Alexandria University
Faculty of Engineering
Production Engineering Department

Reliability Prognosis of Machine Elements

Thesis Submitted to the Production Engineering Department
Faculty of Engineering – Alexandria University
In partial fulfilment of the requirements for the degree of

Ph.D.
in
Production Engineering

By
Dalia Mostafa Ammar
M.Sc. Production Engineering – Alexandria University

August 2017

ABSTRACT

The present thesis is intended to establish a new methodology to predict the actual Remaining Useful Life (RUL) of rolling element bearings. RUL prediction is important for the measurement of reliability which is necessary for customer requirements compliance.The idea is to run an accelerated life test on a component and monitor the state of health of the component by recording its vibration signal. Features extracted from the vibration signal are used as inputs to an artificial neural network (ANN) whose output is the RUL. The first step to implement this methodology is to acquire actual vibration data of the bearing under accelerated life test (ALT).

An experimental setup has been designed and built to carry out accelerated life test of a deep groove ball bearing. The bearing was tested under different loads and speeds. The applied loads ranges between 2.5 to 3.2 times the rated bearing load. During each test the vibration signal in the time domain was collected. The overall level of the vibration signals was expressed in its Root Mean Square (RMS) values. The RMS values were used to construct the bathtub curve and to calculate the Euclidean distances. The Euclidean distance which is a measure of time to failure was also used to construct the degradation curves. The vibration signals were transformed to the frequency domain using both Fast Fourier Transform (FFT) and Discrete Cosine Transform (DCT). Dominant FFT harmonics and DCT coefficients were used as measures of the state of health of the test bearings.

An Artificial Neural Network (ANN) was developed to predict the RUL of the test bearing. Comparative study has been conducted between different types of the input features to the ANN which are the vibration signal in the time domain, the main harmonics of the bearing vibration signal expressed in a set of selected Discrete Cosine Transforms (DCT) coefficients, and the dominant harmonics of the vibration signal as expressed by Fast Fourier Transform (FFT), as a method for accurate RUL prediction of bearing expressed in the Euclidean distance. The Euclidean Distance was used for the validation of the ANN.

Three programs using MATLAB (R14) were prepared for training and testing the ANN depending on the nature and the number of the inputs. The error's percentage in each case was calculated. Based on the accelerated life test results, a model was developed to predict the life of the bearing under test.

Based on the ALT test, a model was developed to predict the bearing remaining useful life using the inverse power law.

Obtained results proved that: first, the proposed ANN predictor provided an effective tool for predicting the RUL of bearings using an accelerated life test, second, the input features in the case of FFT harmonics and DCT coefficients are more practical due to limited number of input features to the developed ANN- predictor, and finally, this new methodology can be implemented on different practical case studies in industry.