ON CONDITION-BASED MAINTENANCE FOR MACHINE COMPONENTS

Astrid Stenholm, Department of Automatic Control
Dennis Andersson, Department of Computer Science

Faculty of Engineering, Lund University

Introduction

In all industrial machines there are components that eventually will have to be replaced. Some of these components are more critical than others and if they fail during machine production it can lead to long downtime and high costs. To avoid these expensive breakdowns some components are being replaced on fixed intervals. Thus, this can lead to fully functional components being discarded despite having several operational hours left. In between running a component until it fails, called corrective maintenance, and replacing it on fixed intervals, called preventive maintenance, is condition-based maintenance (CBM). The goal of CBM is to collect information from the machine and make decisions regarding maintenance based on this information. The optimal goal of CBM is to be able to predict failures and schedule maintenance in time to avoid breakdowns and unnecessary discarding of components. The difference of these methods can be seen in *Figure 1*.

The work in this thesis was performed at a company which is interested in implementing CBM. This project should serve as a pre-study with the goal of implementing customized CBM solutions for a couple of specific components and the work should cover the whole process and define what is needed in order to be successful.

Condition-based maintenance

A CBM tool consists of three main steps which are data acquisition, data processing and decision making. In the data acquisition step, all necessary data from the machine is collected. The data can be both in terms of raw signals from the machine to event data regarding when the last repair of the machine was performed. This data is then processed in the following step, data processing, which turns the collected data into useful information. In the data processing step the data is first cleaned from bad samples, for example caused by a malfunctioning sensor, and then analyzed with a suitable method depending on what kind of data it is. When the data has been processed a decision should be made about if or when maintenance is needed. Decision making is divided into two subgroups; diagnostics and prognostics. In diagnostics the goal is to find if the component is in a state of failure and in that case what caused the failure. Prognostics, on the other hand, have the goal of predicting the time until failure in order to schedule maintenance in time. This time estimate can be given as remaining useful life (RUL) or estimated time to failure (ETTF).

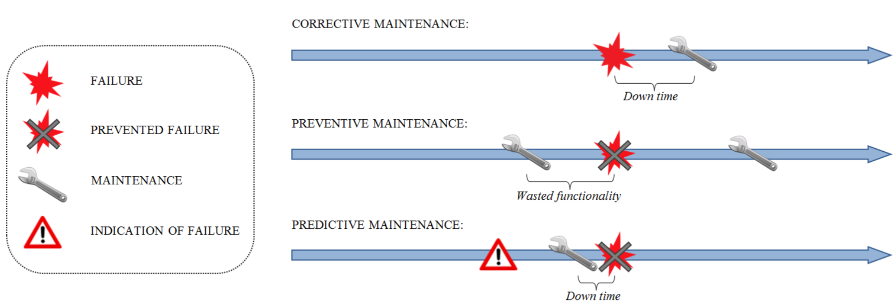

Figure 1: A schematic description of the different maintenance methods.

Method

In this thesis the focus has been on four different components which were selected after discussions with personnel at the company. These components all suffered from some sort of critical breakdown or were being replaced frequently. The goal was to find out if these components were suitable for CBM and what was needed to implement it. Data had already been collected from most of these components and therefore data acquisition was left out of this thesis. Different approaches were taken for the components in the data processing and decision making steps. The following components were studied in this project: a gas concentration sensor, rotating spray nozzles, a servo motor and an injection moulding unit.The first two components, the gas concentration sensor and the rotating spray nozzles, were fairly straightforward with only a few variables and were therefore investigated manually to find correlations between machine breakdowns and patterns in the data. For the other two components, the servo motor and the injection moulding unit, no clear failure cases existed making the analysis difficult. The servo motor was performing a cyclic motion profile and therefore the frequency spectrum of one of the logged signals was analyzed, using FFT, in order to capture the complete frequency amplitude at the cycle frequency. Regarding the injection moulding unit a lot of data had been collected for a large number of variables but since the failure cases were unknown a more complex method was needed. Therefore artificial intelligence, in form of a artificial neural network (ANN), was used to learn how the machine operated and automatically process the data. An ANN needs to be trained to attain the best result using a set of training data with known inputs and outputs. In this project the output was defined to be the health of the unit, but since the correct health was unknown this output had to be estimated together with the involved personnel.

Results

The goal of this thesis was to perform a pre-study of what was needed to implement a CBM tool for a couple of selected machine components. During the analysis of the gas concentration sensor it was discovered that the sensor was configured incorrectly making the collected data unreliable. Thus, it was unfortunately not possible to proceed with the analysis. The rotating spray nozzles did not show sufficient signs of correlation between the data and failure, and therefore this component was not suitable for CBM. Regarding the servo motor differences could be seen between an optimal and a degenerated motor even though the failure case was not established. A measurement of how degraded a component is compared to a functional one was defined, but in order to confirm that this measurement corresponds to the true health further analysis is needed. In order to facilitate this analysis a Matlab-based compare tool was implemented and can be seen in Figure 2.

Artificial intelligence was used on the injection moulding unit and the the algorithm was able to automatically determine the health status of the component according to the assumed health status. Both the FFT and artificial intelligence approach showed promising results in distinguishing between healthy and degraded components which corresponds to the diagnostic part of CBM. Since no historical data for the components was at hand it was not possible to estimate the time until failure. Thus, the prognostic part of the CBM tool was unsuccessful and requires further analysis. However, the analysis performed in this thesis, as well as the information regarding what is needed, can serve as a useful basis in the continuous work of implementing a CBM system.

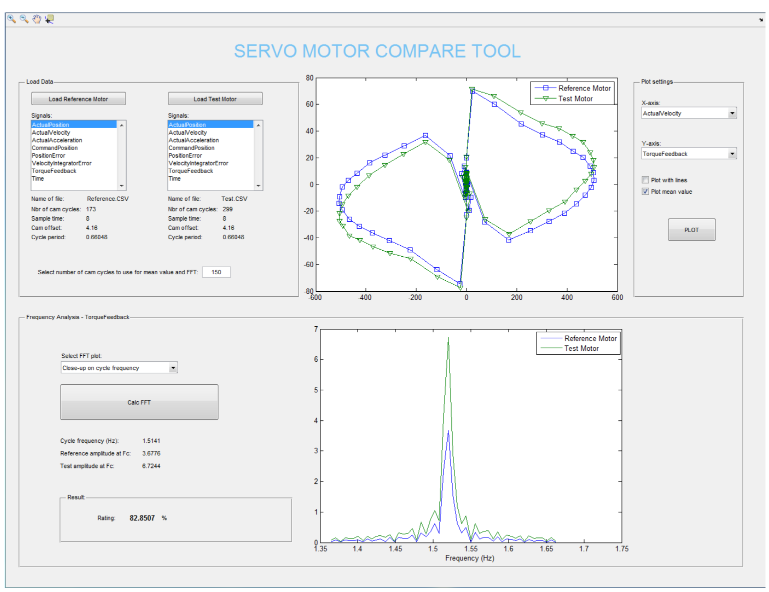

Figure 2: The Matlab-based servo motor compare tool.