Role of an Artificial Neural Network and a Wavelet Transform for Condition Monitoring of the Combined Faults of Unbalance and Cracked Rotors

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The vibration analysis of rotating machinery indicates the condition of potential faults such as unbalance, bent shaft, shaft crack, bearing clearance, rotor rub, misalignment, looseness, oil whirl and whip, and other malfunctions. More than one fault can occur in a rotor. This paper describes the application of an artificial neural network (ANN) and wavelet transform (WT) for the prediction of the effect of the combined faults of unbalance and shaft crack on the frequency components of the vibration signature of the rotating machinery. The experimental data of the frequency components and the corresponding root mean square (RMS) velocity (amplitude) data are used as inputs to train the ANN, which consists of a three-layered network. The ANN is trained using an improved multilayer feed forward back propagation Levenberg-Marquardt algorithm. In particular, the overall success rates achieved were 99.78% for unbalance, 99.81% for shaft crack, and 99.45% for the combined faults of unbalance and shaft crack. The wavelet transform approach enables instant to instant observation of different frequency components over the full spectrum. A new technique combining the WT with ANN performs three general tasks: data acquisition, feature extraction, and fault identification. This method is tested successfully for the individual and combined faults of unbalance and shaft crack at a success rate of 99.9%.

1. INTRODUCTION

In order to avoid the failure of various types of rotating machinery, including mechanical and electrical ones, using sophisticated instrumentation to monitor the conditions of various machine signatures has been found to be of considerable use. Vibration measurement and analysis has been applied with success[1] to machines such as steam and gas turbines, pumps, compressors, and induction motors. Faults such as unbalance, misalignment, looseness, rub, and cracks, generate vibration signals. In the present work, an experimental study has been carried out for a steady state response (constant speed of 1500 rpm) of the rotor for different unbalance masses and cracks on the rotor test rig. The vibration frequency components recorded in the horizontal, vertical, and axial directions for the analysis are applied. The experimental study has also been carried out to discover the difference in vibration characteristics due to the combined faults of unbalance and crack growth. The monitoring of the vibration of rotating machines has been reported as being a useful technique for the analysis of their condition.[2–5] Vibration condition monitoring as an aid to fault diagnosis is examined by Taylor (1995). Smalley and colleagues (1996) present a method of assessing the severity of vibrations in terms of the probability of damage by analyzing the vibration signals. Though the measured vibration signatures of frequency domain features are adequate to identify the faults, there is a need for a reliable, fast, and automated procedure of obtaining diagnostics.[6] Unbalance is an important cause of vibration in rotating machinery, and the reduction of such vibration by balancing needs attention. In this paper, the experimental studies are presented in the dynamic balancing of a flexible shaft using the four run method (FRM) (Mallik & Basu). The vibration frequency of rotor unbalance is synchronous, i.e., one time the shaft rotation speed (1X rpm). Rotor unbalance has been reported to appear occasionally in the frequency domain as a series of harmonics of the shaft running speed, i.e., 1X rpm, 2X rpm, 3X rpm, 4X rpm, etc[7] induction motors, etc.

1.1. Artificial Neural Networks

The neural network techniques are used in conjunction with signal analysis techniques for the classification and quantification of faults in some applications.[8] Kaminski has developed neural networks to identify the approximate location of damage due to cracks through the analysis of changes in the neural frequencies.[9] McCormick and Nandi use a neural network method for automatically classifying the machine condition from the vibration time series.[10] Vyas and Satish Kumar have carried out experimental studies to generate data for rotating machinery faults such as mass unbalance and bearing cap loose.[11] Srinivasan has carried out extensive studies on faults such as parallel misalignment, angular misalignment, unbalance, crack, light and heavy rubs, looseness, and bearing