Energy Distribution Analysis Regarding the Crack Size in a Rotating Shaft

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(Received 11 January 2016; accepted 24 June 2016)

Maintenance is critical to avoid catastrophic failures in rotating machinery, and the detection of cracks plays a critical role because they can originate failures with costly processes of reparation, especially in shafts. Vibration signals are widely used in machine monitoring and fault diagnostics. The most critical issue in machine monitoring is the suitable selection of the vibration parameters that represent the condition of the machine. Discrete Wavelet Transform, and one of its recursive forms, called Wavelet Packet Transform, provide a high potential for pattern extraction. Several factors must be selected and taken into account in the Wavelet Transform application such as the level of decomposition, the suitable mother wavelet, and the level basis or features. In this work, the dynamic response of a shaft with different levels of crack is studied. The evolution of energy of the vibration signals obtained from the rotating shaft and the frequencies where maximum increments of energy appear with the crack are analyzed. The results allow the conclusion that changes in energies computed by means of the Wavelet Packet Transform can be successfully used for crack detection.

1. INTRODUCTION

Great efforts have been made to understand the dynamic behavior of rotating machinery, most times using numerical models, as in the research of Felix et. al.[1] Special interest has been focused on the dynamics of cracked rotating machinery because crack detection in rotors is a very important subject in maintenance. Some states of art are dedicated to the effects of cracks in these elements.[2–4] Studies about the dynamics of cracked rotors have been carried out with different methods with the aim of selecting patterns able to detect fault conditions. It was highlighted by Bachschmid and Penacci that despite the high number of papers published in this area, it was not usual that they present experimental results.[5]

A review of crack identification in rotating shafts was made by Papadopoulos.[6] The diagnosis techniques were classified by applying either model-based or vibration methods.

Model-based methods considered loads in the place of the crack that generates the same effects as the crack does. These types of models were mainly based on information extracted from directly measured signals, signal models, and process models. That is the case of works such as Refs.,[7],[8] and.[9]

On the other hand, vibration methods were based in detecting variations in the response assigned to a crack. Sabnavis et. al. affirmed that 1x and 2x components experience very important changes at the steady state with the presence of a crack, however they were very hard to be detected in practice due to different factors, such as noise or assembly.[10] Signals analyzed by vibration methods can come from real systems as in the case of Ref. 2 or models, as in the cases of Refs. 10 and 1. The run up/down of a rotor has been studied in other works. It was affirmed in Ref.[11] that in a cracked rotor there was no certain critical speed, but a wide frequency band covering the critical speed where violent oscillations were observed. These oscillations can be used for crack detection.

In the last years, different technologies have been used to process signals coming from dynamical systems. Most authors used three approaches for the analysis of vibration signature:[12] time-domain approaches, based on statistical parameters such as mean, root mean square, variance, kurtosis,[13] frequency-domain approaches (based on Fast Fourier Transform (FFT)[14] and its variations),[15] and finally time-frequency analysis approaches, such as Wavelet Transform (WT).[16]

FFT and Hilbert transform have been traditionally used to observe changes in the response in eigenfrequencies when a crack appears.[17,18] However in the last years new techniques classified by Sabnavis et. al. as "non-traditional methods" have appeared.[10] Nowadays the most used technique to treat the signals is WT analysis.[15] WT was used due to its effectiveness treating non-stationary signals. A review of the applications of WT to fault diagnosis in machines was shown in Ref.[19] WT has been successfully applied for the case of bearings,[14] gears,[20] and beams.[21,22]

WT is the next step of FFT, because it gives information both in time and frequency domain, offering the proper treatment both for stationary and for non-stationary signals. However, WT has a disadvantage: the incapability for decomposing high frequency bands where information about faults can be located. The Wavelet Packet Transform (WPT) constitutes an improvement of WT, allowing the decomposition of all frequency bands and the location of the differences of cracked and healthy elements.[23] The applications of WPT are highly increasing and nowadays its use of diagnosing cracked rotating elements is spreading.[24,25] WPT coefficients can be directly used as features as they contain reliable information about faults,[25] nevertheless WPT normalized energy parame-