Networked Maintenance Concept for Improved Reliability

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Abstract: Industrial maintenance has been facing major changes during the last decades. Traditionally the industrial maintenance was carried out by own resources, often the same ones performing the operations. As the processes and equipment developed, the need for more specialised maintenance knowhow become evident and maintenance become the profession of its own.

When the complexity of maintenance increased the maintenance organisations in industry become more and more sophisticated and specialised maintenance service companies started to emerge. These companies started to offer outsourced maintenance and they were often able to increase the maintenance efficiency with their optimised maintenance practices and advanced methodologies.

The concepts are still developing. One of the most important drivers of change today is the rapid development of information and communication technology that makes new networked maintenance models viable. In networked maintenance concept partners bring in their special knowledge for the benefit of all parties. The modern tools allow the best resources to participate decision making instantly regardless of where they are physically located.

Keywords: reliability, networking, predictive maintenance, co-operation, maintenance

1. INTRODUCTION

Traditionally the maintenance in industry was carried out by production operators themselves, with no predefined tasks or targets. The focus was on repairing broken machinery when breakdowns occurred. Today the focus in maintenance is primarily in keeping the assets operational and secondarily in returning them to production as quickly as possible (Galar et al., 2011). Execution of maintenance is today based on systematic planning process that defines maintenance tasks and practices so that assets are performing as defined and maintenance resources are utilised optimally.

Reliability of industrial assets and processes is highly dependent on how predictive maintenance tasks and actions are planned and executed. This very specialized task requires a lot of knowledge and expertise. Therefore it is often technically and economically feasible for the company to use specialised partner for development and execution of these highly developed maintenance tasks rather than to invest in developing all the necessary skills for their own personnel.

This paper describes the networked maintenance concept where the supplier with the deep knowledge of reliability operates as an integral part of the network with production and maintenance partners. Also practical examples and results are discussed.

2. MAINTENANCE TASKS AND TARGETS

Maintenance is a vital function that especially in process industry ensures the production is running without any disturbances. This requires a thorough planning of maintenance activities and well organized processes.

There are several methods for planning and executing maintenance operations but the basics of all modern maintenance philosophies are quite similar. In short, the ultimate targets of maintenance can be simplified to the following two sentences.

1. Machinery failures are not allowed to disturb production or harm people or the environment.
2. It is not acceptable to repair machines that are not broken.

This may sound trivial but the two sentences above describe all the targets that the maintenance organisation needs. The first one states that maintenance has to operate so that Overall Equipment Effectiveness (OEE) losses are minimised. The second one has practically two meanings. Firstly, it will save maintenance costs, as only the necessary tasks will be performed, and secondly, the number of failures is reduced by avoiding human errors due to unnecessary maintenance actions.
The two targets can be met by following means:

1. Critical assets should be maintained based on their condition (Condition Based Maintenance).
2. Systematic preventive maintenance practices have to be planned for all assets.
3. For non-critical machinery, failures can be accepted.

If it is not possible to prevent production disturbances by the above means, there is probably a need to redesign the process or asset in question.

3. MAINTENANCE ORGANISATIONS

No single organizational model or structure has proven to be the best way for organising maintenance. Very good results can be obtained by many models depending on targets, resources and operating environment. In the early days maintenance was considered a necessary evil that had to be done when something went wrong. Later maintenance became a profession of its own and companies gradually started to see maintenance not only as a cost but also as a competitive element which then led to the development of systematic preventive maintenance practices and to predictive and proactive maintenance.

Organisation wise maintenance was first part of operations and later a separate department in an organisation. During the last decades outsourcing of maintenance has become one of the alternatives and lately also the networked maintenance models, where the number of responsible network partners is higher, have become more and more popular.

3.1 Maintenance Outsourcing

Due to the challenging economic environment many industrial companies have been focusing on cost cutting of all the possible functions, including maintenance. This has been possible even in process industry because the market for products has been weak and therefore a risk for unplanned shut has been limited and considered acceptable. In many cases the savings programmes have resulted to improved efficiency of operations but in some cases the reliability considerations have been forgotten and the availability of assets have decreased.

Outsourcing of non-core functions such as maintenance has been widely used as a means to improve operating practices and to change company structure. In maintenance outsourcing the target usually has been to improve maintenance efficiency and asset reliability by bringing in a partner who has maintenance as their core business and can bring in specialized knowhow and efficient processes.

Unfortunately in many cases maintenance outsourcing has been used predominantly as a way of saving costs and not so much as an opportunity to improve overall equipment efficiency which has led to some disappointments.

3.2 Networked maintenance

Networking has been an increasing trend in the industry for some time. In a network different partners are sharing responsibility for the benefit of the whole operation. In Figure 1 there is a schematic example of a simple network with an example of responsibilities shared between the three partners. The network can be very effective way of developing and improving operations. In the efficiently organised network the partners all share the overall goal but they all can focus on their core expertise for the benefit of all. The risks and rewards should of course be in line with the responsibilities.

![Figure 1. Simplified example of networked maintenance and sharing of responsibilities.](image)

In Figure 2 there is another example of a larger scale of networked co-operation including remote monitoring arrangement that is based on cloud services. In this example, there are three partners. The first is the mill operator who owns the assets and runs a number of mills. The second one is the maintenance supplier who is responsible for the overall maintenance of the assets, and the third is the reliability partner who is responsible of predictive maintenance through its remote and local services. (Mikkonen and Lahdelma, 2014).

![Figure 2. An example of a large scale remote monitoring arrangement.](image)
the actual maintenance actions and the operators are responsible for daily operational checks through the Operator Driven Reliability (ODR) concept. The operators utilise PDA equipment in their rounds.

When external partner has a major role in availability development it is essential to understand what the value that the partner brings to the partnership is. If the only value is cost saving, it may mean risking asset availability in a longer term. To be able to manage availability issues in partnership cases requires at least:

1. Long term commitment and thorough trust between the parties
2. Clear task and responsibility definitions
3. Clearly defined targets and performance indicators
4. Well-functioning tools and operating practices to manage and share co-operation data
5. Expertise and systems for effectively utilising data from multiple sources.

3. ELEMENTS OF RELIABILITY IMPROVEMENT

Asset availability and reliability are the key elements for the productivity improvement in industry. Reliability improvement also usually means significant savings in overall costs. Figure 3 shows an illustration on how availability is dependent on multiple factors.

To improve the reliability of rotating machinery in industry is a combination of several elements that all have to be in appropriate level in order to achieve good results.

3.1 People competencies and communication

The more we understand of the needs and drivers of different working areas, the better we are able to adapt for co-operation between individual persons having different knowledge and doing different tasks in a mill. Communication is a key element in co-operation and in environments where different companies are involved, the role and need for communication is even more critical.

Workers’ personal abilities are also affecting how well communication is functioning. In networks people have to be able to work with people having different background, skills, working experience and knowledge – and appreciate each other. (Saarinen, 2014) Socially skilled service people are extremely valuable asset for all service companies and sometimes it is challenge for management to find these personalities. In addition to the social skills these people have to have high level of knowledge on their technical areas of expertise.

To achieve excellent reliability targets it is a must to have committed personnel and good leadership. These two things go normally hand in hand. Commitment requires smart, achievable objectives, tools and an environment where people are able to do the work well. It is a duty of a management to ensure that these conditions are met.

3.2 Preventive maintenance practices

Preventive maintenance includes all pre-determined actions to prevent immature breakdown of machinery. This includes for example cleaning tasks and the change of consumables as well as routine checks and lubrication.

For example, proper lubrication is one of the key prerequisites for ensuring trouble free production. This consists of the selection of right lubricant, right amount of lubricant and properly defined lubrication intervals as well as right working methods.

Thorough lubrication plan requires detailed technical specifications of equipment, the knowhow of running speeds and other operating conditions as well as environmental conditions in which the assets are operating. Same machines operating in different conditions may require significantly different lubrication plans. In short the basic work has to be done properly to be able to calculate the right lubrication program.

By vibration measurements it is possible to detect if lubrication is working well and there is a film of lubricant between the elements of bearings. It is a way to control the quality of lubrication and adapt changes if needed.

3.3 Predictive maintenance practices

Vibration measurements of critical rotating equipment are the most useful method for condition based maintenance. To get full benefit out of vibration measurements requires systematic PdM planning, competent people and up to date tools.

In addition to the vibration monitoring other methods such as thermal imaging, ultrasound and different electrical measurements can be very useful. A method to be used should be selected according to failure modes of equipment.
3.4 Operator involvement in reliability

Operator Driven Reliability (ODR) can be defined as a system of involving the equipment operators in improving reliability by allowing them identify potential equipment problems and failures at an early stage (Gulati et al., 1997). ODR is a plant-wide initiative that combines people, processes and technology, but it is more a matter of how to organise the work than of technology. Similarly, it is more about making daily operator routines of checking assets more systematically instead of adding new maintenance tasks for them. For example, openness, cross-functional cooperation, communication and systematization are the pillars in ODR. This requires that the management is committed to the process right from the beginning, fostering a spirit of teamwork instead of territory protection (Mikkonen and Lahdelma, 2013).

One of the advantages of the ODR concept is that when different parties use the same platform, communication between the parties becomes natural, thus improving the efficiency of the work. All the data from operational checks and from condition monitoring measurements are stored in same database or in cloud computing and all the parties have access to the data.

3.5 Proactive maintenance and continuous improvement

Continuous improvement is the element that concludes the famous Deming cycle. The processes in maintenance have to be systematic, documented and consistent as a pre-condition for proactive development.

Systematic processes allow reliable follow-up which will then provide data for development. When exceptions happen there must be a process in place how to act and proactively find ways of preventing same exceptions to re-occur. For example Root Cause Failure Analysis (RCFA) is a powerful tool for improvements if it is utilised systematically.

4. EXAMPLE OF RELIABILITY IMPROVEMENT IN NETWORKED MAINTENANCE

In this case the paperboard mill had a need to improve the reliability of the operation and they were suffering of production losses that affected their cardboard sales.

The maintenance of the mill was carried out by an external supplier but their competence in predictive maintenance was not adequate for improving the reliability of the assets. Therefore decision was made to quickly overcome these issues by taking an external third partner for reliability development instead of starting to develop the knowhow and resources of their own. The scope of the reliability cooperation includes:

- Predictive maintenance (PdM) program planning and execution
- Lubrication development and some lubrication tasks
- Assisting with root cause analysis (RCA) on rotating machinery
- Spare part deliveries via authorized distributor
- Workshop assessments and improvement actions
- Precision maintenance training
- Proactive management of continuous improvements for rotating equipment
- Follow-up and reporting of activities and results for continuous development

The current state was analysed prior to the start-up and the implementation was started by re-designing condition monitoring settings, routes and schedules as well as updating lubrication practices including lubricant amounts intervals and lubricant types. These tasks were based on the criticality analysis (A-B-C) that the maintenance provider had recently updated.

All critical equipment that were classified as A or B assets were considered necessary for systematic vibration measurements. The measurement intervals of the equipment were defined based on criticality, practical experiences of equipment failure modes and speed the progress of faults. Measurement settings for vibration measurements were calculated based on our experience, how we can best detect failures proactively.

All the reliability processes were systematized, and continuous follow-up and communication practices were taken in to use. Along with the work process development systematic improvement actions were started including RCFA.

4.1 Results

As part of the partnership the quality of reliability work is systematically followed to ensure continuous improvement. One of the Key Performance Indicators (KPI) in contract that is measured is the reliability of condition monitoring measurements (REL_m). This is calculated by:

\[
REL_m = 100\% - 100\% \times \left( \frac{N_1 - N_2}{N_1} \right)
\]

Where

\( N_1 = \text{Total number of mechanical failures in assets under surveillance} \)
\( N_2 = \text{Number of detected failures} \)

Since the beginning of contract in about four years’ time the total amount of failures has been 329. Out of these 325 have been detected in time and by that prevented the unplanned shut. The reliability of PdM programme has though been 98,8%. All of the undetected failures have been analysed and so far all of them have been a caused by a failure mode that is not possible to detect by measurements and actions have been
taken to ensure the same faults will not happen again. For instance plastic cages in gearbox bearings have caused costly unplanned shuts. The reliability trend is in Figure 4.

Annual shut hours due to mechanical reasons have as a result of improved asset availability decreased by tens of percentage points that have had a clear positive effect on increased production. This has also resulted to significant reduction in maintenance and spare part costs.

An integral part of the reliability improvement and continuous development is Root Cause Failure Analyses. During the contract period several cases have been completed and by that improved the availability of problematic assets.

Over the life of this program the number of failures has gone down by about one third and the reduction in bearing failures has exceeded 68%. The failure trend is in Figure 5.

The trend of all failures shown in Figure 5 is a very typical one for this kind of reliability improvement initiatives. In the beginning when detection practices develop the number of detected faults increase. After the faults have been corrected the number usually starts to decrease significantly. This is a combination of improved maintenance practices such as precision alignment and correct installation methods as well as improved preventive maintenance routines such as correct lubrication etc. Also proactive smaller and larger improvements often play a major role in the development.

During the contract period the most important cases have been analysed and the savings have been documented in co-operation with the asset owner. The documented benefits are shown in Figure 6. These documented savings exceed the investment to reliability improvement by many times and it is clear that the investment has been successful. In total the savings are even higher than shown in the graph since the documented cases are only a fraction of all cases.

6. CONCLUSIONS

Networked maintenance can provide excellent results if all the parties are aiming towards same goals. It is an excellent and efficient way for engaging specialised resources and knowhow to develop asset reliability for the common benefit.

The implementation of networked maintenance is predominantly a change process for the people involved. The implementation of new practices requires strong commitment from all the different partners and firm leadership to succeed. In addition the communication in all levels is vital in networked maintenance. It is also extremely important that the roles and responsibilities are clearly defined and communicated and that the risks and rewards are in line with the responsibilities.

There are examples of cases where this kind of co-operation has proved its value in relatively short time.
REFERENCES


