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Model for a Predictive Maintenance System Effectiveness Using the Analytical Hierarchy Process as Analytical Tool

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Abstract: Proper maintenance can enhance the productivity of the company and increases its value in the market. This paper addresses the issue of selecting an effective maintenance technology considering the strategic maintenance and managerial policy of an organization. The research proposes a model frame work for predictive maintenance indicator effectiveness (PMIE) based on the analytical hierarchy process (AHP). The study was done considering three case studies. Firstly a questioner survey was carried out for primary research, secondly a model was developed and thirdly the data were analyzed using the developed model. The main study provided a robust model which can gauge the strategically important available technology and can exclude the out dated or/ and inappropriate technology. There are many researches in this field where number of models were proposed like the maintenance management system, maintenance performance measurement and maintenance performance indicators but the details of the predictive maintenance indicator effectiveness specifically based on condition based maintenance (CBM) with emphasizing on the major strategic maintenance and managerial requirements using analytical hierarchy process (AHP) is hardly available in the literature.

Keywords: – Predictive Maintenance, Maintenance Strategy, Condition Based Maintenance, AHP

1. INTRODUCTION

Maintenance can be defined as the combination of all technical and associated administrative actions intended to retain an item or system in, or restore it to, a state in which it can perform its required function (BSI, 1984). Management personnel often consider plant maintenance an expense, yet a more positive approach is to view maintenance work as a profit centre. In consideration of this new perspective, the requirements for maintenance management have changed drastically from the old concept of 'fix-it-when-broken' to a more complex approach, which entails adopting a maintenance strategy for a more integrated approach and alignment. Furthermore, the high level of complexity of today's industrial plans requires an elevated level of availability and reliability of such systems. Maintenance is mainly classified into run-to-failure maintenance, preventive maintenance, predictive maintenance, total productive maintenance (TPM) and reliability-centred maintenance (RCM) (Mobley, 2002). Predictive maintenance is some form of activity aimed at identifying the presence of deterioration or defining the extent of deterioration that already exists. At the end of a predictive task, the person performing the predictive task knows more about the asset, but the condition of the asset has not been changed. Well defined predictive maintenance will provide a clear indication if further action is currently needed or not. It is also defined as a set of activities that detect changes in the physical condition of equipment (signs of failure) in order to carry out the appropriate maintenance work for maximising the service life of equipment without increasing the risk of failure. A predictive maintenance program can minimize unscheduled breakdowns of all mechanical equipment in the plant and ensure that repaired equipment is in, acceptable mechanical condition. The program can also identify machine-train problems before they become serious. Most mechanical problems can be minimized if they are detected and repaired early. Normal mechanical failure modes degrade at a speed directly proportional to their severity. Predictive maintenance is divided in to two types that is condition based maintenance (CBM) and Statistical based maintenance (SBM). This study has been carried out considering CBM only. The Predictive maintenance technologies specific to CBM are vibration analysis, acoustic emission, ultrasonic testing techniques, oil analysis, strain measurement, electrical effects, shock pulse method (SPM), process parameter, performance monitoring, radiographic inspection, thermography (Marquez et al., 2012). The study is specific to some critical parts of boiler and steam turbine of a power plant hence only some of the technologies were considered in this paper. This study was done to develop a more effective maintenance methodology in maintenance management system. A predictive maintenance tool that is condition based maintenance has been used for this study to develop a generic model for maintenance technology/technique selection. The model incorporated the condition based maintenance technologies with main maintenance management criteria. The study presents a strategic model based on the managerial needs considering the sustainable factors. The model presents an approach for effective technology selection based on the

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organizational needs and strategic requirements. The organization of the paper is as follows section 2: presents the proposed methodology for the study, section 3: presents a detail literature review of the present maintenance system selection, Section 4: elaborates the steps involved in the model development, section 5: presents the model application on the three case studies, section 6: revels the findings, section 7: discusses the analysis and presents the further scope of the work, section 8: concludes the paper.

2. METHODOLOGY

The methodology adopted in the study involves the following steps; firstly a literature review was carried out to find the challenging issues for a practical application of a predictive maintenance methodology and finding the constructs for the strategic managerial requirements. Secondly a survey was carried out to determine the critical parts and the applicable technology for the identified parts; these findings were also supported by the literature. Thirdly a model was developed based on the AHP methodology. Fourthly the importance ratings are obtained through a survey of an expert group for the criteria/constructs. The ratings were obtained based on the consensus of the whole group. Fifthly the ratings obtained were used for the model application via a case studies analysis and an effective strategic maintenance management system was proposed.

3. LITERATURE REVIEW

As a consequence of the implementation of advanced manufacturing technologies, the increase in automation and the reduction in buffers time of inventory the pressure on maintenance management have increased (Marquez et al., 2006) and for this, maintenance management system that is predictive maintenance indicator effectiveness (PMIE) based on the strategic managerial need has become an important aspect for maintenance engineer. To do these effectively maintenance experts needs maintenance performance indicator which have been studied in many of the literature but there is hardly any literature available on the development of a systematic approach that embraces every level of business activities (i.e. strategic, tactical and operational) (Kutucuoglu et al., 2001). A multi-criteria hierarchical maintenance performance measurement framework to resolve this issue was developed but the framework does not provided any guidance on the selection of business specific maintenance performance indicator (MPI) (Parida et al., 2007). An approach of maintenance selection based on risk of equipment failure, cost of maintenance and the analytic hierarchy process (AHP) and goal programming (GP) are used for maintenance policy selection (Arunraj et al., 2010). Wan et al. (2014) describes the development and sustainability of an online predictive maintenance module for the endpoint detection system. Turki et al (2012) presented a combination between production, delivery and maintenance plan for a manufacturing system satisfying a random demand under service level. Azizi & Fathi (2014) presented an empirical investigation to rank factors influencing maintenance strategies. Sipos et al. (2014) presented a data-driven approach based on multiple-instance learning for predicting equipment failures by mining equipment event from maintenance logs. AHP as a tool was proposed for maintenance strategy selection in an Italian oil refinery processing plant, combining many features which are important in the selection of the maintenance policy: economic factors, applicability and costs, safety, etc (Bevilacqua et al., 2000). A 'Lexicographic' Goal Programming (LGP) approach was presented with application of the AHP to define the best strategies for the maintenance of critical centrifugal pumps in an oil refinery (Bertolini et al., 2006). Analytical hierarchy process (AHP) is used to select the most practicable maintenance strategy for equipment (Zhaoyang et al., 2011). This study has been carried out by giving emphasizes to certain critical parts of the boiler and steam turbine. The part considered for the study was lubrication system, bearing systems and gear systems. The various technologies that are used for fault isolation of a machine in predictive maintenance technologies that is condition based maintenance methodology as explained in many of the literature are vibration analysis, acoustic emission (AE), ultrasonic testing techniques, oil analysis, strain measurement, electrical effects, shock pulse method (SPM), process parameters, performance monitoring, radiographic inspection, thermography (Marquez et al., 2012). Some of the technologies are considered for the study as other technologies are not applicable for the critical parts considered for the study. The managerial and maintenance criteria are also identified from the literature as maintenance cost, reliability, maintenance time, operability, flexibility, machine availability, safety, resource uses, energy consumption (Tsang, 1998; Zaim et al., 2012). The technologies applicable for the mentioned critical parts are vibration analysis (Igarashi et al., 1983; Futter, 1995; Lin et al., 1995), acoustic emission (Tandon et al., 1990; Tan, 1990), oil analysis (Barron, 1996; Leske et al., 2006) shock pulse method (SPM) (Butler, 1973; Tandon et al., 1992), process parameters (Muller et al., 2006 and performance monitoring (Sorensen et al., 2002; Muller et al., 2006).

4. MODEL DEVELOPMENT

4.1 Analytical Hierarchy Process Methodologies

An AHP is an analytical tool developed by T.L.Saaty. The Analytic Hierarchy Process (AHP) is a theory of measurement through pair wise comparisons and relies on the judgments of experts to derive priority scales. It is these scales that measure intangibles in relative terms. The comparisons are made using a scale of absolute judgments that represent dominance of one element over another with respect to a given attribute. The judgments may be inconsistent, and how to measure inconsistency and improve the judgments, when possible to obtain better consistency is a concern of the AHP. Decision making, for which we gather most of our information, has become a mathematical science today. Decision making involves many criteria and sub criteria used to rank the alternatives of a decision. Not only does one need to create priorities for the alternatives with respect to the criteria or sub criteria in terms of which they need to be evaluated, but also for the criteria in terms of a