Changing of the Maintenance System in the Production Plant with the Application of Predictive Maintenance

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Abstract – **The main goal of this paper is to analyse the current system of maintenance in selected company and after identification of crucial problems, to propose the new system of maintenance that will be built based on predictive maintenance. The paper is divided into three sections. First section treats predictive maintenance in theoretical plane. Second section deals with analysis of current situation in the selected company in the maintenance area, while in this section you can find information about spare parts consumption and failure rate per year. Third section is about the proposal of improving maintenance status by introducing predictive maintenance.**

Keywords– **maintenance, predictive maintenance, preventive maintenance, failure**

1. Introduction

The prosperity is the highest goal of each production plant. An integral part of the operation of any successful business is the maintenance department.

The production plant doesn´t want to have losses due to longer shutdowns, so the maintenance department has to solve every problem as soon as possible and prevent the problem in the future. Although the maintenance department is a non-productive department, it is one of the most important in the production plant.

The aim of maintenance is to maintain the condition of the device throughout the cycle so that it is functional and performs the required function. The goal of properly performing maintenance begins with properly defined and accepted maintenance activities. These activities may represent product quality, equipment usability, reduction of costs, safety, environmental protection, etc.

The main idea of maintenance is not to repair damaged equipment, but to prevent fatal equipment damage, and also to anticipate the start of failure and fatal equipment damage. The greatest benefit of optimal work of maintenance team is that machines work safely, efficiently and reliably.

2. Predictive Maintenance as a Necessity

Predictive maintenance deals with detection of device degradation and problem solving. This type of maintenance identifies the current state of the device. Predictive maintenance allows you to eliminate or to manage occasional tensions that prevent a significant worsening of the physical condition of machines parts or entire devices.

This leads to future functional capabilities of the device in the future. Predictive maintenance differs from preventive maintenance in the point that the maintenance system is based on determining the actual condition of the equipment rather than a predetermined replacement part plan. Predictive maintenance is used to define the necessary tasks based on material and device status. Studies of the predictive maintenance program estimate that this maintenance system can provide savings of 8% – 12%. The other side of the predictive maintenance

system application are the initial investment costs [1].

However, the initial costs of introducing this kind of maintenance can be quite high.

3. Analysis of the Current Maintenance Situation in the Production Plant

The production plant that will be analyzed in this paper can be characterized as a corporate software-industrial company. This production plant has currently several divisions, and we will focus on the best-known division, which is focused on the automotive industry.

The maintenance department works under the direction of a maintenance manager who is subordinate to the plant manager and to the maintenance manager within the corporation. This manager is responsible for any unwanted production shutdown, success of preventive maintenance and compliance with the budget. Furthermore, the maintenance team consists of two maintenance leaders according to the fact that production plant is divided into the assembly part and machining part. Maintenance leaders are directly responsible for maintenance engineers. Maintenance engineers are another important part of the maintenance team. Their responsibility is directly linked to complete maintenance solutions on their parts. They take part in the most difficult and most important failures, correctly set up the maintenance system on their parts, participate in line innovations, look for new opportunities to save costs and repair time. The most important part of the maintenance department are maintenance engineers who are directly involved in repairing devices and bringing in improvement ideas [2], [3].

Correct setting of control items achieves results that are realistic, measurable, defined, acceptable and within a timeframe. The maintenance department has established control items for reports, targets are set according to the previous year and there is a space for improvement. One of the most important control items is Machine availability (MA). Other known control items are Mean Time to Repair (MTTR) and Mean Time Between Failures (MTBR), and the monitoring of maintenance costs. This includes services and used spare parts. Tab. 1. shows how the results are reported to the manager at TIER meetings.

Table 1. Maintenance report

Goals													
OG	NG	CHRA	FA	VSR	FA MA	SWA MA	SITE						
93%	93%	96%	97%	99%	97%	93%	95%						
REPORTING T3/T4													
List of machines	Time planned for production	Failure duration	Number of failures	Availability of machines	MTTR	MTBF	MA	COST			SAP	TIME	MHS
SWA1A	639.25	25.84	77	96.0%	0.34	7.97			SITE	95.71%	775.2	0.00%
SWA2A	679.80	38.62	121	94.3%	0.32	5.30			SWA MA	96.59%	245.9	0.00%
SWA3A	648.02	34.43	82	94.7%	0.42	7.48			OG	94.97%	229.58	0.00%
SWA4A	649.10	22.9	74	96.6%	0.30	8.47	94.97%		NG	98.21%	16.31	0.00%
SWA5A	645.55	51.33	105	92.0%	0.49	5.66			FA MA	95.27%	529.4	0.00%
SWA6A	647.28	57.27	125	91.2%	0.46	4.72			FA MA	96.53%	285.74	0.00%
SWA7A	88.63	0.00	0	100.0%	0.00	0.00			CHRA	94.00%	243.61	0.00%
SWA1B	570.00	6.23	32	99.0%	0.19	17.62			FA w/o VSR	97.14%	219.92	7700.94
SWA2B	0.00	0.00	0	0.0%	0.00	0.00	98.21%		VSR	99.27%	56.19	
SWA3B	405.30	10.8	35	98.0%	0.29	11.29			MTTR	0.36	NoB	2141

Preventive maintenance is planned in the SAP system. Preventive maintenance scheduling is planned in individual periods. Scheduling frequencies are day, week, two weeks, month, two months, three months, four months, six months, year, two years, three years, four years and five years. With very precise and detailed maintenance planning it is possible to achieve very good results in spare parts consumption and inspections during preventive maintenance. The task of a maintenance engineer is to manage preventive maintenance scheduling, inspection of how much preventive maintenance has to be performed, and negotiate with colleagues from the production department to free up the production line for preventive maintenance that is necessary to the most important goal for each production plant and that is zero failures [1], [4].

After equipping the preventive maintenance shutdown, he must allocate the resources that are necessary to perform maintenance. The success of performing preventive maintenance is shown in Fig. 1. It is evaluated once a week. The success rate of preventive maintenance performed is compared with the planned time for preventive maintenance. Preventive maintenance is built systematically in the operating environment of the PM SAP maintenance module. After withdrawal of preventive maintenance in the SAP system, usually 2 weeks after the change, it is printed for maintenance engineers and postponed to the maintenance workplace. Maintenance engineers will take preventive maintenance before the work shift begins. Fig 2. shows the preventive maintenance order in SAP.
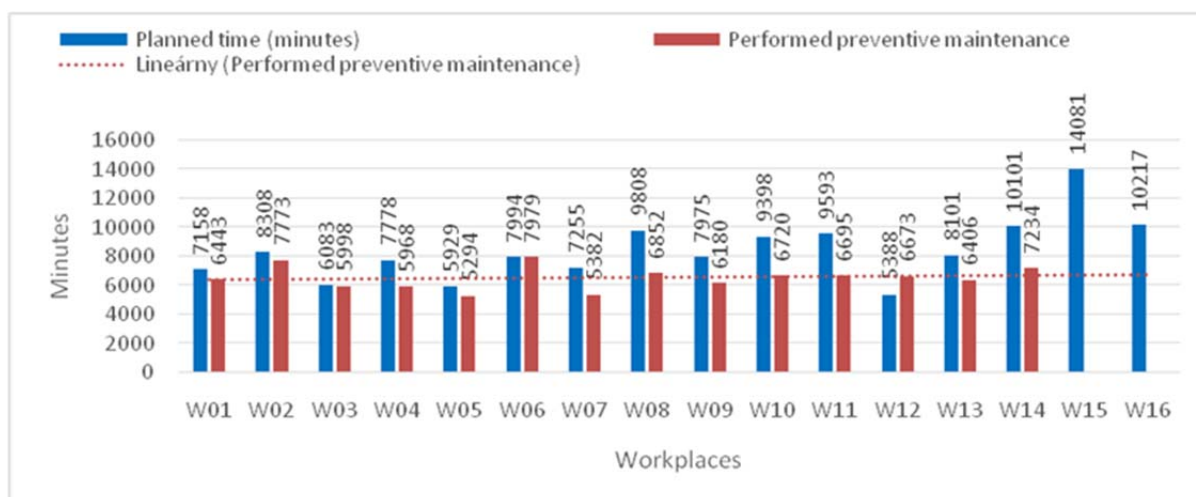
Figure 1. Evaluation of preventive maintenance

Figure 2. Preventive maintenance order

Another necessary part is corrective maintenance – failure solving. The corrective maintenance system works in SAP, which is linked to the MHS system. The start of the failure occurs immediately after the first escalation by the operator, respectively by process engineer, who loads a barcode of the failure [5]. Maintenance engineers logging in on the failure in the MHS mobile application shown in Fig. 3., where we can see the failure logging systematically.

Figure 3. MHS mobile application – corrective maintenance

They can assign to the failure the type of failure, respectively the material used in the failure. After the failure the analysis part occurs. The analysis is completed in the SAP system, where maintenance engineers modify the maintenance notification, respectively write what they did, what helped to repair the machine and what the root cause of the failure was [6], [7].

Autonomous maintenance is an important part of every maintenance department. Everyone knows TPM as a totally productive maintenance system that is built on TPM control plans. The operator on the machine before each work shift will go through his equipment according to the control plan, i.e. important things like water level, tire and hydraulic pressure, losses and visual inspection of anomalies on the production equipment. If he finds any deficiency, he writes it to the TPM card and hangs it on the machine, which serves as a system and visual aid. He places a second card on the TPM board to inform maintenance engineers that any of the TPM activity is not fulfilled. It also serves as a visual aid to the success of autonomous maintenance.

Management of spare parts (SP) is located directly in the production plant. Most of the critical spare parts are stocked mainly because it is unthinkable in the automotive industry to shut down the machine unexpectedly, even for a few hours. On a daily basis, the consumption of spare parts (Fig. 4.) is monitored by Pareto analysis. Proper management of spare parts is very important because of budget compliance. All spare parts are classified according to the ABC classification [5], [8].
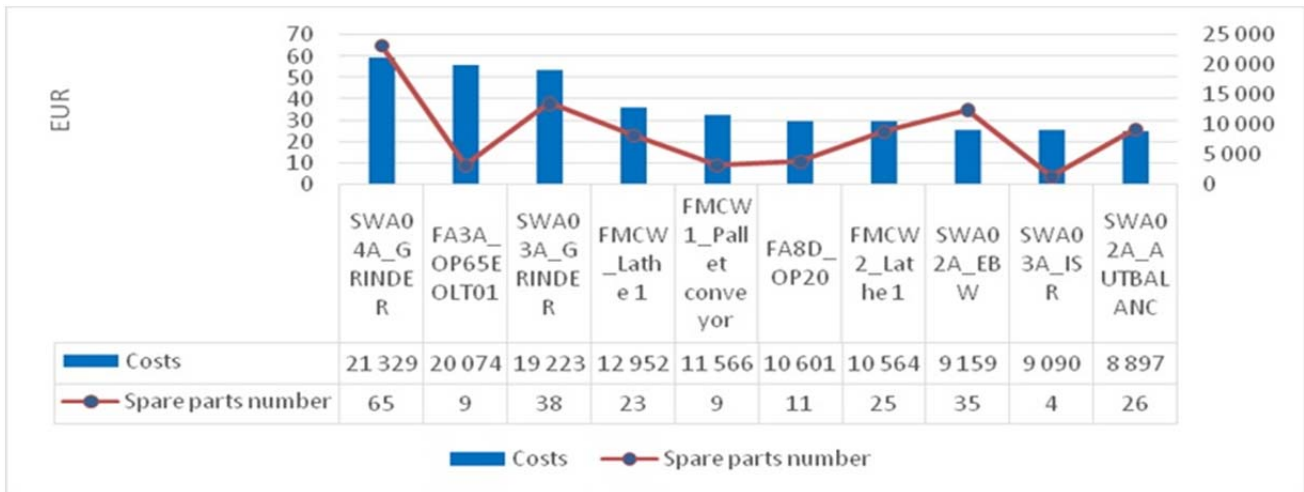

Figure 4. Consumption of spare parts per year

Using Pareto analysis, we have found that up to 38% of all the costs consumed are part of the FMCW – machining the compressor propeller. In Fig. 5. there is a graph of spare parts consumption per year in the form of costs. Replacement of spindles was the largest part of the consumed costs.
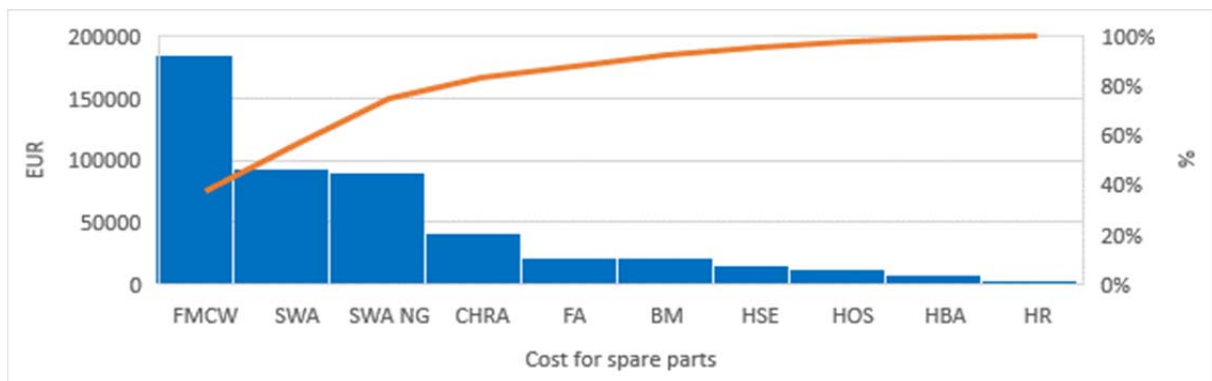

Figure 5. Consumption of spare parts in the form of costs per year

By analysing the failures, we found out whether the costs can be compared on the FMCW line also in terms of failures. Fig. 6. shows the number of failures on the FMCW line, where 40 failures are a problem with milling machines. In nominal representation, it was 4755 minutes [1], [9].
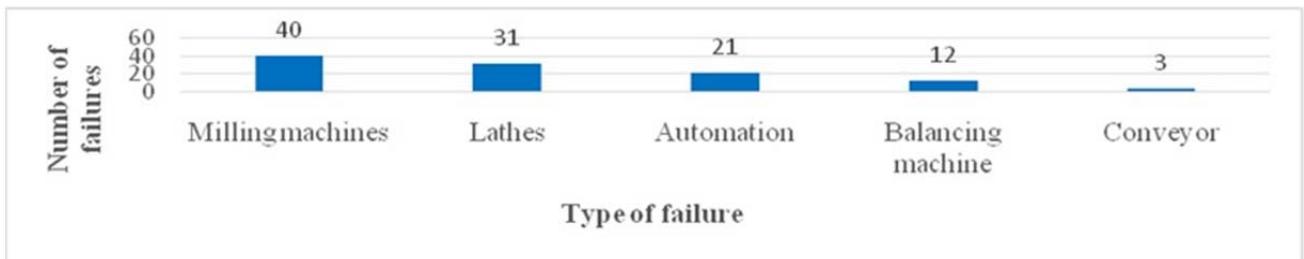

Figure 6. The frequency of faults on the FMCW line per year in terms of source of failure

By analysing the shutdown time (Fig. 7.) on milling machines, we concluded that out of the total failure time, up to 54% of all shutdowns are spindle replacement, which is also described in the analysis in terms of maintenance costs.
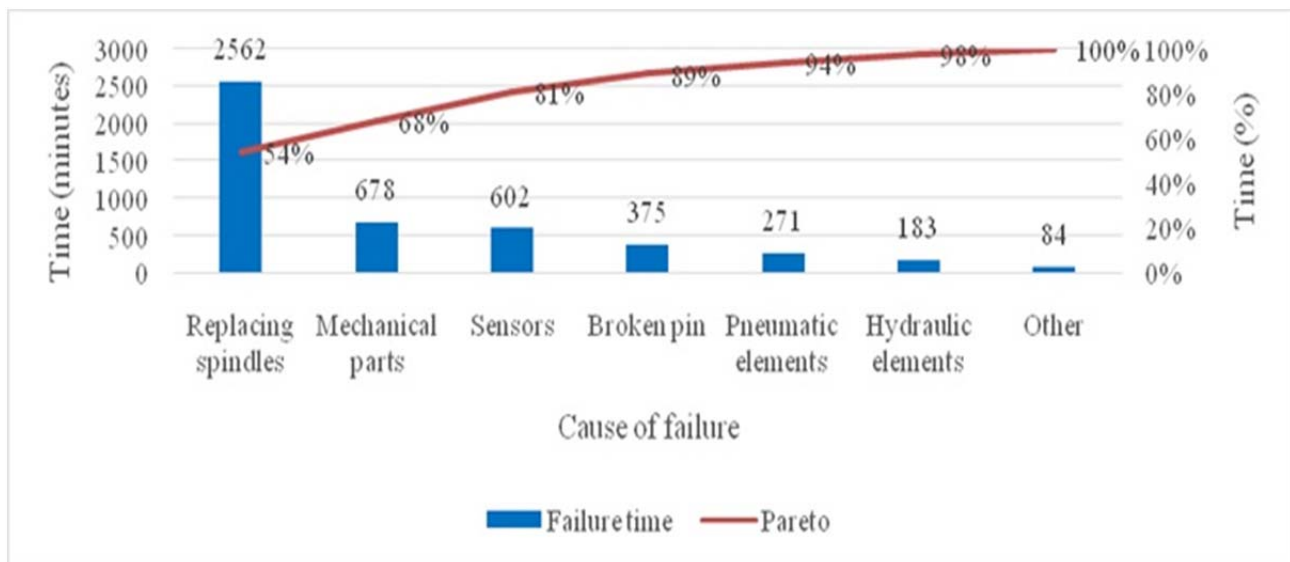
Figure 7. Total time of failures on milling machines per year

The depth analysis revealed that from the both point of views (costs and length of shutdowns) were the biggest problem with the spindles on the milling machines, and in terms of the largest number of failures was the problem with mechanical parts.

4. Proposal for Maintenance Status Improvement by Introducing Predictive Maintenance

The milling machine operates at very high speeds during machining. It is a 5-axis CNC milling machine and during the machining, it is very big speed variability. The speed in the largest spectrum is 40,000 revolutions per minute. The spindle construction is based on four ceramic bearings and a clamping hydraulic system that clamps the tool. Fig. 8. shows a high-speed spindle from company Fischer `[10].

Figure 8. Spindle Fischer MFW-12

The proposal of a predictive maintenance system is the usage an online measuring device to measure the vibration of rolling bearings. Usage of accelerometer sensors that allows capturing bearing speed and acceleration can diagnose bearing condition, predict fatal machine damage, and plan preventive action for bearing replacement. The advantage is continuous online monitoring, so you can see in real condition how is the behaviour of spindle during machining. Another advantage of these sensors is the fact that they can also determine the tool condition, wear, or tool imbalance, which is very important at this machining speed.

For vibration diagnostics, we have proposed to use a vibration-diagnostic unit from the company IFM. The unit is marked VS100 (Fig. 9.). The unit has four channels. It can be connected to four vibration sensors. This diagnostic unit will be placed on a DIN sheet in the machine's electrical switchboard. We set the diagnostic unit period in 10-minute repetitions. The evaluation unit will record the RMS (root mean square) – the effective value of speed in mm/s (tool imbalance) and the effective value of acceleration mm/s^2 (bearing frequencies). We propose to use the vibration sensor from the IFM VSA005 (Fig. 9.). It is the lowest-sized sensor of the entire company's portfolio, because it has to fit next to the spindle. The sensor has a very high sensitivity and frequency range. The sensor can be screwed to the selected spindle position. It has a molded cable due to possible contamination with operating fluids [9], [11].

Figure 9. Diagnostic unit of IFM and the vibration sensor of IFM

The key action for the correct application of predictive maintenance is the selection of the correct measuring point of the sensors. We have chosen two measuring points for our application. The first measuring point in Fig. 10. (B1) will be placed on the first bearings from the tool in a vertical direction, the second measuring point (B2) will be placed in the middle of the spindle to catch the rear bearings in the direction away from the tool.
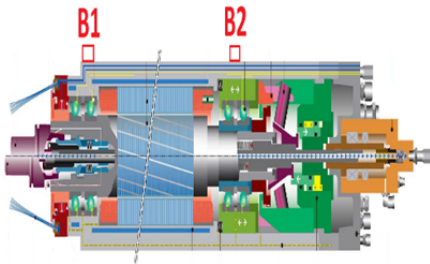

Figure 10. Schematic representation of the spindle with the location of the diagnostic measuring points

The analysis found that the most frequent repeating failures are mechanical parts. Everything is due to no implementation of preventive maintenance. The proposed solution is to divide preventive maintenance into activities that can be performed during the operation of the equipment and those during which it is necessary to shut down the equipment. Therefore, preventive maintenance can be performed more efficiently and accurately. To change preventive maintenance, it is necessary to read the machine documentation and add experience to prevent failures [12].

The example of the correct functionality of the predictive maintenance system is shown in Fig. 11. In this figure, the trend of imbalance and bearings from the IFM diagnostic system is shown, where it can be seen very well that the value of imbalance and bearings (on the right side of the red graph) has worsened and that spindle replacement will be necessary. Immediately was planned spindle replacement with the assist of authorized service of the machine supplier, while the replacement was without complications.

After replacing the spindle, it was visible that the effective value of imbalance and bearings has fallen to a much lower value. Thus, it can be seen that the predictive maintenance system is proposed correctly and can detect the problem.
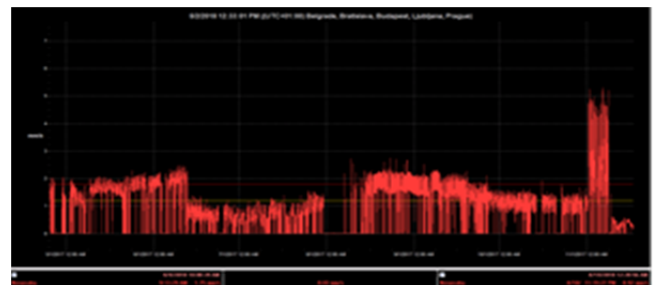

Figure 11. Trends of ineffective and effective value

Another problem that has to be solved is that high-speed milling spindles often failure due to tools. The diagnostic system detected this in the frequency band of spindle unbalance. There were extremely high values, while the bearing values were low. We propose to solve this by changing the design of the tool.

The design change is shown in Fig. 12., where we can see the designed change of the milling tools, which will be shorter in the first step. The new tool type is shown on the left. We propose a difference in tool length of 15 mm, which at such high speeds has a considerable impact on reducing the unbalance of tools.

Figure 12. Comparison of milling tools

Another proposal is the overall system change of preventive maintenance. Preventive maintenance has to be completely remodelled, not only in terms of current preventive maintenance, but all documentation from machine producers has also to be studied, reviewing the time spent on preventive maintenance activities. But the most important point will be a distribution between activities that are performed during the time that equipment is running and activities that are performed are done during machine shutdown. By dividing operations during machine operation and during downtime, we will be able to effectively use machine downtime and fill it with other important actions to improve machine condition. In the old preventive maintenance, the shutdown time was approximately 285 min. Modified preventive maintenance will require a shutdown of the machine for only 235 minutes, which makes it possible to use 2600 minutes per year for other activities [1], [9], [13].

The proposal of the maintenance system innovation can be divided into two parts. The first part is focused on the application of a non-established predictive maintenance system. With this proposal, it is expected that it brings benefits in the form of a 10-15% reduction in time and shutdowns and a 17% reduction in costs and losses for unexpected shutdowns. The second part contains changes of the preventive maintenance system. The change in the preventive maintenance system will improve this system, because the preventive maintenance time will be used more efficiently and there remains time for other necessary activities. After the implementation of the new predictive maintenance system and after the change in the preventive maintenance system, we expect improvements in the form stabilization of the company´s costs, reduction of unexpected shutdowns, increased preventive maintenance efficiency and stabilization of the management of the maintenance system.

5. Conclusion

This paper pointed out that the maintenance department is undoubtedly one of the most important departments for the prosperity of the production plant. Proper process and maintenance system setup not only make processes more efficient, but also shortens unexpected downtimes that could disrupt business productivity. This is unacceptable in the policy of companies that try to reduce transformation costs, since almost none of the modern enterprises doesn´t produce products in the warehouses, but on demand from the customer (Just in Time) and because of this fact, a 100% machine condition is required. After the implementation of the proposals, we expect the overall improvement of the maintenance system. After the implementation of proposal of maintenance system changing, we expect not only the reduction of downtimes, but also the maintenance stabilization. The philosophy in the future (after completing the application of the predictive maintenance system) is to learn from each failure, store the spare part in the warehouse, and apply preventive inspection of the spare part or preventive replacement of the spare part to prevent any failure. It is important to think about the fact that preventive maintenance is a live process that has to be modified and to live with it. Properly applied preventive maintenance will prevent undesirable downtimes. After application of appropriate preventive maintenance activities and after dividing the activities we can achieve higher efficiency, better capacity utilization by maintenance engineers and better planned machine shutdowns.

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