Vibration-Based Bearing Fault Diagnosis by an Integrated DWT-FFT Approach and an Adaptive Neuro-Fuzzy Inference System

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Abstract—The rotating machine, which can be subject to breakdowns or dysfunctions in its time-of-use, represents an essential part in the majority of industrial applications. Hence, their reliability, productivity, safety and availability are very important issues that are imposed to increase production with quality assurance as per given specification at a reasonable cost. Furthermore, because the bearing faults are the most frequent and critical defects in rotating machinery that may have a direct influence on the availability of the machine itself and also on those of the surrounding systems, a particular interest is carried in this paper to the analysis and diagnosis of these defects which can appear in the bearing’s ball, inner race and outer race with various fault severity and rotating speed. This paper consists of the application of the Discrete Wavelet Transform DWT and Fast Fourier Transform FFT theories to extract the amplitude of the fundamental bearing defect frequencies in the vibration signal from a rotating machine. These parameters will be used by the Adaptive Neural Fuzzy Inference System ANFIS to automate the fault detection and diagnosis process. Experimental results show that the proposed procedure can classify with precision various types of bearing faults according to the fault location and severity.

Keywords—bearing faults; vibration signal; fault diagnosis; ANFIS; DWT; FFT

I. INTRODUCTION

Currently, more and more industrial production competition results in the machine tool community to identify the machine condition in order to achieve economic performance through increased availability and reduced component replacement costs through predictive maintenance. In fact, the early detection and diagnosis of any rotating machine malfunction and avoidance of breakdown caused by faulty components prior to a complete failure provides an opportunity for maintenance to be performed on a scheduled routine without the loss of production time. To serve this purpose, the online application of vibration signal analysis technique that can estimate the health state of rotating machinery during the entire duration of their operation has been found to be an efficient strategy [1]. In fact, the vibration analysis [2] is one of the most applied tools in the condition monitoring of rotating machines that starts, generally, by drawing a comparison between extracted useful features that can be related to the severity and type of bearing damage from both the historical measurements and recent values using some classifiers as in [3, 4]. For this purpose, three types of analysis can be used in: time domain, frequency domain and time-frequency domain.

Time domain approaches such as the time-series averaging method [5], the signal enveloping method [5, 6], the Kurtosis method [5, 7], and the spike energy method [5, 8] are based on the analysis of the vibration data as a function of time. The principal advantage of this type of analysis is that no data is lost prior to inspection. However, the disadvantage is that there is often too much data for easy and clear fault diagnosis [9]. Features are extracted from the time-domain representation of vibration signals such as peak value, mean, root-mean-square (RMS), kurtosis, crest factor, impulse factor, shape factor, and clearance factor.

The frequency domain analysis is the most popular and attractive approach. It provides more detailed information about the status of the machine than the time domain analysis. This advantage is due to the availability of Fourier transform technique, as characteristics of vibration signals are more easily noticed in the frequency domain rather than in the time domain analysis that can give qualitative information about the machine condition. The frequency domain methods often involve frequency analysis of the vibration signal and they consider the periodicity of high frequency transients. In those processes, the frequency domain methods search for a train of ringing occurring at any of the characteristic defect frequencies. These frequency domain techniques include the frequency averaging technique, adaptive noise cancellation [10], the bearing defect frequencies analysis method, [11], [4],[15], the enveloped spectrum analysis [12] that as presented by McFadden and Smith (1984) and the high frequency resonance technique HFRT [13], [14]. The main disadvantage of the frequency domain analysis is that it tends to average out transient vibrations and therefore becomes more sensitive to background noise. To overcome this problem, the time-frequency domain analysis can be used.

Time-frequency domain techniques use both time and frequency domain information allowing for the investigation of transient features. A number of time-frequency domain techniques have been proposed including the short time