Automatic Selection of the WPT Decomposition Level for Condition Monitoring of Rotor Elements Based on the Sensitivity Analysis of the Wavelet Energy

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Vibration signals are a widely used technique for machine monitoring and fault diagnostics. However, it is necessary to select a suitable pattern that represents the condition of the machine. Wavelet Packet Transform (WPT) provides 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 which frequency bands (obtained from the decomposition process) contain the necessary information for the diagnosis system. The selection of the parameters commented above is a complex task that depends on many factors. Most of the works found in the literature select these factors based on experience, graphical methods, or trial and error methods. In this work, a method based on the relative wavelet energy is developed in order to automatically select the parameter defined by the WPT. The selection allows for the efficient extraction of the most suitable patterns for a later classification and fault detection process. In order to prove the soundness of the method proposed, a Jeffcott rotor model with four crack levels will be developed, and the vibratory signals provided by this model will be used for the monitoring condition.

NOMENCLATURE

WT	Wavelet Transform
FT	Fourier Transform
MRA	Multirresolution Analysis
ANN	Artificial Neural Network
CWT	Continuous Wavelet Transform
DWT	Discrete Wavelet Transform
WPT	Wavelet Packets Transform
Db6	Daubechies 6
RBF	Radial Basis Function Neural Network

1. INTRODUCTION

The study of the vibration signal is a main technique in the study and diagnosis of the failures in rotator and structural elements, which is one of the main objectives in condition-based maintenance. The concepts, procedures, and challenges of this kind of maintenance are consolidating for real industrial practice.[1] There are several methods focused in the fault detection, mainly with the intention of extracting behaviour patterns able to identify a failure. Among them, the Wavelet Transform (WT) is one of the techniques that has been adopted by a vast amount of applications, frequently replacing the conventional Fourier Transform (FT); however, sometimes it is still used in combination with other techniques as intelligent classifiers, as in the case of Wang and Chen.[2] Peng et al. carried out a bibliographical review on the application of WT on vibration signals to monitoring and fault diagnosis in machines.[3] Researchers such as Douka et al. have developed a method of crack identification for structures based on the continuous wavelet analysis.[4] Adewusi[5] presented an experimental study, using the wavelet analysis in vibratory signals provided by a rotor. In this previous work, the configuration was performed in a cantilever and with a V-notch of 4 mm, propagating a transversal crack.

Specifically for industrial maintenance, the diagnostics of cracked rotors is a critical subject. This area has focused the attention of many researchers in the last decades. A lot of studies about the dynamics of cracked rotating machinery have been carried out with different methods in order to detect the effects of cracks. Concretely, dynamics and modelling of cracked shafts have been highly developed; however, the inverse problem of the identification of cracks has not been commonly included.[6] A lot of studies have tried to characterize the behaviour of rotors.[7,8] Some wide reviews about the behaviour and modelling of cracked rotating machinery can be consulted,[9,10] as well as more recent studies about this issue.[11] The most common cracks are superficial and transversal that breathe, i.e, that open and close during rotation. There are a lot of theoretical works that propose models of the breathing phenomena.[6] Some classical approximations are the Gash function[12] and the Mayes and Davies function.[13] A review of the classical and modern breathing functions can also be consulted.[14]

Related to rotatory elements, WT theory combined with intelligent classification systems has been applied with success in the last decade in vibration signals from rotors[15] rolling bearing elements using the Continuous Wavelet Transform (CWT)[16] or Discrete Wavelet Transform (DWT).[17,18] In all cases, the selection of the mother wavelet for the transformation is carried out based on experience, and the test of the