

MEASURING THE EFFICIENCY OF AN INDUSTRIAL CONDITION MONITORING SERVICE

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Abstract. *The mode how industrial physical assets are maintained is very important to assure high equipment availability. It is important to find a metric or a key indicator that will point out the effectiveness of such function. Once condition based maintenance is widely assumed to be one of the most important maintenance strategies, it is fundamental to observe how assets are being monitored. The purpose of this paper is to observe the performance of the condition monitoring service within all maintenance activities. With this goal it is possible to determine the efficiency of this service and identify the gaps regarding the maximum achievable efficiency. The methodology or approach used called Overall Service Efficiency (OSE) refers to the Organization of the condition monitoring service, the Competencies and abilities of human resources affected to the service and the Interface between condition monitoring and other services inside the organization.*

Key words: *Condition monitoring, Efficiency, Gap, Maintenance.*

1. INTRODUCTION

It is very important for the top management of a company or a department to know how their industrial physical assets are maintained. It is fundamental to have a metric or some information or value to better understand the performance of maintenance function regarding the overall

objectives. The objective of this paper is to observe the performance of the condition monitoring service within all maintenance activities, once it is very common in the industrial field, gaining a huge importance in the last two decades. It is possible to determine the efficiency level of this service and identify the gaps regarding the maximum achievable efficiency.

The paper is structured into six sections. Section 2 defines condition monitoring under the scope of condition-based maintenance (CBM), refers its importance and points out recent developments in the area. Section 3 refers to audit processes and in particular on the maintenance field. Section 3 presents a proposal for an innovative methodology directed towards condition monitoring service audit. In Section 4 a demonstrative example of the methodology based on a real case study is presented and in Section 5 some conclusions are stated.

2. CONDITION MONITORING

Maintenance plays a key role in industry competitiveness. Maintenance activities such as in military equipment, transportation, manufacturing systems, electric power generation, transmission, and distribution often incur high costs and thus demand high service quality [10].

Maintenance involves preventive and corrective actions carried out to retain a system in or restore it to an operating condition. In accordance to BS EN

13306 [3] maintenance can be performed before or after a failure occurrence. The former corresponds to preventive maintenance and the later one to corrective maintenance. Preventive maintenance can be classified into two categories:

- Scheduled Maintenance (SM) (also known as time-based maintenance or hard time maintenance);
- Condition-based maintenance (CBM) (or predictive maintenance).

Condition-based maintenance has been proven effective in reducing unexpected failures with minimum operational costs. Therefore, the use of condition monitoring techniques and CBM has increased rapidly over recent years [5].

The heart of CBM is condition monitoring which, in principle, involves periodic or continuous (online) data acquisition, processing, analysis, interpretation and extracting useful information from it. The information helps to identify if the asset health has diverged from the normal. If so, then fault diagnosis and prognosis often follow. Finally, a decision regarding when and what maintenance tasks are to be performed, is taken [4]. Fig. 1 illustrates the CBM process, including the condition monitoring.

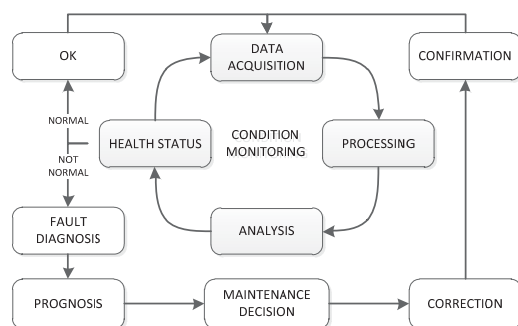


Figure 1 – Condition-based Maintenance process

Condition-based maintenance has been used in a large variety of applications. Regarding the published literature it is possible to observe the usage of CBM and reference to condition monitoring in several works [8] [13].

Concerning the energy sector it is also possible to find some works using condition monitoring techniques as for example for condition monitoring and fault diagnosis for hydropower plants [11] or wind farms [1] [12] [6].

Recently huge developments on the field of condition monitoring were achieved using information and communication technologies (ICT) with online and wireless techniques, providing

reliable and continuous information with lower costs [4] [7] [14].

Condition monitoring refers to maintenance tasks performed on physical assets that includes collect data, process all the information gathered, perform a data analysis and decide the current asset status. This process must be reliable once a good or bad decision to perform subsequent maintenance activities could have a huge impact on safety, production or environment, with inherent costs and resource allocation.

3. AUDITING MAINTENANCE SERVICES

Maintenance quality in industry means to achieve the maximum availability of physical assets at minimum cost. This is somehow ambitious and ambiguous once we are facing contradictory objectives. One way to improve maintenance quality is to produce regular audits to this function or service.

The measurement of maintenance performance through audits can be observed in several papers on the area [9] [2]. Usually an audit process is based on inquiries, interviews and data analysis (when available). Condition monitoring service is one of the most audited services due to its importance inside a common maintenance department. Usually it uses high technological equipment that requires high investment on hardware, software and human competencies. Thus, it is important to be efficient in all activities performed under the scope of condition monitoring.

4. PROPOSED METHODOLOGY

Following the previous explanations and theoretical approaches concerning maintenance services and auditing, it is presented in the following paragraphs a methodology to evaluate the efficiency of the condition monitoring service in an organization.

The main objective of the implementation of such methodology is to determine the efficiency of the condition monitoring service comparing the actual situation of the service with one considered as ideal, and thus performing a gap analysis between these two situations. Fig. 2 shows a schematic representation of the proposed methodology, explained in the following paragraphs.

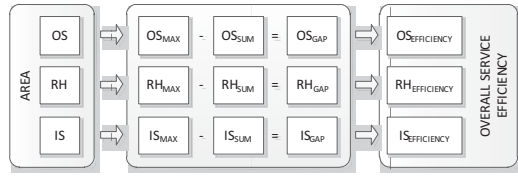


Figure 2 – Methodology proposed

The method analyses three main areas: the Organization of the condition monitoring Service (OS), the Human Resources affected to condition monitoring service (RH) and the Interface between condition monitoring service and other Services (IS). These three main areas resume most of the aspects related to a condition monitoring service once they cover fundamental issues that could have impact on the efficiency of the referred service. Each question of the inquiry has four possible answers and a fifth alternative if the question is not applicable. For each answer there is a specific punctuation in accordance to the matrix represented in Table 1.

Punctuation	Answers
3	Highly positive
2	Acceptable, but with recommendations
1	Not favourable, needing changes
0	Highly negative, unacceptable

Each question will be weighted in accordance to its level of importance for the condition monitoring service. In this way they will be evaluated in one of the four levels presented in Table 2.

Punctuation	Answers
1	Very Low
2	Low
3	High
4	Very High

Then, the efficiency value of each area under analysis will be determined considering the value achieved and the gap to the maximum possible punctuation. For example, the efficiency of RH is given by:

$$RH_{EFF} = \frac{RH_{SUM}}{RH_{MAX}} \quad (1)$$

Where the maximum punctuation is given by:

$$RH_{MAX} = \sum_{i=1}^n (RH)_{max} \cdot (Wp)_i \quad (2)$$

And the punctuation achieved by the answers given by:

$$RH_{SUM} = \sum_{i=1}^n (RH)_i \cdot (Wp)_i \quad (3)$$

The last step of the methodology refers to the determination of the Overall Service Efficiency (OSE) taking into account the punctuation of each area under analysis and the weight allocated to them in accordance to the following expression:

$$OSE = \frac{3 \cdot RH_{EFF} + 2 \cdot OS_{EFF} + IS_{EFF}}{6} \quad (4)$$

Now, it is possible to make a qualitative evaluation of the condition monitoring service based on the achieved OSE and on the following criteria:

- $OSE < 40\%$ - Highly Negative
- $40\% < OSE < 60\%$ - Acceptable, with recommend.
- $60\% < OSE < 75\%$ - Good
- $75\% < OSE < 90\%$ - Very Good
- $OSE > 90\%$ - Excellent (world class)

Based on the qualitative evaluation and on the gap analysis of each area it is time to establish a strategic plan. This plan is performed trying to fill up the identified gaps.

5. DEMONSTRATIVE EXAMPLE

The demonstrative example presented in this section is based on a real auditing process made to the condition monitoring service in a huge petrochemical installation. In this particular aspect this service plays an important role inside the maintenance department once more than 3000 assets are under condition monitoring.

Based on the weight of the person answering to enquiry and on the weight of the question for the condition monitoring service the efficiency value in each area was determined. The gap between these values and the maximum possible ones can be observed in Fig. 3.

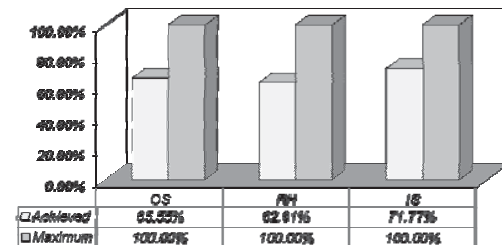


Figure 3 – Gap analysis

In a first sight it is possible to observe that RH is the weakest area with 62.61% of efficiency, followed by

the OS with an efficiency of 65.55%. The higher value of efficiency is achieved in the IS area with 71.77% of efficiency. Based on these values it is time to determine the Overall Service Efficiency (OSE), as stated on the proposed methodology in section 4. Applying the weight on each area a value of 65.12% was determined for the OSE.

According to the qualitative scale for OSE it can be said that we have a “*Good Condition Monitoring Service*” in this facility. Although this positive result it is clear that condition monitoring service is far from a “Very Good” or “Excellent” qualification. Making a deeper analysis at the identified gaps and on the consistency of the answers it is possible to point out some actions or recommendations in a way to improve the referred service. Based on a preliminary analysis of the final report it was established a calendar to implement the top priority recommendations and responsibilities were defined for each activity.

6. CONCLUSIONS

In the present work it was proposed a new methodology to determine the Overall Service Efficiency (OSE). To achieve the value of the OSE there are three main areas under observation: the organization of the condition monitoring service (OS), the human resources affected to condition monitoring service (RH) and the interface between condition monitoring service and other services within the organization (IS). It was presented a real case study where the referred methodology was applied with results.

The originality of the work developed is centred on an innovative methodology that can be easily applied in a huge number of industrial fields, although its simplicity.

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