egypt

Shawki Abouel-seoud

Department of Automotive Engineering, Helwan University, Cairo, P.O box 11718, Egypt

El-Adl Rabeih

Department of Mechanical Design, Helwan University, Cairo, P.O box 11718, Egypt

(Received 4 January 2009, revision received 18 May 2011, accepted 15 September 2011)

Vibration-based schemes are founded on the assumption that vibration signals from gearboxes measured using accelerometers reflect their condition accurately. A large number of vibration based techniques are used to make this reflection. They include various spectral analyses such as traditional Fourier transform, short-time Fourier transform, amplitude phase modulation and time synchronous averaging and non-parametric special estimation. Recently, Wavelet Transform (WT) has been proven to be more suitable for analysis of vibration signals, since most of the time-vibration signals have instantaneous impulse trains and exhibit a transient (non-stationary) nature. This paper uses an adaptive wavelet filter, based on the Morlet wavelet, applied on the torsional vibration data measured from a single-stage gearbox with artificially induced cracks in the gear. This is done to extract some parameters and check their diagnostic behavior in an effort to search for those with the most potential and appropriateness for future health monitoring schemes. The results demonstrate that the adaptive wavelet filter is found to be very effective in detection of symptoms from vibration signals of a gearbox with early tooth cracks. Moreover the influence of crack depth, speed, and load on the wavelet entropy are interduced. Multi-hour tests were conducted and recordings were acquired using torsional vibration monitoring. The transitions in the wavelet entropy values with the recording time were highlighted suggesting critical changes in the operation of the gearbox.

NOMENCLATURE

$g(t)$	Mother wavelet
$G(\omega)$	Fourier transform of $g(t)$
a	Scale parameter
b	Time translation
$\Delta f/f$	Relative frequency resolution
E_j	bEnergy of the individual daughter wavelet
E_{total}	Total energy of the signal
SWE	Sub-band wavelet entropy
Δt_g	The duration of the basic wavelet function
Δf_g	The bandwidth of the basic wavelet function
f	The wavelet frequency
f_x	The signal frequency
f_w	The sampling frequency of the analysing wavelet function
M	The number of samples used in the analysis
n_f	The number of frequency lines
Kurt(x)	Kurtosis of the signal
β	The shape of the daughter

1. INTRODUCTION

Machine fault diagnostics is a procedure of mapping the information obtained in the measurement space and/or features in the feature space to machine faults in the fault space. This mapping process is also called pattern recognition. Traditionally, pattern recognition is done manually with auxiliary graphical tools such as power spectrum graphs, phase spectrum graphs, cepstrum graphs, AR spectrum graphs, spectrograms, wavelet scalograms, wavelet phase graphs, etc. However, manual pattern recognition requires expertise in the specific area of the diagnostic application. Thus, highly trained and skilled personnel are needed. Therefore, automatic pattern recognition is highly desirable in diagnostics programs. This can be achieved by classification of signals based on the information and/or feature extracted from the signals. The most popular diagnostic approaches are statistical approaches and artificial intelligence approaches. Various topics in fault diagnosis with emphasis on practical issues were discussed.[1]

Recently, a lot of work has been done on the analysis of vibration signals in the time-frequency domain, with a view to combine the advantages of both time and frequency domain representation of a signal.[2] Undoubtedly, wavelet analysis has proved itself as the best time-frequency domain technique that keeps a good balance between time and frequency resolution. The most important feature of wavelet transform is its ability to characterize the local features of the signal at different scales. This is highly advantageous in examining a vibration signal from a rotating machine with faults, where either large scale or small scale change in the vibration may occur, corresponding to distributed damage or local damage respectively.[3]

So far, many different techniques have been proposed for the surveillance and diagnosis of the rotating machinery in the literature, such as critical discrete wavelet transform