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Advanced Techniques for Assets Maintenance Management

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Abstract: The aim of this paper is to remark the importance of new and advanced techniques supporting decision making in different business processes for maintenance and assets management, as well as the basic need of adopting a certain management framework with a clear processes map and the corresponding IT supporting systems. Framework processes and systems will be the key fundamental enablers for success and for continuous improvement. The suggested framework will help to define and improve business policies and work procedures for the assets operation and maintenance along their life cycle. The following sections present some achievements on this focus, proposing finally possible future lines for a research agenda within this field of assets management.

Keywords: Advanced maintenance techniques, Risk assessment, Prognostics and health monitoring, Lifecycle management, knowledge management.

1. INTRODUCTION

The emergence of physical asset management as an important field of action in the industry is an indisputable fact that has given renewed attention to the maintenance of equipment and infrastructure. In order to ensure the sustainability of assets in organizations, the formulation of global models allows the coherent and integrated use of different techniques, activities, areas of knowledge, tools, etc. That can be applied to a specific engineering problem Assets management itself has the handicap of being intensive in the use of information, for which one of the main challenges is the development of information systems that support it. The complete integration of Operations and Maintenance (O&M) processes into assets and production systems from its own conception phase is a key matter within this new paradigm known as Industry 4.0. This paper is concerned about the development of innovative models and techniques that may help to address issues of interest, within the field of asset management, responding to key questions such as:

- What is the process to ensure that maintenance can be properly integrated into an overall asset management framework?
- What types of quantitative reliability engineering techniques can be developed to facilitate and improve asset management?
- How can maintenance policies benefit from the development of emerging capabilities?

2. A CHANGING ASSET MANAGEMENT FRAMEWORK

2.1 A maintenance management framework based on PAS55

According to López-Campos & Crespo Márquez (2011), in the historical development of maintenance, several models and frameworks have been developed looking for the optimal maintenance management structure. This reference shows the process of modelling a MMF that represents the general requirements of PAS 55. For the realization of that research, the modelling work involved researching about the basic concepts in the area (business process, modelling, business architecture, etc.) to select the most suitable language and software tool to the case. Summarizing, the general steps to model the proposed MMF and that have been shown in that reference are: (i) PAS 55 analysis, (ii) design of the conceptual MMF according to standards, (iii) selection of modelling language and modelling software tool, (iv) definition of the business architecture, (v) modelling of goals tree, (vi) identification of top value chain process, (vii) modelling of involved processes and activities, (viii) tracing several UML and BPMN diagrams to represent specific features of the system, (ix) analysis of the ICT issues related to the implementation of the MMF and conclusions. Code generation and the development of a software application; involve a hard work detailing the data and operation models for the MMF, and a profound development of algorithms and artefacts describing the use of the tools and techniques required for the operation of the MMF.

2.2 The integration of open reliability, maintenance and condition monitoring management systems

In López-Campos et Al. (2013), the integration approach is preferred over the interoperability because of the software requirements of the enterprise where the system has been applied. The operation algorithms of the system are modelled using UML and BPMN diagrams. The chapter presents a case study for the implementation of the designed platform in a power transformer. The implementation begins doing a RCM analysis, which determines the operational context of the transformer, the required functions, failure modes and effects, and maintenance policies for each maintainable item. UML

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and BPMN models are developed theoretically and then implemented in a prototype hardware + software by integration. The integration system is implemented as software which controls variables related to the principal failure modes occurring in the transformer system, by means of probes assembled in various mechanical devices. The derived information (signals) is used as an input for decision-making in real time. To achieve this end, a mathematical algorithm has been developed to interpret the measurement results of one or more physical variables, emerging the "economical-maintenance prognosis" process. The developed demonstration software includes also features as: a real-time monitoring panel, a panel of risk comparison, a geographic information system and a knowledge management system. Some ideas for the future of the project are oriented to add a complete Reliability Analysis module, and to improve the interoperability and transmission of information between different systems and platforms.

2.3 Prognostics and health management in advanced maintenance systems

Guillén et Al. (2016a) remark the importance of using the existing methodologies for the design and implementation of maintenance policies: it is indeed essential to consider the capabilities of CBM/PHM in the development of a RCM process, especially in high-tech complex engineering systems, for full exploitation of the PHM potential. On the whole, the chapter provides a handy synthesis of the PHM potential into a framework for a system maintenance management: in fact, we believe that the research finding will contribute fixing the role of PHM in relationship to consolidated matters as the maintenance policies design and RCM framework. PHM impact on maintenance policies can modify levels and lines of maintenance (changing the actions that can be executed on a system and defining who runs the actions). The information actually available by PHM may also modify the assets indenture levels for maintenance definition, and may even render new maintenance actions convenient, contributing to extend the levels of maintenance.

2.4 A framework for effective management of CBM Programs

The CBM framework, as presented by Guillén et Al. (2016b), fulfils consistency and robustness by using precise standards and well-known methodologies requirements. This framework stresses the importance of key concepts (such as fault detection, diagnosis & prognosis), and describes the key building blocks for the characterization of any CBM solution. The framework and template have been exemplified for an electrical power transformer CBM solution. An UML model has been developed theoretically and implemented integrating databases in a prototype + software, which has been validated in practice, thanks to proper interoperability of well-known proprietary information systems.

3. PURSUING HIGH MANAGEMENT EFFECTIVENESS IN A DYNAMIC ENVIRONMENT

3.1 Criticality analysis for maintenance purposes

Crespo et Al. (2015) design a process and model for criticality analysis with the idea to easy the maintenance planning process. The methodology ensures analysis consistency to business needs and for existing data of in-service complex engineering assets. At the same time, there is an effort to describe how to turn this process into a practical management tool. Issues arising related to extensive data handling and easy result representations are addressed. The authors believe that this type of analysis will become a must for complex in-service asset maintenance strategy review and redesign. Further research can use this methodology for the improvement of specific operational scenarios or to refine the different steps of the process presented in this work.

3.2 AHP method according to a changing environment

González-Prida et Al., (2014) describe how the well-known AHP method can be dynamically applied within the area of maintenance. This reference adds the possibility to track, over time and on a common scale, those variables (alternatives) becoming more relevant to the business when strategy is changing dynamically according to emerging needs. This can add value to managers by identifying trends of issues becoming critical to the business, and can foster more proactive business behaviour. A new modified version of the AHP methodology, called Dynamic Analytic Hierarchy Process (DAHP), has been developed and presented in this chapter. Using DAHP, a case study is presented where this tool uses the tendency of each failure mode in time to enable the manager a better selection of possible maintenance policies over time. The case study shows that the fact of decision constraints that change gradually with each adopted decision is a phenomenon that occurs in highly dynamic systems, so the criticalities resulted affected by changes in the production plan. In other words, the feedback of decision taken at time t influences the AHP parameters at time t+1.

3.3 Reliability stochastic modelling for repairable physical assets

According to Viveros et Al. (2016), the reliability model is an essential aspect for the management and optimization of physical industrial assets. This reference stresses the learning process required for the proper implementation of this type of models. This research includes a very explicative procedure for the modelling of repairable industrial assets reliability. The study includes the possibility of different degradation levels, where the assets could be placed after specific maintenance activities. A case study was developed for the mining industry of Chile. The performance of assets under ideal conditions (lab test) is extremely different compared to real process operational conditions.

3.4 Economic impact of a failure using life cycle cost analysis

Parra et Al. (2012) present an analysis of the impact of the lack of reliability on asset's life cycle cost. It is also important to mention that, for the LCCA, there is room for improvement in the impact of reliability assessment, by using advanced mathematical methods such as: (i) Stochastic methods; (ii) Advanced maintenance optimization using genetic algorithms; (iii) Monte Carlo simulation techniques; (iv) Advanced reliability distribution analyses; (v) Markov simulation methods. See Table 1 for a list of the stochastic processes that can be used in the reliability analysis of repairable systems. This consideration will support the decision-making process.

Table 1. Stochastic processes used in reliability analysis of repairable systems

Stochastic process	Uses	Background/Difficulty
Renewal process	Spare parts provisioning in the case of arbitrary failure rates and negligible replacement or repair time (Poisson process)	Renewal theory/Medium
Alternating renewal process	One-item repairable (renewable) structure with arbitrary failure and repair rates	Renewal theory/Medium
Markov process (MP)	Systems of arbitrary structure whose elements have constant failure and repair rates during the stay time sojourn time) in every state (not necessarily at a state (change, e.g. because of load sharing)	Differential equations or integral equations/Low
Semi-Markov process (SMP)	Some systems whose elements have constant or Erlangian failure rates (Erlang distributed failure-free times) and arbitrary repair rates	Integral equations/Medium
Semi-Regenerative process	Systems with only one repair crew, arbitrary structure, and whose elements have constant failure rates and arbitrary repair rates	Integral equations/High
Non-regenerative process	Systems of arbitrary structure whose elements have arbitrary failure and repair rates	Partial diff. eq.; case by base sol./High to very high

4. ADVANCED METHODS AND TECHNIQUES TO IMPROVE MANAGEMENT EFFICIENCY

4.1 On-line reliability and risk to schedule the preventive maintenance in network utilities

Crespo et Al. (2013) present a methodology that can generate suitable estimations of risk per critical failure mode. This can help in the process of releasing PM activities for these assets, minimizing them, as well as minimizing CM activities by increasing reliability. Minimization of maintenance activities can increase asset durability and considerably reduce network technical deterioration. This methodology also offers managers the possibility of controlling maintenance budgets based on asset risk expectations for a certain period, because:

Management of spare parts can now be improved by considering times to deterioration instead of times to failure. Asset depreciation can be better defined, according to reliability and original purchasing value. Obviously, the equipment reliability affects aging equipment depreciating the equipment from this purchase value. Consequently, proper maintenance strategies may ensure that assets value is more accurate, resulting repair or replacement decisions more accountable.

4.2 Customer-oriented risk assessment in network utilities

Gómez et Al. (2016a) discuss about the relationship between loyalty of customer and service reliability. The methodology proposed in this chapter is focused on analysing the economic implications of maintenance and the occurrence (and reoccurrence) of failures in different scenarios, calculating the economic risk of the failure and comparing it with the costs of prevention. It can be appreciated how maintenance performance affects the offered and the perceived quality by the customers, and how investments in maintenance activities (especially preventive/predictive) represent economic advantages. In the cases analysed in the a.m. reference, investment in preventive maintenance actions has a direct effect is reducing customer's abandonment rates, besides diminishing the costs of corrective activities. The methodology presented is demonstrated to be useful when comparing different technical or management alternatives, or to determine whether the investment in preventive/predictive maintenance has been profitable. Another important insight is related to the assessment of maintenance in network distribution companies. Taking into account the impacts of risks, allows maintenance management to be accountable and comparable with other organizations or reference standards, from different areas and levels of detail, identifying improvements in network reliability and ensuring service quality from customer, business and society perspectives.

4.3 Analysis of dynamic reliability surveillance

Gómez et Al. (2016b) suggest applying an ANN model per failure mode and a practical implementation in SCADA systems for different plants. Furthermore, advanced ANN models could be applied when supporting additional variables. A process-oriented management ensures proper decision-making by controlling process performance as a way to pursue effectiveness and efficiency. Maintenance decision-making will rely importantly on reliable and available information and knowledge, to control possible variation of assets performance. The trend can be automated through the easy use of statistic techniques and diagnostic tools, facilitating its control and proper knowledge management.

5. THE NEED FOR INNOVATION IN ASSESSMENT AND CONTROL

5.1 A quantitative graphical analysis to support maintenance

Barberá et Al. (2012) presents an innovative method named Graphical Analysis for Maintenance Management (GAMM). This method is a graphical tool providing useful information regarding the reliability and maintainability of systems or equipment for analysis when considering variables such as type of intervention, duration of intervention or the existence of a stop during the intervention of the equipment/system. The GAMM graphics described in that reference illustrate aspects related to: trend of maintenance interventions, deviation in the frequency of preventive interventions, reliability modelling, efficiency of maintenance operations, impact by unavailability, quality in the intervention performance, quality in the use and operation of equipment by staff responsible of it, among others. Successful results of GAMM implementation requires experience and advanced knowledge about the maintenance management process. In Barberá et Al. (2013a-b), GAMM is applied to determine and graphically characterize the deficiencies of the slurry pump that presents an elevated failure rate. Once the information provided by GAMM is compared to the technical information of the pump, the causes of the problems could be identified. Several measures were adopted to eliminate these causes. The GAMM method could also support the decision-making process for the definition of a new maintenance plan.

5.2 A graphical method to support operation performance assessment

Viveros et Al. (2015) present another graphical method (GAOM), which integrates the main maintenance and production indicators, mainly: cumulative production, intervention times (corrective maintenance, preventive and operational interventions) and time between failures/intervention. With GAOM it is possible to identify individual or systemic phenomenon, measuring, evaluating or auditing the impact of decision related to operational procedures or maintenance policies or strategies; as well as incorporating the tool as a "big picture" of process performance, supporting to control operation and maintenance management. GAOM summarizes and complements the decision process to reduce production losses and thus maximizing business benefits. The GAOM method consists of seven input information and one optional production data (production target). The information is classified as "intervention" (number of intervention, type of intervention, and stopped/not stopped equipment); "production" (cumulative production and defective products) and "time" (calendar accumulated time and time intervention). GAOM, through a preliminary analysis, manages to answer all original questions, demonstrating its effectiveness to support in a joint and independent manner, maintenance and production areas.

6. CONTINUOUS IMPROVEMENT THROUGH EMERGENT PROCESS AND TECHNOLOGIES

6.1 Value-driven engineering of e-maintenance platforms

Innovations measures and internal proposals in organizational culture could be established in order to avoid complacency and regression, encouraging a move towards sustainable world class maintenance. Nowadays, in almost all maintenance tasks, some new technology is to be used and some new concepts need to be mastered. Defining the common bases of knowledge and the support of appropriate technologies based on adequate foundation is critical. There is a variety of technological tools and innovation measures in order to gain knowledge as a competitive advantage in asset management. For instance, in reference Macchi et Al. (2014), a starting point is presented to further develop the theory of value assessment of E-maintenance. Missing issues are the analysis of intangible values as well as the complete coverage of technologies and processes target of interest for the development of applied services.

6.2 Assistance to dynamic maintenance tasks by ANN based models

Olivencia et Al. (2015) presents a work related to PV Plants, where managers want to ensure critical equipment reliability and maximum extension of their life cycle. This reference suggests again the application of an ANN model per failure mode and fosters a practical implementation in SCADA systems for different plants. This methodology may ease and may improve decision-making processed in condition-based maintenance and risk modelling, enabling reductions of corrective maintenance direct and indirect costs or allowing showing residual life until total equipment failure.

6.3 Expected impact quantification based on reliability assessment

In Kristjampoller et Al. (2016), the FEI methodology is presented, which is a powerful tool that can be used in various phases of an industrial project via life cycle cost analysis (LCCA) for design-oriented operations, such as CAPEX and OPEX, which are associated with the improvement process. This proposal complements plant modelling and analysis, from traditional methodologies.

6.4 Influence of the input load on the reliability of the grinding line

The methodology developed and proposed by Barberá et Al. (2014), aims to support the decision making process in the field of maintenance management, operation and reliability analysis so that such decisions remain aligned with the vision, strategy and objectives of the company. As a future research in this field, the development of tools to integrate and re-late reliability knowledge, workloads and the state in which the equipment or sub-systems are operating (failure, preventive or operational stop) is suggested. This kind of tool will make easier the analysis and decision-making in asset management and maintenance in industrial organizations. A computer system that monitors online system behaviour could be developed, assessing workload for which the system/equipment is configured, linking it directly with the reliability curve that corresponds to the load. This information is useful for managing maintenance guidelines, control failures and their causes, energizing maintenance plans and to analyse features of the accelerated wear phenomena and its possible causes.

7. CONCLUSIONS

Asset management is a relevant topic both for academic and industry at the moment. Therefore, there are many interesting references available on this topic besides the ones here presented. It is not in the target of this paper to provide any comparison with other researches which would adopt alternative tools/techniques, or to show advantages and limitations among different approaches.

On the contrary, the aim of this paper has been to highlight the importance of advanced techniques for decision making in assets management, from an original framework presented by Crespo Márquez (2006), to a new advanced management framework shown in Crespo et Al. (2017), whose main references has been reviewed in this paper, defining and improving business policies and work procedures during asset lifecycle.

In this sense, the existence of increasingly complex equipment and processes, the increase in the number of assets, the speed of technological change, the need to reduce costs in the modern world, together with increases in the level of excellence of commercial goals such as quality and delivery time, and concern for the safety of workers and the environment, make asset management an important source of benefits and competitive advantages for present and future world class enterprises. This paper has analysed above mentioned factors, and has identified different areas where research lines connected to assets management topics could be developed, contributing by this way not only to academic knowledge, but also to the industrial practice:

- Maintenance policy selection (mainly in section 2).
- After-sales management (mainly in section 3).
- Knowledge management (mainly in section 6).
- Critical asset and infrastructure management (mainly in section 3).
- Asset life-cycle management (mainly in section 6).
- After-sales maintenance (mainly in section 3).
- Performance measurement system (mainly in section 4).
- Sensors and health monitoring systems (mainly in section 5).
- Reliability centred maintenance (mainly in sensor 4).
- Building information modelling (mainly in section 2).
- Advanced maintenance techniques (mainly in section 4).
- The set-up process (mainly in section 5).

Besides the importance of new and advanced techniques for asset maintenance management already highlighted by this paper, future research lines can deepen in the topic appraising critically the perspectives of the different techniques presented.

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