Introducing autonomous maintenance by implementing OTH hybrid positions and TPM methods in metallurgical company

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Abstract— From perspective of needs and prosperity of operational practice machinery has central role in any factory. In terms of competitiveness, in global world companies must have synergistically developed all areas, processes and systems that are carried out there. Unstructured development of these ingredients promotes competition advancement and development. For this reason, problems of machinery and equipment maintenance appear as important.

Keywords: autonomous maintenance, TPM, implementation, metallurgy,

I. INTRODUCTION

Surveys and analyses show that for maximum efficiency it is necessary that manufacturing equipment and systems operate and are managed in a reliable manner. Most of these deficiencies are manifested in form of problems related to equipment (failures and maintenance problems associated with corrective actions). Sustainable level of maintenance is an essential requirement for long-term survival of all factories. Ignoring this requirement will cause that operation of the facility will incur higher operating costs, which causes a loss of competitiveness on the market.

Maintenance task can no longer be confined to immediate emergency responses, overcoming problems through several bodies and excessive overtime. Maintenance is one of the essential elements of a comprehensive production system. Maintenance is a set of activities that ensure technical competence, availability and economical operation of fixed assets. It is a set of tasks that ensure specific conditions necessary for the smooth operation of each item of equipment. For carrying out these activities is also essential a management to provide essential supplies and maintenance: spare parts - in the required quality, quantity and time; staff - at a sufficient level of knowledge; tools and resources (material as well as financial resources).

Maintenance history is also history of culture and image of industrial design and philosophy. Efficient and effective maintenance is more than ever essential for further development, especially in times of financial crisis and reduced turnover, rising cost of energy, raw materials and labour.

In past century, various approaches have been developed to perform maintenance to ensure achieving or exceeding of the life of the product. Therefore can be identified, specify various methods for maintenance from partial (preventative and predictive maintenance through maintenance focused on reliability) to complex types of maintenance, such as TPM (Total Productivity Maintenance).

Maintenance processes developed in parallel with the development of technical systems, in particular production systems - means of production. First stage can be described as quantitative stage of development of maintenance, was related to quantitative increase in industrial production and an increase in mechanical work machines. Failures with regard to the level of machinery were an everyday situation and production downtime was long. Nobody systematically cared about development of organizational forms, methods and maintenance economics. Maintenance after fault prevailed - "action to repair damaged parts, and simple operations such as cleaning and lubrication of machine elements, which only respond to machinery and equipment failure".

Transition from maintenance after fault to preventive maintenance began at traffic technology, as first with trains, later with aviation. Immediate threat of human life and problems associated with maintenance operation has been a driving force in development of preventive maintenance. It did not start in Europe, nor the U.S., but in post-war Japan. After World War II the industry there has undergone an exemplary transformation. A simple concept was to follow the recommendations of manufacturer, make controlled repairs and maintenance of machinery and equipment, which was not normal in times around 1950. It was a part of Japanese philosophy called Kaizen, which can be loosely described as "continuous improvement". The post-war period and expansion of production, with the first IBM PC, meant revolution in data monitoring and evaluation, also requirements on product quality. Pressure to reduce losses and need for preventive maintenance of equipment

has increased; failure has not been any more a self-evident event. Reducing downtimes and requirements for equipment reliability increasing led to planning and scheduling of maintenance activities. It is called “Planned Preventive Maintenance“- maintenance carried out at predetermined intervals or, according to prescribed criteria and it is intended to reduce the probability of failure or item performance limitation".

Around 1960 a growing competitive pressure led to continuing improvement and continuous operation of production facilities. As a result, the reliability of equipment and probability of failure became predictable, depending on the load and operating time. These findings have led to an increase in quality standards, used materials and manufacturing processes. Predictive maintenance was not able to predict events caused by accident or failure, but this approach has led to statistical knowledge, which was reused in modern technology and software. This maintenance is "carried out on basis of item after previous estimate based on the analysis and evaluation of main parameters determining gradual deterioration."

In early 70s global competition necessitated further increase in production efficiency and reduced costs. Japanese "Institute of Plant Engineering” merged American concepts of maintenance and set a new standard. The core of the new concept was "autonomous maintenance". The key to its success were skilled and experienced machine operators. Based on this new philosophy maintenance has become a part of development and manufacturing process. Prerequisite was to improve all aspects of production and maintenance: from planning and system development to subsequent care. Unique on this concept was an idea of "zero targets," meaning in language of maintenance no unplanned downtime caused by disorders that could be preventable, with ultimate objective of continuous improvement. Maintenance is seen as one fundamental practice affecting product price, becomes essential to ensure quality and reliability of products, i.e. maintenance is understood as part of the logistics chain to ensure products and services to customers. We move to the complex system of production and proactive maintenance such as RCM (Reliability Centered Maintenance) - Maintenance focused on reliability, which base "is to increase the safety of cost-effective maintenance activities" and TPM (Total Productive Maintenance) - which is "system based on principle of early detection of peculiarities arising randomly by machine operation and their professional elimination. The actual implementation of method, however, is based on teamwork and change in employees thinking”.

End of the second millennium is characterized by a new phenomenon - development of Electrical and Information Technology. Know-how, software, information are becoming means of production. Their maintenance has its own specifics and can easily transfer activities, methods, systems maintenance of particular machinery on these systems. Maintenance of databases, updating knowledge base, computer upgrades, maintenance software packages, etc. necessitated new methods of maintenance.

The aim of intelligent maintenance is to monitor machinery state for the purposes of calculating the likelihood of failure and perform maintenance at moment, when it is most cost-efficient. Therefore, comprehensive and targeted monitoring mode (CM) and load of installation components essential to obtain the data needed to calculate risk. Modern CM systems meet the highest requirements for sensors, data acquisition, data transmission and automatic processing, analysis and diagnostics as well as specific knowledge about the device. Intelligent maintenance based on risk also offers huge potential for cost savings. Life critical items of equipment can be used, while at the same time it is possible to plan necessary maintenance actions in coordination with production plan.

II. CASE STUDY ON IMPLEMENTING OTH HYBRID POSITIONS

A. USS – United States Steel

United States Steel Corporation, headquartered in Pittsburgh, Pa., is an integrated steel producer with major production operations in the United States, Canada and Central Europe and an annual raw steelmaking capability of 29.3 million net tons. The company manufactures a wide range of value-added steel sheet and tubular products for the automotive, appliance, container, industrial machinery, construction, and oil and gas industries. The steel production has great tradition in Košice. The company in Slovakia has been established in 1961. The company has been bought by USX corporation in 2000

B. Current state of maintenance in the company

The maintenance is realized by combination of centralized and decentralized maintenance. Centralized maintenance refers to the specialized maintenance department consist of maintenance workers. This department provides full support as the maintenance logistics, spare parts management, technical diagnostics or reliability centred support. This department is no limited by any functional department. Under maintenance department competences fall also the cares of whole facility management (buildings, lights, cranes and other facility).

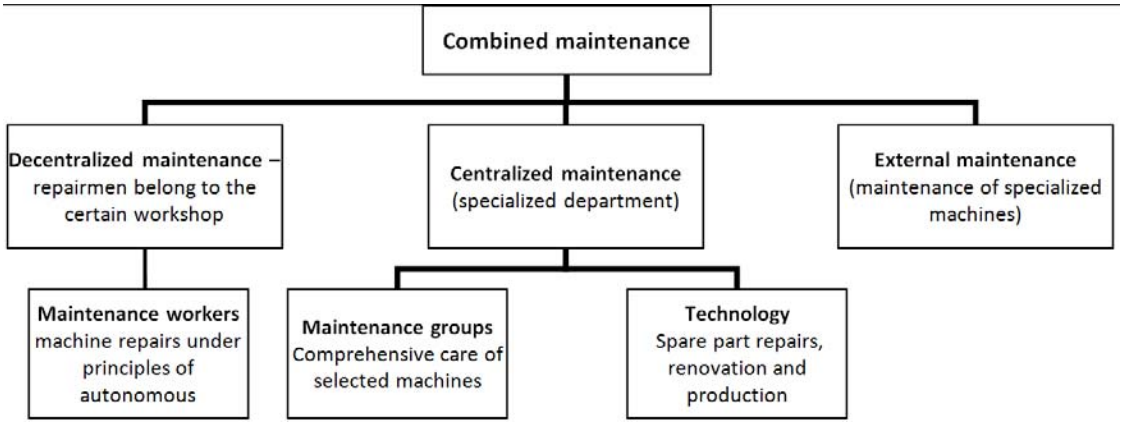

Fig. 1. 1Combined maintenance

Decentralized (production) maintenance is composed by workers (repairmen) which take care only of certain part of company (like workshop, or departments of milling, foundry, etc.) Their main responsibilities are regular inspections, removing of common failures and preparation of spare parts. The repairmen perform their job under principles of autonomous maintenance.

C. The analysis of company maintenance

There was used the SWOT analysis for the determination of main goals for the area of maintenance in the company.

The results from SWOT analysis are show on the figure

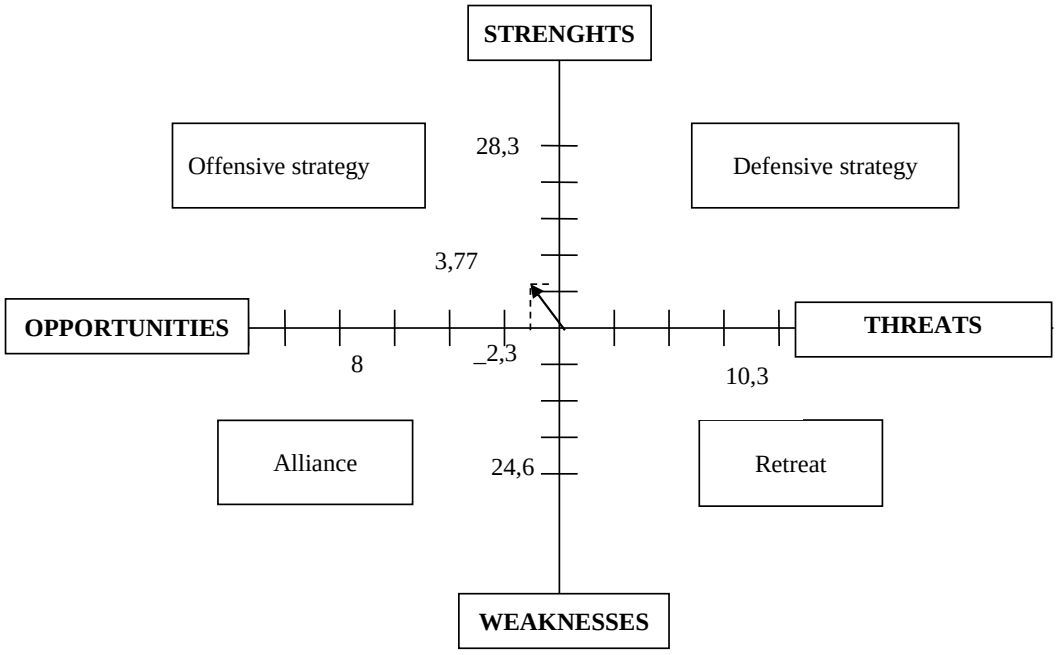

Fig. 2. SWOT analysis

Based on the results can be assumed that the company supports offensive conception of the maintenance. It means that the company is affected more by its strengths and opportunities than its weaknesses and threats.

The comparison of Strengths and Weaknesses of company maintenance shows the possibility to transfer competences from “repairmen position” directly to worker - operator. Thereby will be created new job the “maintenance operator.” The transfer cause less workload of repairmen. Repairmen could further handle only the serious failures and will not waste time for minor trifles. This will cause significant decrease of costs connected with maintenance. This is also one of main principles of TPM (Total Productive Maintenance). The expected contribution of the job “maintenance operator is increased equipment reliability and operability.

D. Total Productive Maintenance

TPM was founded in the years 1950-1970 in Japan. TPM was created under pressure of Just in Time systems deployment and was supported by Japan Productivity Center and Japanese Institute of Plant Maintenance.

T - Total (participation of all employees of the organization)

P - Productive (efficiency of production facilities, maintenance and continuous improvement)

M - Maintenance (maintenance)

If a fault occurs, the device is shut down, correction usually lasts longer than planned implementation of intervention, failure often occurs well as damage to other parts, the company has lost at standstill. Equipment was often breaks down just when you least need it. Janitors thus becoming "firefighters" problems to be addressed and prosecute preventive, planned activities. In addition, there is usually a change in just a few servicemen who have no chance to carry out routine maintenance of equipment - lubrication, cleaning, inspection. Equipment fell into disrepair. A good maintenance system must provide a firm maintenance of equipment at a reasonable cost and optimize performance and condition of equipment. TPM is a very good approach to the functioning maintenance - how to ensure the production of quality production delivered to the customer on time and at a good price impact of maintenance.

TPM is a set of activities that covers all areas of the company to:

- Creation of such a company structure that ensures maximum efficiency of the manufacturing system.
- Elimination of defects, errors and all other losses on equipment
- Gradual increase effectiveness of the device,
- Improving the company's profit,
- Creating satisfactory working conditions,
- Motivation and involvement of all employees and all departments of the top workers in improving management,
- Achieve zero losses through teamwork. [10]

TPM Goals

The goal of TPM is also continuous growth of the skills of all workers, not only maintenance but also the operators so that they can properly take care of the equipment or machine, and also involvement of all employees in improving processes, which result in an increase in company performance. The goals tells us where we want to reach by implementing TPM. At our case study the goal were determined as following:

A. To create and keep safe and healthy working environment

B. To permanently implement steps for costs minimalization and efficiency maximalization of corresponding devices.

C. Decrease of work intensive maintenance activities due to autonomous maintenance implementation. (Hybrid work positions – maintenance operators)

D. Increase OEE and equipment availability

E. Increase quality

III. TPM IMPLEMENTATION

Probably there is no one type of maintenance strategy, which would be suitable for all kinds of businesses in any industry, so care must be taken when selecting an appropriate maintenance strategy. Every company must choose a strategy that does not unnecessarily increase the cost of a high amount if it is not needed, nor neglect the maintenance of production machinery, which downtime would cost the organization large losses. The choice of strategy is carried out in part by the impact that failure of the machines on the production process, how often repeated, and whether they can be predicted, or according to the likelihood of their occurrence.

Despite that absolutely perfect maintenance strategy does not exist, it is recommended, for production machines and equipment, which directly produces products perform, maintenance before failure.

A. Preliminary step

The first step mainly deals with autonomous maintenance implementation. This step reduce the work load of repairmen through the competence movement from repairmen to the machine operator. This step ensure the safety and reliable production. This step was splitted in to the two phases:

A. Phase I – create job position “maintenance operator” (the main job tasks are mainly focused on daily routine maintenance)

   a. Watch over the equipment status (determination of possible failures, its causes and effects)

   b. Elimination of failures – scheduled maintenance activities

B. Phase II – create of another „maintenance operator“ position (the operators are becoming main elements of autonomous maintenance). Their main responsibilities are following activities:

a. Activities of preventive maintenance (regulary repeated maintenance activities – cleaning, lubrication, small parts changing)

b. All other regularly performed activities which has been executed by the department of preventive maintenance.

c. Watching over the equipment status – inspections and technical diagnosis

The most important step is to get the management support coming out of the company leadership.

B. Implementation

Description of the process of maintenance development and creation of corresponding documentation – guidelines (whole maintenance system, activities, responsibilities and obligations for each work positions)

A. Selection of pilot lines

For the pilot production production on the line ZPO II – DZ Steel was used.

B. Key Performance Indicators – to define proper KPI

- OEE - to achieve as high percentage of OEE (Overall Equipment Effectiveness) as possible
- Work hours - amount of worked hours for OTH position
- Failures - the amount of founded and removed failures
- Performance and Quality,

TABLE I. OEE Table

Date	Quality in %	Performance in %	Availability %	OEE in%
February	**97,3924**	**63,9156**	**94,6386**	**58,91152**
March	**96,6966**	**64,827**	**94,8346**	**59,44755**
April	**97,0592**	**72,8336**	**96,971**	**68,55046**
May	**96,9024**	**65,2484**	**92,5414**	**58,5114**
Juny	**97,3434**	**67,375**	**93,6194**	**61,40039**
July	**97,3434**	**64,141**	**92,5659**	**57,7954**
August	**97,5002**	**64,729**	**93,6292**	**59,09023**
September	**97,5296**	**64,3664**	**94,9424**	**59,60132**
Oktober	**97,6962**	**64,827**	**96,138**	**60,88758**
Movember	**97,5002**	**63,8862**	**94,6288**	**58,9435**
December	**97,6766**	**68,2178**	**94,7856**	**63,15833**
January	**97,5688**	**64,778**	**96,9416**	**61,27011**
February	**97,4414**	**68,1884**	**92,5414**	**61,48796**
March	**97,8432**	**72,8924**	**93,59**	**66,74863**
April	**98**	**74,088**	**92,5708**	**67,21218**
Average	**97,43291**	**66,95425**	**94,32925**	**61,53444**

C. Training

It is necessary to teach all workers how to maintain device. It is appropriate to define several different ways of training which were focused on theoretical and practical as well. In the condition of USS Steel have been developed training schedule for chosen employees - operators. The practical tasks were performed in participation of headman/ foreman of the line. As verification tool serve tests and case studies in participation of workers of maintenance department. The test shows employers knowledge and skills which approve them to do maintenance activities.

D. Communication

The communication serves for settings of proper communication channels. There have been arranged two crucial channels. The first tool, meetings are regular appointments participation of workers of all degree of management. Second tool, reporting simply refers to reports are one of the necessary parts of all meetings. Reports have to contain all constantly recorded KPIs which can be recorded generally in two situations.

A. In production - during the shift – whatching over the state of production equipment and elimination of sources of possible failure.

All deficiences have to be immediately reported to direct supervisor. All findings (eliminated even not-eliminated) have to be daily and shift evaluated and assessed by workers from production and maintenance department. All informations have to be considered by production and maintenance scheduling.

B. In the time of scheduled maintenance

There have to be created cooperation with production maintenance. The worker have to communicate with direct supervisor and informs him about performed maintenance activities at least at the end of the shift.

E. Motivation

Motivation serves to define different kind motivation and stimulation strategies. Motivation is very closely connected with visualization management. Under the conditions of USS Steel were established autonomous maintenance tables. These tables have to contain informations about KPIs and its visualization and also have to define all activities performed on device / machine. There could be also stated week schedule of OTH worker.

F. Standardization

Standardization refers to work standards, simply how to do all maintenance activities.The standards of maintenance activities have to contain following activities

- The Picture of device with marked maintained parts.
- Description of maintenance activities
- Time interval / frequency of all maintenance activities
- Description of all possible deficiencies or failures
- The consequences of all deficiencies – possible failures
- The way of failure elimination
- Standard: Check box sheet, what to do list
  - Detected failure YES/NO
  - Eliminated failure YES/NO

G. IT – to define IT support

One of the factors for successful implementation of autonomous maintenance - OTH position is that the employee (OTH employee) continues to perform well maintenance activities, and the only operator action. This factor is important in terms of reliability equipment operator, but also in terms of employee motivation.

In terms of USSK is secure using ISRÚ (Maintenance management information systems), which is formed by a weekly action plan.

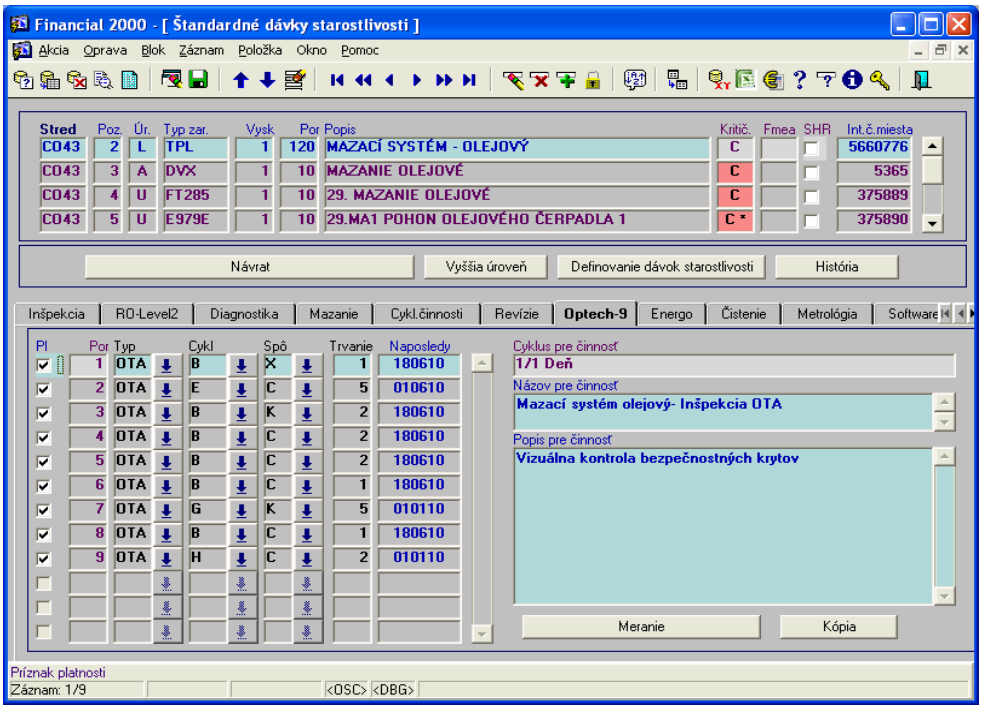

Fig. 3 CMMS used in USS

A. Stabilization Audits - to establish internal system audit

B. Evaluation – to establish regularly measurement and evaluation of KPIs

IV. BENEFITS OF ESTABLISHED SYSTEM AND CONCLUSION

We assume 2% improvement in OEE, while maintaining the same quality and performance of the device (do not expect a deterioration in the quality of production and also enormous reduction in device performance) improvement is reflected in the availability of equipment. 2% improvement represents about 96% achieve level access to the device, thus reducing downtime on the device. (Diameter of the availability for the last 15 months was approximately 94.32%, an improvement of 2% will represent about 96%).

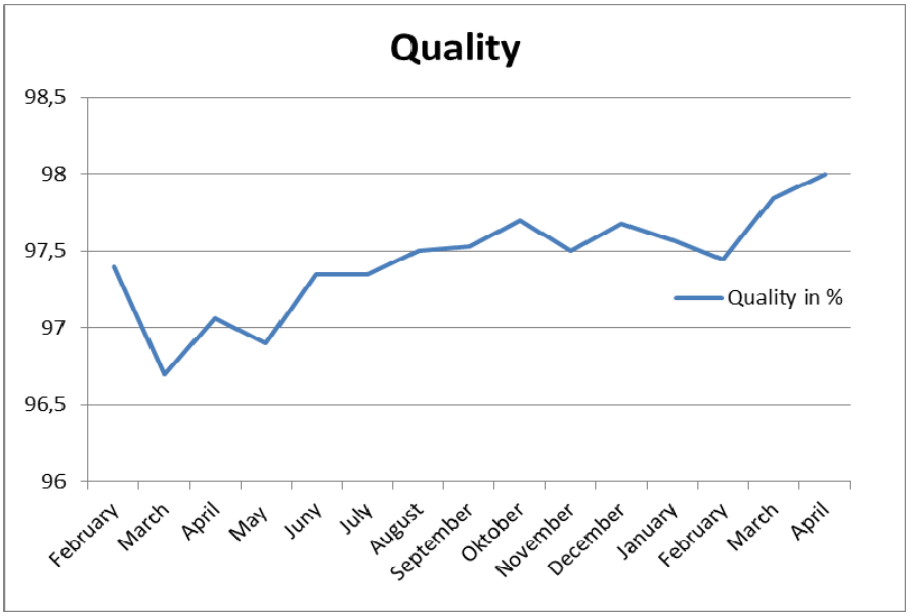

Figure 1Quality improvement introducing TPM

The introduction of OTH position also expect immediate removal of small defects (abnormalities) on the machine which is of great importance to the prevention of major disorders that need to shut down the device and ensure that the necessary parts (spare parts). Prevention of major faults are ultimately reflected on the cost reductions necessary for repair and maintenance of equipment. We expect a reduction in the cost of repairs and maintenance in the amount of 3% - 4% in the horizon 2-3 years.

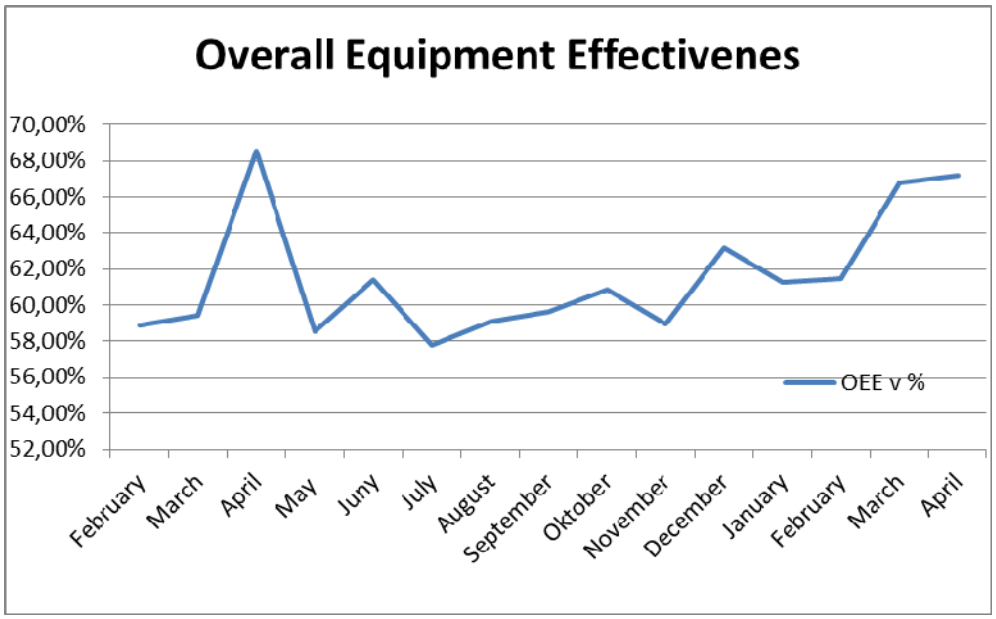

Figure 2 OEE improvement introducing TPM

At the beginning, however, we expect a partial increase in costs, due to the improvement of inspection equipment (position OTH) and thus a greater number of findings of abnormalities on the machine that will be removed, and that represents a cost.)

V. CONCLUSION

The introduction of position OTH also expect better operation and maintenance of the device as a result of knowing that when the apparatus has been damaged by misuse, so it will have to consequently corrected. Also expect improved cooperation (as a team) between operators and maintenance. This aspect will have a major impact on the subsequent implementation phase II (which of the operators we do OTH employees)

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