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Selection of diagnostic techniques and instrumentation in a predictive maintenance program. A case study

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Abstract

Predictive maintenance programs (PMPs) can provide significant advantages in relation to quality, safety, availability and cost reduction in industrial plants. Nevertheless, during implementation, different decision making processes are involved, such as the selection of the most suitable diagnostic techniques. A wrong decision can lead to the failure of the setting up of the predictive maintenance program and its elimination, with the consequent economic losses, as the setting up of these programs is a strategic decision. In this article, a model is proposed that carries out the decision making in relation to the selection of the diagnostic techniques and instrumentation in the predictive maintenance programs. The model uses a combination of tools belonging to operational research such as: analytic hierarchy process (AHP) and factor analysis (FA). The model has been tested in screw compressors when lubricant and vibration analyses are integrated.

Keywords: Predictive maintenance; Decision making; Analytic hierarchy process; Factor analysis

1. Introduction

The continuous production process requires a high degree of availability and the elimination of unexpected breakdown that could cause a prolonged stoppage in production [9]. Predictive maintenance can contribute to improving plant availability, safety, quality, reduction of maintenance costs, etc. This has led to an increase in the number of predictive maintenance programs (PMPs) applied, but, during the setting up of a PMP, there is a number of decisions involved that lack decision support systems or models. This article aims to contribute towards resolving this problem.

Although there is a limited number of decision support systems related to predictive maintenance, the following models should be taken into consideration. In Ref. [15], a proportional-hazards model with Weibull baseline hazard function and time-dependent stochastic covariates representing monitored conditions is suggested and a software is developed to assist engineers to optimize decisions. In Ref. [30], Markov models are described for establishing optimum inspection intervals for phased deterioration of monitored complex components in a system with severe down time costs. In Ref. [16], statistical analysis of vibration data is undertaken using a software package to establish the key vibration signals

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that are necessary for risk estimation. Ref. [19] presents a real-time neural network-based condition monitoring system for rotating mechanical equipment. In Ref. [29], condition predictors of significant items of the system are monitoring taking into account the availability and cost-effectiveness of the monitoring techniques.

In this article, a model is presented for the selection of diagnostic techniques and instrumentation in a predictive maintenance program. To construct the model, factor analysis and analytic hierarchy process are combined. The model is applied to screw compressors which are monitored by means of PMPs based on lubricant and vibration analyses and when the aforementioned techniques are applied simultaneously.

The layout of the paper is as follows. Section 2 is an introduction to predictive maintenance techniques, lubricant and vibration analyses and the integration of both techniques are presented. Section 3 describes the characteristics of the mathematical tools used in the construction of the decision support model proposed: factor analysis and analytic hierarchy process. Section 4 presents the model for the selection of diagnostic techniques and instrumentation in predictive maintenance. Section 5 describes the application of the model to a screw compressor. Section 6 presents the results obtained from applying the model to a PMP integrating lubricant and vibration analyses. Section 7 presents the conclusions.

2. Predictive maintenance techniques: lubricant and vibration analyses

Predictive maintenance is a maintenance policy in which selected physical parameters associated with an operating machine are sensed, measured and recorded intermittently or continuously for the purpose of reducing, analyzing, comparing and displaying the data and information so obtained for support decisions related to the operation and maintenance of the machine [5]. There are numerous predictive techniques, as can be checked in Ref. [12]: lubricant analysis, vibration analysis, thermography, penetrating liquids, radiography, ultrasound, control of corrosion, etc.; each technique is applied to a type of specific industrial equipment.

The advantages of the introduction of predictive maintenance programs (PMPs) are:

- Exclusive control of the machines that show the beginning of a malfunction.
- An increase in the availability of the industrial plants [40].
- The capacity to carry out quality checks of both internal and subcontracted maintenance interventions.
- An increase in the security of the factory [9].
- It facilitates certification and ensures the verification of the requisites of the standard ISO 9000.
- Provides the best programming of maintenance actions.
- Enables the effective programming of supplies and staff.
- Production quality is optimized by operating machinery without interruption due to failures [21].
- Support in the design phase of equipment, particularly by means of the application of modal analysis [3].
- Reduction of direct maintenance costs by checking only the equipment that is developing a fault [38].
- By keeping to delivery dates, and by satisfying the customers' demand for quality, the image of the company is improved.
- Costs are brought down in relation to spare parts and labour [18].
- By maintaining the industrial equipment operational whilst applying the predictive tools, the measuring process does not directly affect the availability of the equipment.
- Decrease in the costs related to insurance policies as security within the factory increases.
- Historical information on each piece of equipment is completed, which helps to determine reliability parameters and to optimize maintenance planning [2]. This information on the machines and equipment is available to the management for decision making.
- Reduction of energy consumption.

Industrial plants generally possess PMPs based on vibration analysis [4], whereas medium-sized companies are starting to incorporate them in their Maintenance Departments. Their suitability for application to rotary and reciprocating machines [36], which can be