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Development of an empirical formula for machine classification: Prioritization of maintenance tasks

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ABSTRACT

Continuous type production and discrete type manufacturing systems face challenges in optimizing the maintenance related costs. The risk based maintenance approach has been carried out within the continuous type production systems to classify equipment in production and process facilities based on the risk of failure that can cause financial, societal and environmental challenges to the asset owner. At the same time the term 'machine classification' (MC) has been used within the discrete type manufacturing systems to classify machines based on the influence on; production process to continue, delay in deliveries, product quality as well as personnel, process, societal and environmental safety. Initially, this paper discusses the role of the MC in mitigating health, safety and environmental challenges. Then, it derives an empirical formula performing classification of machines. The derivation has been performed by carrying out a case study in three manufacturing companies and utilizing the three different MC models employed by them. Finally, the manuscript verifies the empirical formula with an arbitrarily selected manufacturing organization.

1. Introduction

Well maintained infrastructures, machines and equipment (i.e. physical assets) are the backbone for realizing desirable processes and that ensures stability and quality of products manufactured in discrete type manufacturing systems (Song, 2009; Gabriella et al., 2008). This guaranties that clients receive products of good quality at the right place at the right time (Löfsten, 2000; Muchiri et al., 2011; Ratnayake, 2013). The relationship between maintenance strategies and business is present in literature (Antosz and Sęp, 2010; Pinjalaa et al., 2006). However, due to challenges pertaining to maintenance in manufacturing processes, unexpected failures of infrastructure, machines or equipment can disturb assets operations as well as lead to hazardous situations (in terms of emission, waste, accidents, personnel, etc.) (Arunraj and Maiti, 2010; Bevilacqua and Braglia, 2000; Ratnayake, 2012a).

Apart from that, in relation to continuous type production (e.g. Oil and Gas (O&G) industry) health, safety and environmental issues dominate and at the same time they are minimized by maintaining physical assets which undergone different operations (Liyanage, 2010; Ratnayake and Markeset, 2010). In process type production systems, as the product differentiation is smaller and consequence of failure is high, the risk based approaches [e.g. risk based inspection (RBI), risk based maintenance (RBM), etc.] are used to classify systems, sub-systems and equipment in a production and/or process plant in order to carry out inspection and maintenance (Dehayem Nodem et al., 2011; Waeyenbergh and Pintelon, 2004; Zhaoyang et al., 2011).

Various prognostic models were developed to assess equipment condition and to facilitate decision making process (Peng et al., 2010) or to optimize maintenance costs (Marais and Saleh, 2009; Pan et al., 2010; Mckone and Weiss, 2002). In addition, to that various maintenance strategies are used in various companies (Bevilacqua and Braglia, 2000). On the other hand, basis for any maintenance planning is to carry out machine classification and/or criticality analysis (Luce, 1999; Rosqvista et al., 2009; Waeyenbergh and Pintelon, 2002). It is obvious, that if machine classification is insufficient, then achieving optimum maintenance plan cannot be guaranteed.

A recent audit carried out by Petroleum Safety Authority Norway reveals that insufficient classification is one of the significant non-conformities (Oien, 2010). Fig. 1 illustrates the percentages of common non-conformities from seven audits of the maintenance management of several companies.

It is vital to focus quite extensively on classification as wrong classification or wrong use of classification can either result in critical equipment being insufficiently maintained or less critical

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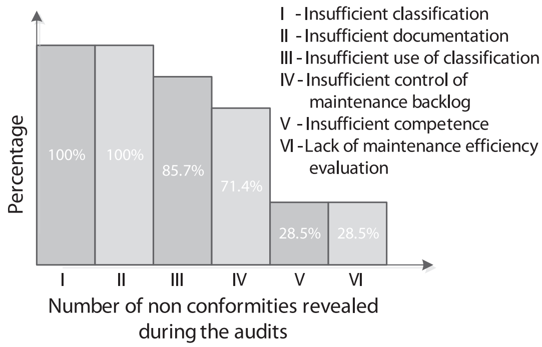

Fig. 1. Percentages of common non-conformities.

equipment being excessively maintained. The both aforementioned cases can increase the probability of maintenance induced failures whilst deteriorating the safety due to increased failure frequency (Oien, 2010; Ratnayake, 2012a). In addition, it is paramount to update the criticality analysis while the foundations for the analysis are changed (Oien, 2010; Ratnayake, 2012a). Hence, it is necessary for the correct classification in the first place (i.e. documented in traceable manner) and also for the correct use of the classification (e.g. for maintenance prioritization) and updating the classification on a regular basis.

The maintenance activities may be wrongly executed even though the criticality analysis is correct. Therefore, the correct classification of systems and equipment and correct use of classification are prerequisites for good maintenance management. This paper derives an empirical formula for classification of machines based on a case study carried out in three manufacturing companies whilst utilizing three different models employed by them. Initially, the three models have been presented in the paper. Then, an empirical formula has been derived utilizing the experts' knowledge gained from the three aforementioned manufacturing companies. The empirical formula has been verified with an arbitrarily selected manufacturing firm. Finally, the suggested empirical formula has been proposed to use performing MC in any manufacturing organization with a few modifications regardless of the manufacturing environment.

2. Industrial challenge

Discrete manufacturing organizations, located in the case study region, use one or combination of maintenance strategies such as corrective maintenance, schedule maintenance (or time based maintenance), condition based maintenance (CBM), Total Production Maintenance (TPM), reliability centered maintenance (RCM), etc. in order to, to implement the maintenance policy. In this context, when the appropriate maintenance strategy becomes costly, these organizations require to classify machines into groups in order to optimize the expenditure to the asset owner. The case study manufacturing organizations have used their own machine classification methods for carrying out cost reductions. In general, these companies utilize consistent criteria to prioritize the machines located in different production areas for performing maintenance tasks (e.g. machine work time, failure frequency, etc.) (Swanson, 2001).

In some cases, the machine prioritization process is time consuming as it requires taking many factors into consideration (Ratnayake and Vik, 2012). It is also observed that the time devoted for prioritization depends on the complexity of the model used and the data gathering method (e.g. if the data is available in a comprehensive data base or not) depending on how many different number or type of criteria, a person or more people are involved in such a prioritization process (Ratnayake, 2012b). Hence, it is vital to use a model that consumes acceptable period of time so that the prioritization process will be economically viable.

However, a company can choose a criterion or criteria in the way that machine classification shall not reflect the reality. For instance, a machine shall be assessed as important or very important based on the pre-specified criteria which may not be accurate. It is also found that some occasions the criteria are subjective in nature and the results of evaluations can be dissimilar depending on who assess the machines. Hence, it is vital to have set of criteria indicating the particular situation with a specific number or interval to reduce *ad hoc* evaluations. This enables to make new or use available computer software (e.g. MS Excel) for the machine classification when the data are stored in a complete data base to improve the productivity of prioritization process.

3. Case study methodology

Three manufacturing companies were selected based on their machine classification approaches. The selection criteria of them were based on: the type of machines (manual and Computer Numerical Control – CNC), type of production (job-shop and batch production), ownership of the company (i.e. fully stated-owned, partly stated-owned, and mostly foreign-owned), size of the company (i.e. medium and large). The selection of the company was also done based on their ability to invest in maintenance. For instance, a company has mostly foreign-owned to have more potential to invest on new strategies and methodologies. However, it is not always the case with.

The companies which use prioritization models that can be generalized were considered as candidates for deriving final empirical model. Hence, out of twelve, three companies were selected based on their own machine prioritization models. Each model was thoroughly studied by means of their own real data for e.g., the data corresponding to machine failures, product quality deterioration, machine up-down time, cost of failures and elimination, etc. Apart from that, an effort was made to validate those three models with another company data. However, it was not possible as data did not comply with used models. Hence, the advantages and disadvantages were listed to be taken them into consideration in concluding the final model.

4. Data collection and analysis

An analysis is performed using three models available in three different manufacturing organizations in order to study the criteria

Table 1
Machine classification categories for the model-I (Source: Frańczak, 2010).

Category	Range	Description
I	<8	Machines with low priority
II	8–11	Machines with average priority
III	12–15	Machines with high priority
IV	>16	Critical machines

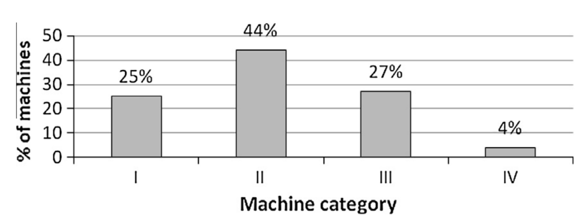

Fig. 2. Percentage of machines in each category (Source: Frańczak, 2010).