Condition Monitoring of Rotating Machines Using the Artificial Intelligence and Vibration Analysis

By

WaelSaadyAbdEllateef Salman

A Thesis submitted to the
Faculty of Engineering-Shoubra atBenha University
in partial fulfillment ofthe
requirements for the degree of

Philosophy ofDoctor

In Mechanical Engineering

FACULTY OF ENGINEERING-SHOUBRA, BENHA UNIVERSITY
CAIRO-EGYPT

2021

Condition Monitoring of Rotating Machines Using the Artificial Intelligence and Vibration Analysis

By

WaelSaadyAbdEllateef Salman

A Thesis submitted to the
Faculty of Engineering-Shoubra atBenha University
in partial fulfillment ofthe
requirements for the degree of

Philosophy of Doctor

In

Mechanical Engineering

Under the Supervision of

Prof.AbdElkaderAbdElkareem Ibrahim

Professor
Mechanical Engineering Department
Faculty of Engineering - Shoubra,Benha University

Dr. Mahmoud Mohammed Elsamanty

Assistant Professor
Mechanical Engineering Department
Faculty of Engineering - Shoubra,BenhaUniversity
Smart Engineering Systems Research Center (SESC)
Faculty of Engineering, Nile University

FACULTY OF ENGINEERING-SHOUBRA, BENHA UNIVERSITY
CAIRO-EGYPT

2021

Condition Monitoring of Rotating Machines Using the Artificial Intelligence and Vibration Analysis

By

WaelSaadyAbdEllateef Salman

A Thesis submitted to the
Faculty of Engineering-Shoubra atBenha University
in partial fulfillment ofthe
requirements for the degree of

Philosophy of Doctor

In

Mechanical Engineering

Approved by the Examining Committee

Prof. Dr. AbdElkaderAbdElkareem Ibrahim, Thesis Main Advisor

Prof. Dr. Saber Mahmoud AbdRaboh, Internal Examiner

Prof. Dr.Aref Mohammed Ahmed Soliman, External Examiner

FACULTY OF ENGINEERING-SHOUBRA, BENHA UNIVERSITY
CAIRO-EGYPT

2021

Abstract

Condition monitoring of rotating machines is one of the most considered maintenance methods for detecting faults early to save maintenance cost and time and to increase the productivity. Nowadays, many effective techniques are established based on the assumption of stationary operating regime (i.e. load and/or speed). However, most rotating machines in the industry operate under non-stationary regimes to achieve the tasks for which they have been manufactured. These techniques, which are based on conventional analysis for vibration signals, fail to predict some types of fault initiated in the machine. The main goal of this research is to improve the condition monitoring methods for detecting faults in rotating machines operated with non-stationary regimes (i.e. variable operating speed and constant load). The proposed improvement was performed in two methods. Firstly, the conventional vibration evaluating parameter defined as the root mean square (RMS) of vibration time signal was employed to one against all multi-class support vector machine (OAAMCSVM) to classify and identify selected mechanical faults. Different kernel functions, such as linear, radial basis function (RBF), and polynomialfunctions, were used in the classification process to obtain a higher classification performance. It was found that OAAMCSVM can create a class for each type of fault (up to eight classes) and the highest classification performance can be obtained by using polynomial kernel function of degree 7. The second improvement method is based on data fusion for vibration and electrical signals and producing new fused signatures for healthy and different faulty cases. After that, the principal component analysis (PCA) was applied to reduce the dimensionality of vibration evaluating parameters and preserve as much of the data's variation as possible in a few principal components (PCs). Backpropagation neural network (BPNN) was trained based on the first and second PC which contained the almost data's variation. It was observed that the BPNN achieves the optimal training performance and regression for all healthy and faulty cases which displays the superior of data fusion solutions in condition monitoring of rotating machines.

Key Words: Condition Monitoring; Rotating Machines; Data Fusion; Principal Component Analysis; Multi-Class Support Vector Machine