Predictive Asset Management and Condition Monitoring

Introduction

This document discusses the factors that affect asset performance, the requirement for data of good quality and sufficient quantity for predictive asset management, and how condition monitoring can be used for real-time operational maintenance.

Factors Affecting Asset Performance

The rapidly changing and volatile global economy are putting enormous pressure on organisations to control or preferably reduce their operating costs in all aspects of their business, including asset performance. These demands are compounded by a range of new and complex factors, for example:

- ageing infrastructure and assets
- more demanding operating conditions
- higher throughputs
- stricter regulations and much higher penalties for not meeting them
- increasing awareness of and care for the environment
- the demand for high levels of customer service
- increasing global demand for water and other natural resources
- shifting economic and political power balances
- investors' attitudes to risk and how it can be controlled or preferably mitigated.

At the same time as companies grapple with these factors and work out how they affect asset performance, they must ensure that the assets continue to operate safely and reliably.

Asset Management Policies

Reactive asset management, the norm in some industries, does not meet these demands nearly well enough but proactive asset management based on predictive analytics can help meet them. This approach mitigates the risk of future asset failure and will result in optimised asset management with lower asset maintenance and replacement costs, fewer and shorter downtime periods, longer asset lifetimes and improved customer service by, for example, fewer flooding and pollution incidents, and service interruptions.

An unnamed American executive has been quoted as saying ‘Most current practice is to wait for the service-failure event and judge performance by reacting to it, because the utility doesn’t get credit from regulators or the media for preventing leaks that the public doesn’t know about’. The method by which the additional costs are paid for varies between countries. For example, in the UK, Australia and Israel the regulators fine the utilities very heavily but in other countries the costs are passed on to customers. Given this difference in approach, it is not surprising that utilities that have to pay for their own failings are keener than other utilities to adopt newer technologies and tools (*Harvard Business Review*, March 2017).

Data Quality, Data Quantity and Implementing a Predictive Asset Management System

Unfortunately, some organisations do not have accurate or up-to-date information on asset performance but this situation is changing as organisations become increasingly aware of the value of their data and how they can be used to improve the performance of the organisation. Poor quality data and insufficient data limit the extent to which the value of the data can be realised and used to improve asset performance as measured by lower costs, less unscheduled downtime and improved customer service. All these outcomes will have adverse consequences on the financial and operational performance of organisations.

The amount of data being collected and stored is increasing, and the rate at which this is happening is itself increasing. All these data provide very rich foundations for optimising asset management using predictive analytics and simulation. This will in turn improve the financial and operational performance of organisations. However, a word of caution is required – the abundance of data must not be confused with the different and separate subject of data quality – data quality and data quantity do not go hand-in-hand: *more data does not necessarily mean better quality data* (see *Data Quality* in Modelling).

Implementing and then using a proactive asset management system based on predictive analytics and accurately recorded data can require a cultural change in organisations. Initial scepticism about such systems due to, for example, fear of the unknown and a reluctance to change can be overcome by explaining why the current system does not meet future requirements and how the new system meets them, for example the requirement for much less reactive maintenance. Such a cultural change is a major undertaking and needs detailed planning and explanation to gain the confidence of staff.

Condition Monitoring Data

Condition Monitoring (CM) is being used increasingly in asset management to improve proactive asset management. It provides real-time information at high frequency, for example every 15 or 30 minutes, on the performance of assets by monitoring parameters that reflect the condition of the assets, for example vibration frequency, oil viscosity and temperature. CM data are leading indicators of possible imminent failure and are analysed, modelled and projected forward in real-time to give warning using the RAG system of problems due to, for example, a temperature close to its threshold value that may cause the asset to fail or not perform optimally. The cause of the warning can then be investigated and the necessary proactive maintenance carried out.

The condition of an asset is determined by many factors. The CM parameter must be sensitive and respond rapidly to changes in the condition of the asset for it to be an effective leading indicator of possible asset failure. Additionally, the forecasts must reflect the very recent values of the parameter. These considerations determine the most appropriate forecasting model for CM data. The sampling frequency of the data depends on a number of factors, including the role and criticality of the asset.

Modelling Condition Monitoring Data

CM data are time series data, i.e. observations at regular frequency. Since CM is used in real-time, the model for CM data must be simple and able to be calibrated and updated quickly and easily. The highly autocorrelated nature of CM data, i.e. the observation at time t is strongly correlated with the observation at time $t-1$, suggests that a univariate time series model is the most appropriate forecasting model (a univariate model is a model in which the value of the series at time t is only calculated from previous values of the series). Furthermore, the correlation between observations decreases as the time (or lag) between them increases. These properties should be the basis of predictive models for CM data. Additionally, the models should:

- use a finite number of observations with more recent observations having higher weights
- have one parameter that can be calculated and updated quickly and easily
- generate non-linear forecasts (the world is non-linear)
- be able to be applied to a range of asset parameters.

The model should only be used for short-term forecasting (because of the high sampling frequency). The forecasts will show if the signal is level or if it may be trending towards its threshold value or if the change in level is permanent and indicating possible failure. It is for these reasons that CM data are used for operational asset management to address immediate operational issues – CM data cannot address tactical and strategic issues.

A circular situation arises when trying to develop dynamic multivariate forecasting models for CM data. Such models have static, i.e. time invariant, predictors and dynamic CM predictors measured at the same frequency as the target CM variable. Each dynamic predictor requires its own multivariate forecasting model and so a set of simultaneous equations is generated. The equations must be specified, calibrated, and solved regularly and frequently – not a viable task when results are required in real-time.

Other aspects of CM are discussed in *Asset Maintenance Policies* in PAM System.

Using Condition Monitoring Data and Asset Performance Data Together

CM data and asset performance, i.e. maintenance and failure, data are sampled at very different frequencies. CM data are sampled and modelled at high frequency, for example half-hourly, whereas asset performance data are modelled at much lower frequencies, for example monthly. Sampling CM data and asset performance data at the same frequency is not realistic because the compromise frequency would be too low for CM data and too high for performance data. Since it is not clear how to combine the two sets of data (because of their different frequencies), they cannot be used in the same model and so it is best to regard them as meeting different needs for monitoring and modelling asset performance.

CM identifies imminent operational issues and potential failures whereas performance data are used for longer term asset management optimisation. Thus, the two approaches lead to different measures of asset performance, one at the micro time level and one at the macro time level.

The Future

Predictive analytics has a big and important role to play in improving asset performance at the micro time level using CM data and at the macro time level using maintenance and failure data. Applying predictive analytics to asset management at both time levels is now more possible than ever before for many reasons, including:

- technology for recording and storing high frequency CM data is available
- improved data governance procedures
- greater emphasis on data quality and consistency
- the availability of more data and better quality data
- the availability of powerful and flexible visualisation software for viewing the results of the analytics and simulations
- recognition that source data must be stored in databases where data structures are well defined and must be adhered to rather than in (silo) spreadsheets where such structures do not exist.

None of these improvements in procedures and technology detract from the imperative of understanding the data fully and preparing them for analysis and modelling (see *The CRISP-DM Methodology* in Analytics Modelling and *Data Preparation, Exploratory Data Analysis and Predictive Asset Management* in PAM Introduction). Indeed, it can be argued that the sheer quantity of data increases the importance of assessing their quality and understanding them fully before applying predictive analytics. Only when the data and the current systems and processes are fully understood, and the business objectives clearly defined can predictive analytics be applied successfully to improve business performance by mitigating the risk of future asset failure and optimising asset performance.