Identification of wear statistics to determine the need for a new approach to maintenance

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Abstract

Condition Based Maintenance (CBM) is widely accepted and used as a financially effective maintenance strategy, able to anticipate failure, without an unnecessary economic effort in preventive periodic maintenance. The economic benefit of CBM is achieved if such maintenance approach is applied to the right equipment and through appropriate tools. In particular the degradation behaviour of the equipment is needs to be understood to correctly deploy a CBM approach. Understanding of degradation is then strongly related with failure models . However, very little is known or published about the importance and the role of various failure models in different industrial sectors. Thus, if failure models are not understood and handled properly, the use of CBM cannot lead to financial benefits.

This paper aims at deeping the research on this topic, introducing a discussion on CBM and presenting the results of a survey carried out with different experts to obtain information about failure models. This research activity aims at encouraging the research community on the the importance and understanding of various failure models.

1 Introduction

The increasing sensibility for safety, the high quality requirements, the sustainability needs and the goods preservation are becoming, in our societies, critical success factors for companies' competitiveness. In order to answer these requests, a scientific, technological and organizational upgrade of maintenance is required.

A company competitiveness requires being able to use production facilities with a high level of reliability, availability and safety. This can be achieved through a maintenance service which is effective (i.e. able to look ahead for possible breakdowns and failures) and efficient (i.e. able to minimize maintenance costs). To this end, research has been looking for techniques and tools for diagnosing and predicting the degradation of the state of health of components, machines, etc.; thus, anticipating failures or breakdowns.

In this context, a difficulty is represented by the costs of already available solutions. Technologies (sensors, diagnostic systems, etc.) are available today in order to improve safety, availability and reliability, often these devices are not adopted due to their cost i.e. cost of software/hardware solution, cost of maintenance engineering methodologies and processes, and cost of the organizational changes needed for the implementation. This is also true in the manufacturing sector, where cost and complexity of diagnostic systems are seen as an obstacle (Fumagalli et al. 2009).

Maintenance is a subject that is underestimated in many companies. In order to change these wrong attitudes, several actions are necessary on a political, social, and technical level. Regarding this last point of view, there is clearly a lot to do. It is essential to provide maintenance with methods and tools that could make it a science rather than improvisation. The concept of maintenance has evolved over the last few decades from a corrective attitude (maintenance intervention after a failure), to a predictive attitude (maintenance intervention fixed to prevent the fault). More in detail, under the name of Maintenance Engineering or Reliability Engineering, several approaches, tools and techniques have been developed in order to provide a scientific basis to maintenance activities. The analysis presented in this paper relies on a questionnaire study/survey carried among professionals in the area of maintenance and the scientific and technical data publicly available regarding the statistics about failure types in different industrial sectors. The study covers several European countries and the most important industrial sectors. For these sectors the failure characteristics of machinery are analysed and discussed.

There is a plethora of academic and industrial books and papers which explain in detail the use of different maintenance strategies, while the basic understanding of need for maintenance is very low or non-existent.

. As the gathered data clearly shows the great differences between various industrial sectors, this finding stresses the pronounced need for good data to support these types of studies. In the light of this study it is clear that all investments to support modern maintenance technologies have relatively short payback time in all main industrial sectors and even in the case of less challenging production environment. Naturally, the highest benefits can be gained in industrial sectors where the production forms a chain where an individual part of production equipment can stop the whole production line. Most of the sectors in the process industry and manufacturing systems for high demand: i.e. white goods, automotive. It is remarkable to notice that the payback time of technological investments in CBM in many cases is only months which is a level that cannot be reached by any other type of investments.

2 CBM issues

Condition-Based Maintenance is a methodology that strives to identify a range of faults before they become critical to enable more accurate planning of preventive actions. CBM is based on the idea that maintenance should be carried out when it is needed. This logic is very clear and easy to understand. In the case of maintenance actions based on calendar interval (e.g. once a month), it might be that too many maintenance interventions are carried out and consequently a lot of effort is spent in vane which could be costly. Another adverse effect with too high activity with maintenance is that every now and then the maintenance actions can create additional need for maintenance if something has gone wrong. This can be costly, especially if the entire production line has to be stopped.

The CBM strategy can be introduced if patterns of degradation and wear follow in such a way that they can be detected with condition monitoring tools as is the case for some of the wear models detailed later. Naturally, there is a great technical challenge as the condition monitoring technology has to be so efficient so that the fault can be detected prior to the stoppage of the machine or to the quality decrease of production. On the other hand, there is a risk for condition monitoring systems to trigger too early the maintenance action. No fault found (NFF) events are important problems at condition monitoring solutions, as they may ruin rapidly user confidence on CM tools.

In fact there is a great need for the development of monitoring and prognosis technologies that can give the indication of maintenance need at the right moment (i.e. allowing the organization of properly and efficiently maintenance interventions).

In case of wear models 4, 5 & 6 the use of CBM is not possible and logical as the failures can take place without a warning in the measuring signals. In such a case the best solution is to run the component until the failure takes place so the optimal maintenance strategy is actually corrective maintenance. It is easy to notice that changing components based on calendar might in some cases be the silliest option e.g. for fault models 1 & 6, when infant mortality is high.

It seems that there is a lot of faith in statistics, in the sense that good statistics could help in the definition when maintenance needs to be carried out. Unfortunately this is not true. In fact, there are very few examples that support the use of statistics in defining the optimal time for maintenance for an individual machine. One such might be the change of the light bulbs which follow pretty well Gaussian life time distribution. In addition an individual light bulb is not critical in a factory as there are so many. On the other hand even statistics are useless in the definition of the optimal time for maintenance for individual part machinery, as their lifetime most often depends on specific loads and ways of usage. Statistics can be very valuable in the definition of global needs for spare parts and maintenance personnel i.e. when the focus is on a fleet of components instead of on an individual component.

Statistics may rely on indicators and, to this concern, there are numerous indicators for maintenance performance, e.g. key indicators defined by EFNMS (www.efnms.org) and by EN 15341 (EN 15341: Maintenance – Key Performance Indicators) as standard “Maintenance Key Performance Indicators”. The norms propose and explain the indicators and standardized definitions (e.g. EN 13306) are also available. From this current situation, one can see that there are various approaches to creation, classification and use of maintenance indicators. Many indicators of the one mentioned by the above provided references concern failure models (i.e. failure rate and related indicators), but they do not properly discuss how different failure models strongly impact on the way the indicators must be read and used.

Indeed, it is surprising how many authors developed their research on mathematical models and dissertations that ground on statistic measures and indicators related with failure rates (e.g. Dinesh et al. 1999, Martorell et al. 1999, Moss 1991, Muchiri et al. 2011, Tsang et al. 1999, Wireman 1998) and instead how little has been published about the percentage of different failure models in various industrial sectors, especially considering the great interest of using statistics as basis for maintenance planning, even if some remarkable works in specific sectors exist (e.g. OREDA in the oil and gas – Helge et al., 1996).

One possible reason for this is that statistics have been used in reliability studies for a considerable number of years and well developed approaches have proven successful in several technological sectors. Success has encouraged the use of statistics for individual components of machines when little or no understanding of real failure models has been available. At the same time the understanding of wear related phenomenon has not reached similar maturity and the great difference in different type wear models has not been understood.

It should be noted that having access to and using accurate statistics about the percentage of different wear models would actually prove that statistics are not helpful in maintenance planning of machines and their individual components.

In order for CBM to be successful it is important to use an appropriate method for modelling deterioration, the different conditions and their effects, and the optimal selection and scheduling of inspections and preventive maintenance actions. There are different types of failure characteristics often grouped in six categories (Tutorial, 2013):

1) Bathtub curve, infant mortality, useful life, rapid wear out;
2) Rapid wear out after long useful life;
3) Gradual wear out after long useful life;
4) No infant mortality followed by indefinite useful life (constant failure rate);
5) Indefinite useful life (constant failure rate);
6) Infant mortality followed by indefinite useful life.

Of these three (1, 2 & 3) can be monitored and it does not make any sense to monitor the remaining three (4, 5 & 6) as there is no such change that could be used to justify the diagnosis of maintenance need.

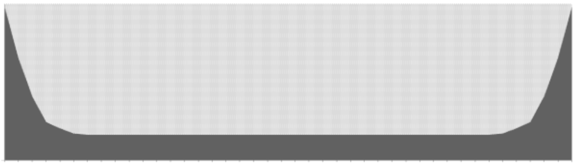

Figure 1. Bathtub curve: Infant mortality – useful life – rapid wear out.

Figure 2. Rapid wear out after long useful life.

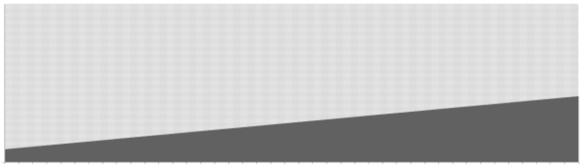

Figure 3. Gradual wear out.

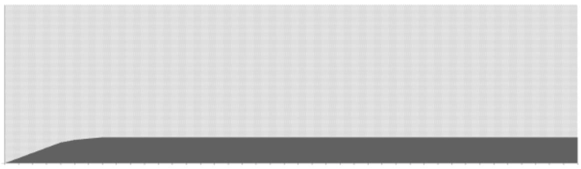

Figure 4. No infant mortality followed by indefinite useful life.

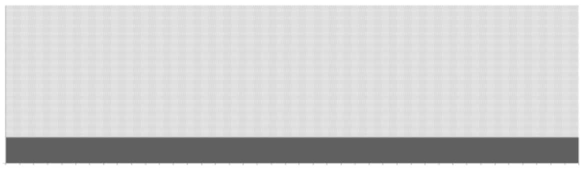

Figure 5. Indefinite useful life.

Figure 6. Infant mortality followed by indefinite useful life.

3 *Available wear statistics for maintenance needs identification*

The data that has been available for this paper regarding the percentage of the different failure models is limited; this is related to the few academic studies which exist. Moreover they usually cover only one industrial sector.

In order to further understand the subject a questionnaire has been distributed to maintenance professionals in order to collect their professional view on the industrial sector they are currently working on, or they know very well. The questionnaire has also been given to a number of individuals who are experts in a number of technical sectors but not necessarily experts in maintenance or wear. The currently available data collected from a range of industrial sectors, mostly European, is presented in Table 1.

Clearly this data can only be seen as an estimate and not as scientific data, but in any case it helps showing different interesting aspects. For instance, it is interesting to notice that more than 68% of the failures are related to failure modes representing a recognisable wear out pattern (whether rapid or slow), which stresses on the convenience of CBM solutions.

On the other hand, it is interesting to note that the data sets include significant variations that illustrate the difficulties to have solid arguments. Although some differences among sectors are expected, there are important differences between similar respondents. For instance, there are notable differences between USA and UK aerospace figures, as well as between similar car figures at the same country. These differences can only be understood on the light of partial misunderstanding of the way the different failure modes occur or the way the failure causes are computed.

Based on this the authors of this paper see that there is a great need for reliable data for different sectors of industry and would like to challenge the different European national maintenance societies to take an active role in collecting this kind of data.

4 *Economy of CBM*

The data shown in table 6 identifies that 30% of respondents believe that equipment will suffer from a ‘rapid wear out after long useful life’. However, due to many contributing factors, such as cost to replace and a lack of skilled staff certain companies may find it difficult to implement a new system.

Table 1. % of failures per category, survey results.

Industrial sector	Country	Bath tub curve, infant mortality, useful life, rapid wear out	Rapid wear out after long useful life	Gradual wear out after long useful life	No infant mortality followed by indefinite useful life	Indefinite useful life	Infant mortality followed by indefinite useful life
Aerospace	UK	10,00 %	10,00 %	70,00 %	0,00 %	0,00 %	0,00 %
Aircraft	USA	4,00 %	2,00 %	5,00 %	7,00 %	14,00 %	68,00 %
Cars	UK	10,00 %	30,00 %	30,00 %	15,00 %	10,00 %	5,00 %
Cars	UK	10,00 %	20,00 %	10,00 %	5,00 %	20,00 %	5,00 %
Cars	UK	12,00 %	6,00 %	8,00 %	9,00 %	20,00 %	45,00 %
Cars	UK	10,00 %	30,00 %	50,00 %	10,00 %	0,00 %	0,00 %
Manufacturing	Italy	5,00 %	20,00 %	40,00 %	20,00 %	14,00 %	1,00 %
Paper industry	Sweden	4,00 %	6,00 %	15,00 %	18,00 %	20,00 %	37,00 %
Process industry	UK	60,00 %	15,00 %	10,00 %	10,00 %	5,00 %	5,00 %
Process industry	Sweden	10,00 %	50,00 %	10,00 %	10,00 %	15,00 %	5,00 %
Ships	USA		17,00 %			42,00 %	29,00 %
Home electronics	UK	70,00 %	20,00 %	10,00 %	5,00 %	0,00 %	5,00 %
Home electronics	UK	15,00 %	80,00 %	5,00 %	0,00 %	0,00 %	0,00 %
Home electronics	UK	5,00 %	70,00 %	25,00 %	0,00 %	0,00 %	0,00 %
Lifts	Spain		35,00 %	30,00 %		35,00 %	
Machine tools	Spain	10,00 %	40,00 %	5,00 %		40,00 %	5,00 %
Electric motors /batteries	Spain	5,00 %	35,00 %	30,00 %		30,00 %	

Mechanical components	Spain	10,00 %	30,00 %	50,00 %		5,00 %	5,00 %
Manufacturing	Spain	10,00 %	25,00 %	25,00 %		30,00 %	10,00 %
Robotic systems	Spain		30,00 %	30,00 %		35,00 %	5,00 %
Rail	UK	15,00 %	60,00 %	5,00 %	10,00 %	10,00 %	
Average		15,28 %	30,05 %	23,15 %	8,50 %	16,43 %	12,78 %

Interviews conducted by Trimble et al. (2004) were undertaken with a large number of maintenance professionals in a number of industrial sectors to firstly determine how they perceived their maintenance strategy in terms of maintenance maturity, shown in figure 7 and how they could introduce modern maintenance technologies, such as condition based maintenance.

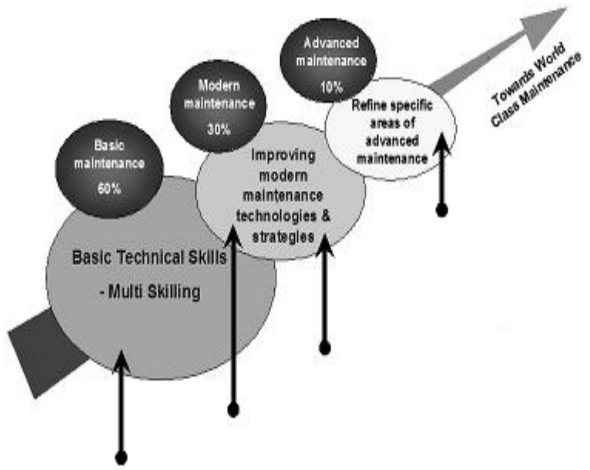

Figure 7. Levels of maintenance strategies

The aim was to categorise companies based upon basic, modern and advanced maintenance practices. As the figure 7 shows, 60% of companies have basic skilled staff and follow a mainly reactive strategy, whereas only 10% used advanced maintenance (i.e. CBM).

A barrier which, according to the data, would impede the development of an advanced maintenance strategy, which involves condition based maintenance, is cost. It is important to a) determine the cost of failures and b) determine the cost benefit of avoiding failure. This requires detailed cost analyses of the current cost of maintenance and the necessary investment required to increase planned maintenance activities. First attempts of this calculation have been provided by Jantunen et al. (2010) and Fumagalli et al. (2010). Nevertheless, demonstrating the magnitude of the savings that can be generated using CBM is difficult due to internal accounting systems, inherent skill levels and potential cost to implement a range of sensors. However, many examples exist in manufacturing, especially within the automotive industry, where the implementation of CBM tools and techniques has had a financial impact.

Condition Monitoring tools have proven successful in reducing unplanned downtime by preventing equipment or process failure. This is achieved by providing asset managers with the information they need to implement real-time, need-based maintenance for deteriorating equipment.

5 Conclusions

This paper has provided the results from a study on maintenance, in particular aspects of wear, from a range of maintenance professionals working in a number of industry sectors. The results have shown that approximately 30% of equipment wears out rapidly after long useful life. In order to extend the useful life of equipment, advanced maintenance strategies, in particular condition based maintenance, should be examined and if possible implemented. The aim is to move towards world class maintenance standards by developing an appropriate strategy. However, it is important to understand the costs involved with CBM. The paper also identifies the need for standard data collection methods which could be supported by the European National Maintenance Societies.

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