Research Journal of Recent Sciences ISSN 2277-2502
Vol. **2(6),** 58-65, June **(2013)** *Res.J.Recent Sci.*

Overall Equipment Effectiveness (OEE) Diagnosis and Improving in a Small Business as an Essential tool for Business Competitiveness

Ponce-Hernández M.M.[1], **González-Angeles A.**[1*], **Navarro-González C.R.**[2] and **Cabrera-Córdova** E.[2]
[1]Universidad Autónoma de Baja California, Facultad de Ingeniería, Ingeniería Mecánica, Blvd. Benito Juárez s/n, Col. Ex Ejido Coahuila, C.P. 21900, Mexicali B.C., MÉXICO
[2]Universidad Politécnica de Baja California, Ingeniería en Tecnologías de Manufactura, Calle de la Claridad s/n, Col. Plutarco Elías Calles, C.P. 21376, Mexicali, B.C., MÉXICO

Available online at: www.isca.in
Received 9th February 2013, revised 22nd February 2013, accepted 20th March 2013

Abstract

Improvements and benefits than can be obtained by using lean manufacturing and six sigma have been documented widely, however there are several reasons why a small business does not apply such philosophies, impacting seriously their competitiveness. It is shown a study case of small company, where the measurement and analysis of the Overall Equipment Effectiveness (OEE) not only represented a framework of the company, but rather a guide to change and improve the competitiveness of the organization. It also shows and proves the benefits that can be achieved by applying tools of lean manufacturing and six sigma.

Keywords: Overall equipment effectiveness (OEE), essential tool for business competitiveness, total productive maintenance, planned preventive maintenance.

Introduction

At present the level of competition between firms is increasingly demanding, levels of demand by the customer are more stringent so that only the companies that have the ability to adapt easily to these needs are protruding.

Maintenance plays a very important role in the industry, since to be able to produce goods of quality and quantity, and to deliver at the right time according to customer needs; machinery and equipment must operate efficient and accurate. Although it is not always recognized as an important area, as rightly says Sharma and Trikha, maintenance has been widely regarded as a support function that is not productive, since it does not generate cash directly and sometimes relegated for that reason[1].

Overall Equipment Effectiveness (OEE) is a measure used in Total Productive Maintenance (TPM) to indicate how efficiently the machines are working, to know clearly the impact of the six big losses and to measure the overall health of the equipment. Since TPM and OEE are part of Lean Manufacturing, this time measurement could be considered as the most important indicator for assessing the competitiveness level of an industrial plant; OEE indicator shows the actual losses from machines related with production time. Because lean manufacturing is a competitive practice that reduces costs, improves environment and quality, and improves the bottom line through creation value for the customer and elimination of waste, also Supply Chain is better be seen as a pull system who reduces waste and losses[2,3].

OEE in the control of the six big losses of equipment: It is very important that companies recognize the essential role that maintenance area has; because usually, the traditional maintenance practices represent one of the main problems in companies today. According to Chand and Shirvani, there is a vicious cycle of reactive maintenance whenever a problem occurs on equipments. This cycle is that no one can predict the problem as there is not preventive maintenance because there are not records of problems generated in the equipment, and no time or resources to prevention activities, leading to always react when the problem arises[4].

To break this habit is necessary to work with prevention, a great tool to use for this situation is the OEE (Overall Equipment Effectiveness); thus according to Sermin and Birol, the OEE will allow measure the effectiveness of equipment, identifying the major sources of losses in productivity, which are called the six big losses of TPM (Total Productive Maintenance). These losses are quantified as three areas from OEE: availability, efficiency and quality. See table-1[5].

Table-1
Six Big Losses (Sermin and Elevli, 2010)

Six Big Loss Category	OEE Loss Category	OEE Factor
Equipment Failure	Downtime Losses	Availability
Setup and Adjustment		
Idling and Minor Stoppages	Speed Losses	Performance
Reduced Speed		
Reduced Yield	Defect Losses	Quality
Quality Defects		

Table-2
OEE parameters (Sermin and Elevli, 2010)

<table>
<tr><td colspan="5">Total time</td></tr>
<tr><td colspan="4">Net available time</td><td>Planned downs</td></tr>
<tr><td colspan="3">Operating time</td><td>Downtime losses</td><td>Availability = $\frac{\text{Operating time}}{\text{Net available time}}$</td></tr>
<tr><td colspan="2">Net operating time</td><td>Speed losses</td><td colspan="2">Performance = $\frac{\text{Net Operating Time}}{\text{Operating Time}}$</td></tr>
<tr><td>Productive time</td><td>defect losses</td><td colspan="3">Quality = $\frac{\text{Productive Time}}{\text{Net Operating Time}}$</td></tr>
</table>

Table-1 shows the relation between six big losses and the OEE. Where the OEE value is obtained by multiplying the three factors: availability, performance and quality. A mathematical expression of this OEE factors are:
OEE = availability x performance x quality (1),
Availability = (Net available time – Downtime losses) / Net available time x 100 (2),
Performance = (Operating time – speed losses) / Operating time x 100 (3),
Quality = (Net operating time – defect losses) / Net operating time x 100 (4).

In table-2 it can observe how the available total time for production could be reduced because of the six big losses.

Subsequent to the calculation of the three OEE factors, there are valid values for a company to be considered world class the ideal percentage for availability must be 90% for the performance 95% and 99% for quality; which when multiplied produces an 85% of OEE[6].

The effectiveness of organizational performance can not be achieved without the involvement of all company, taking each person as part of the project through the application of efficient strategies over personnel; since organizational commitment is increasing by supporting organizational goals and creating interest in decision making[7,8].

Methodology

The presented case was realized in an industrial company from the packaging field that produce expanded polystyrene foam for packaging throw a mold process; which at the beginning did not have any OEE record, so the first step was to establish the starting conditions to collect this indicator, for this purpose five machines were taken as a pilot to start reviewing the production and maintenance report and gathering information to determine the status of the three OEE factors above mentioned.

During this activity, it was found that lack of data, wrong filling and gathering misinformation, it was a common situation. According to Jeong and Philips, the success of the OEE depends on the quality of data collection, so it proceeded primarily to correct this situation and training personnel in fill up forms and capture information from production and maintenance areas[9]. In addition, an analysis of the founded OEE factors is presented as well as the developed activities for their control and improvement.

Results and Discussion

After taking the information, it was calculated the OEE in accordance with the formulas already mentioned, obtaining the information shown in figure-1.

Figure-1 shows the initial status of the OEE, as it can see, all the machines are below the 85% minimum required at the global level. A disaggregation of the three OEE factors was made to determine which most affects the OEE indicator. See figure-2.

According to figure-2, it can note that the problem lies in the lowest indicators (availability and performance); due to this, it was established a minimum goal of 69% and 76% for availability and efficiency respectively, according to historical data. After finding out that the problem lies in the availability and performance, it was carried out the classification of breakdown types generated in the machines according to the six big losses, see table-3.

Table-3
Classification of the six big losses

Availability	Performance
Mold change	Lack of personnel
Service failure	Lack of material
Pieces jammed	
Filling failure	

Table-3 shows the main reasons why the availability decreases; which are the high times in the mold changes, the constant jamming of parts on demolding process, failure to correct filling the mold cavities, and services supply failure (pressurized air, water and steam; needs of working machines). All this kind of breakdowns were called “stops that can be controlled directly” because there are related with something that the company can handle at middle manager level without the corporate bureaucracy. On the other hand, stoppages that generate low performance are called “breakdowns that cannot be controlled directly” because their improvement will depend from showing information and sharing decisions with top manager level. In this project was decided to work on first category the “work stoppages that can be directly controlled”.

Mold change loss: For the analysis of mold changes, a detailed study of all operations was realized. It was made a step by step list of how these changes were taken (in this case for two types of machines: Erlenbach and Kurtz); It was found that Erlenbach machines had activities that did not add value, they wasted time looking and cleaning parts or tools because staff neither did know what they had nor what they needed. Also some parts or molds could be cleaned before starting a scheduled change. Furthermore they had reworks that were made at the time of mold change due to the disorganization that existed in the area.

All this analysis of mold change operations showed the waste of 32.36 minutes; this time may vary depending on mold type but it is important to highlight that this loss of time is just because there were not an organized work area. For machines Kurtz were made the same procedure; finding 4 hours of wasting time only for not having the organized area to carry out reworks, and search for parts and tools. With these results it was determined that the lack of an organized area in the maintenance department and do not have an established procedure for carrying out operation make mold change times increase.

Subsequently a brainstorming with the team was carried out to produce a cause - effect diagram, determining that the critical variables to evaluate were: lack of control and cleaning over tools and materials, as well as do not have a documented procedure on mold changes; so that, it had to work with the lean manufacturing tools of 5's and SMED.

One of the most important objectives of SMED (Single Minute Exchange Die) is to reduce the preparation time by eliminating waste associated with tools change and increase availability of the machine. So, with SMED, separate the internal operations (activities can only be made with the machine off) and the external operations (activities that can be done while the machine is working) as the mold preparation. Based on this technique, it was established a procedure for each type of machine and some activities were improved and standardized for mold change process[10,11].

According to Michalska and Szewieczek, “five S” methodology is the tool that helps with the analysis and improvement of the running processes in the workplace, its result is the effective organization of the workplace, increase of the work environment capabilities by eliminating losses associated with failure and breakage, improved quality and safety of operation[12].

With the application of this methodology it could achieve both the location control of tools and their existence; and the reduction of delay time by lack of tools or materials. Applying 5’s tool, it could separate each type of screw, putting them in assigned shelf for each type, with its corresponding identification tag. It was annexed a red box as a control card, that was placed inside of every shelf over a certain number of screws as a level indicator before fill the entire shelf; so while the operator is working, he consumes screws who are above the control board; when the control card is found; this is an indicator that needs to refill the shelf, so the operator will take the card and give it to the supervisor for the material be provided, and thus avoid stoppages or delays due to lack of screws.

With 5’s and SMED implementation, the reduction in mold changes was between 30 and 50% due to this depends on the complexity of the mold to be mounted. To control these improvements, audits 5's and SMED will be conducted to verify that changes are maintained.

Loses by services area failure: Loses by services area failure is represented by problems on the supply of water, steam or pressurized air than machines need to leave parts within established quality parameters. Since the services area failure may depend on three factors, it was developed a Pareto to determine the factor with highest impact on the machines and to propose improvements over it (figure-3).

According to the Pareto in figure-3, it can determine that the problem lies mainly in the pressurized air service; based on these results it was designed a cause-effect diagram that shown that the problem was in the air compressor because an internal mechanism did not work properly (turning off the compressor and therefore decreasing the required air pressure for the working machines). Three options were discussed: the first was the acquisition of a new compressor, which was not viable at the moment by the required investment; the second option was to hire a person exclusively for monitoring the entire service area and thus detect the problem early, which also was not viable at the moment. The third was accepted, and it was the installation of an “andon system”, where an audible alarm was connected to the service pressure and it was activated when pressure was down to 120 psi, allowing stabilizing the service before the issue hit the machines.

Although the installed alarm on the air compressor gave good results and controlled the problem, it has to take into account that the root problem was not resolved; as this lies in the condition of the compressor (decision does not viable at the moment).

Losses by jammed pieces: For the analysis of jammed pieces, a Pareto was performed for machines 2-5, to determine which molds are generating mostly this problem. For machine 1 this issue was not important. The figure-4 shows the Pareto analysis of pieces jammed for machine 4.

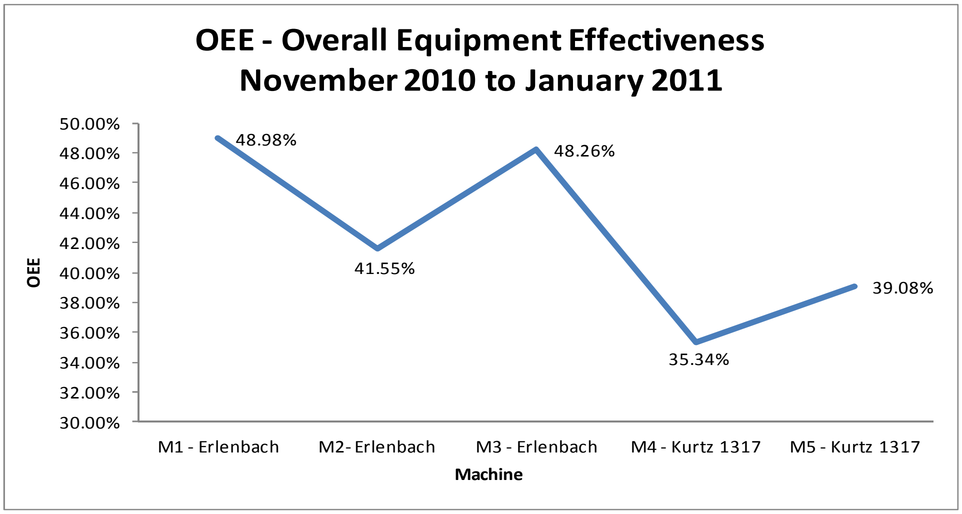


Figure-1
Overall Equipment Effectiveness (OEE) from November 2010 to January 2011

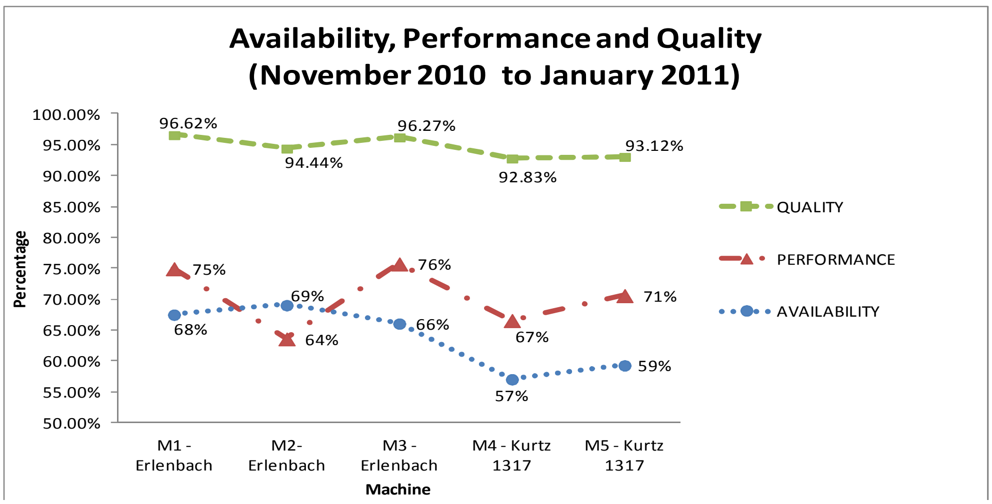


Figure-2
The three OEE Factors behavior from November 2010 to January 2011

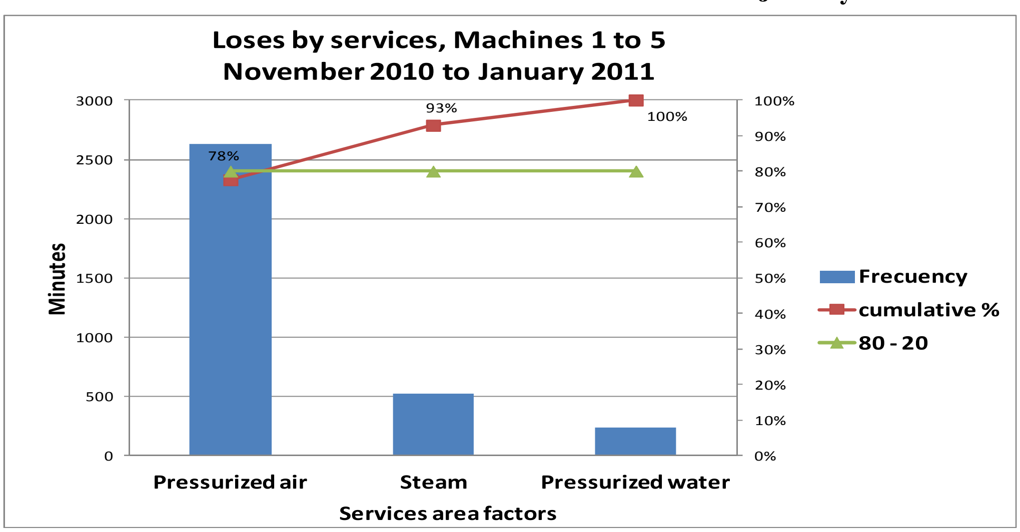


Figure-3
Pareto from service area

According to the results of the Pareto analysis, it was determined that the molds with most jammed pieces are: CM5220, CM0620, CM5186, CM5224, CM5221 and CM5188. Based on this information, a cause-effect diagram was made with the team and they concluded that the critical variables to be evaluated were: i. lack of control in the service area, ii. mold design and iii. wrong adaptation of the mold.

For first variable (lack of control over the service area), it must consider that the demolding of the pieces will depend largely on an air pressure that allows the pieces to push out of the cavity, this issue was previously solved. The second variable to evaluate was mold design, it was found that molds CM5220, CM0620, CM5186 and CM5224 are considerable larger than those normally used in the factory so when designing the mold was not considered the size of the dumper (part that pushes the product completely out of the cavity). To try to eject the pieces never come out completely, remained stuck, so it got springs and lifters 15 cm longer than those used usually. The third variable (poor adaptation of the mold) was detected in CM5221 and CM5188 molds (designed to be fitted in machinery Kurtz) but in order to meet customer requirements and deliver on time, they were adapted to be mounted in Erlenbach machines, having bad adaptations. It was treated to improve the adjustments but not succeeded so it was decided to reduce changes of the mold to 50% less frequency; these changes allowed returning these two molds to their corresponding type machine.

Losses by filling failure: For analysis of filling failure, a Pareto diagram was carried out to separate vital from trivial problems; this was made for all studied machines but showing the analysis only for machine 1 in figure-5.

According to the Pareto diagram realized for each machine, it was determined that the main cause for filling failure was owing to guns malfunction in all machines; based on this information and on brainstorm with the team, a cause-effect diagram was realized, resulting that the main cause was that lack of maintenance to the guns by not having an appropriate procedure. So a detailed working instruction about the proper maintenance of guns was realized, as well as personnel training on the instruction and with this started with preventive maintenance rather than corrective as they used to have.

OEE impact reached: Once the improvements above mentioned were implemented, it was evaluated the impact achieved on OEE. The positive effects of the realized changes during the project in the indicators of availability and performance are shown in figures-6 and 7.

The Figure-6 shows the behavior of availability factor for all projects (without and with the realized improvements), as it can see, at the first 3 months there were no data because there was no reliable information by not properly complete the production format. The 4th to 6th months were taken as sample to know the initial conditions (after a proper training to personnel on the format); 7th and 8th months were taken to analyze the root causes and to propose the best actions; in the ninth month began the implementation of the improvements; for the eleventh month the target set was overcome and maintained without great variation in contrast with the beginning of the project.

For the Performance factor was developed a similar procedure than that realized for availability factor; data was reviewed, the initial conditions and major problems where established with an analysis; improvements were proposed allowing to meet the target set and finally, achieving stability from month 11.

This information shows that the 5 machines have reached and even exceeded the established targets. The average availability of the machines at the beginning was around 63.8% at the end of the project was enhanced to 78.6%. The implemented improvements increased the availability of equipment a 14.84%.

The machines had a Performance of 64.2%, and with implemented improvements enhanced to 78% (increase of 13.83%). Besides improving the availability and efficiency factors, other goals were realized also. i. Trained production personnel for correct filling of daily production and rejection formats. ii. Trained maintenance personnel on the 5's methodology and SMED technical as a prelude from lean manufacturing philosophy. iii. A study was carried out on changes of molds by SMED technique having a reduction in time between 30 and 50%, and the application of 5's in the maintenance area.

It is important to note that although the goals have been met, further work is needed on improving the OEE, because higher be this indicator, better control will have over equipments and processes.

Reflected improvement over production area: As it is known, for the companies the most important issue is to produce more with less, so it is important to show these improvements deeply. Due to all machines can be used to produce several molds is not possible to determine an exact profit for each machine because each mold produces different quantities of parts at different prices. Figure 8 shows the benefits of the implemented improvements on machine 3 with mold CM 5236.

As it can see in Figure-8 the implemented improvements reflected in increase on production and in earnings. For this mold profits rise about $ 5.733 U.S. dollars per month.

Conclusion

It could determine that a good implementation of OEE can allow any company to make a detailed analysis on its basic areas (availability, performance and quality) allowing to identify the best opportunity areas; working on them for improvements that benefit not only the company but also to customers. In every business is essential to establish and monitor key indicators, due to it cannot control what cannot measure, also, if the process behavior is not known, then the problems that might arise would not be detected early. The OEE study allows to analyze comprehensively the state of equipment, but also to detect the main problems, focusing on what is the most important without wasting time or resources in other things.

For OEE study be a success, it is important that the collection of data be reliable, due to this is the basis for development of any study. The OEE analysis allows only us to make a diagnosis and control on the condition of the equipment. To identify the main problem, it is important to consider implementing lean tools and six sigma which will allow achieving great improvements. Much of the success depends on the involvement of all company personnel, so it is important to consider each person as part of the project.

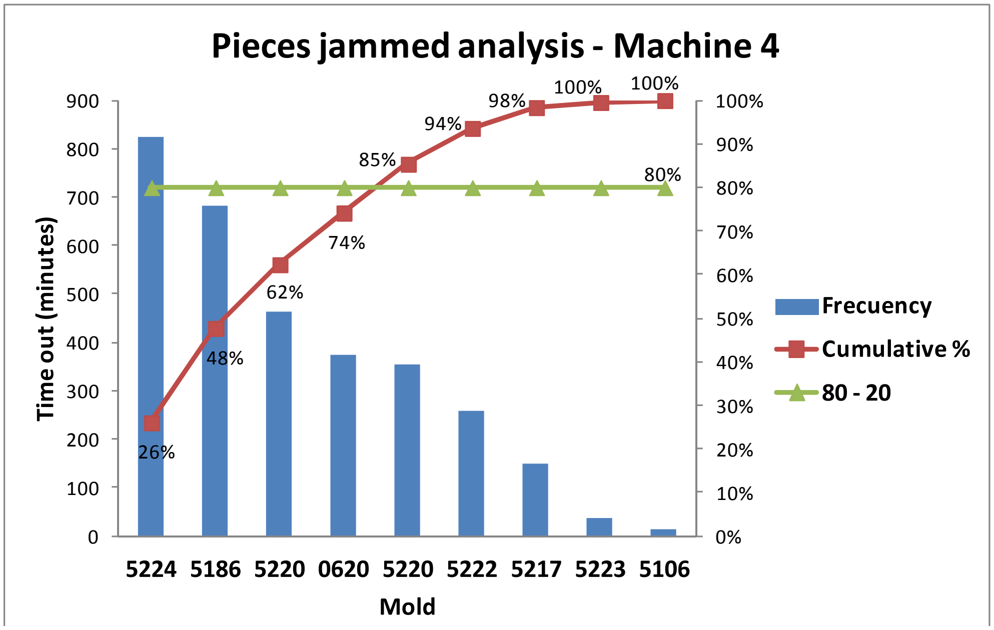


Figure-4
Mold Pareto analysis of pieces jammed for machine 4

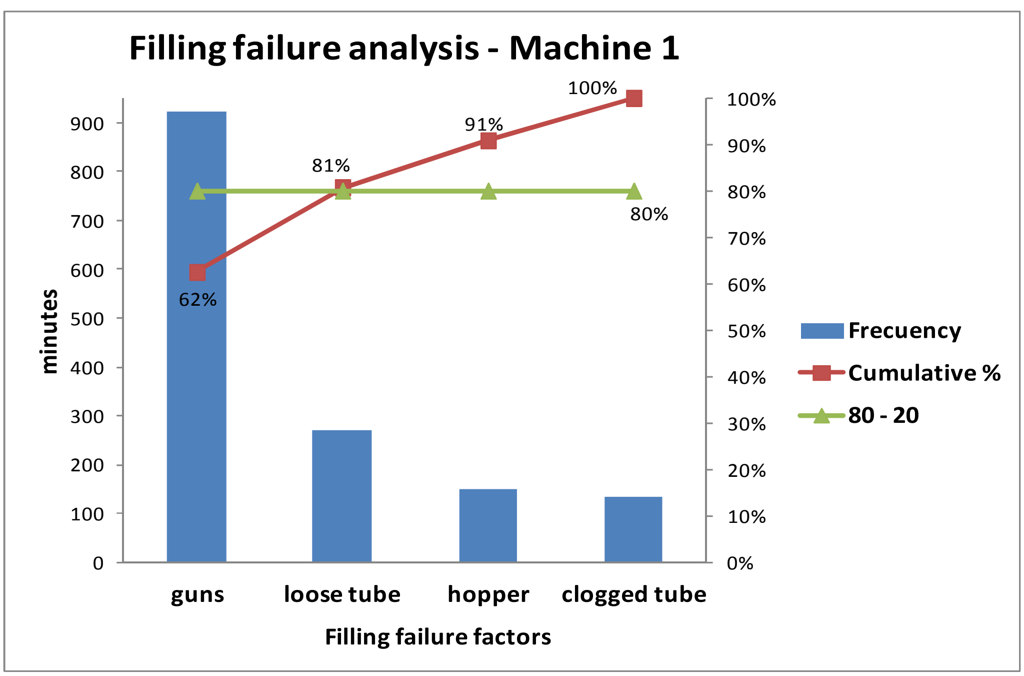
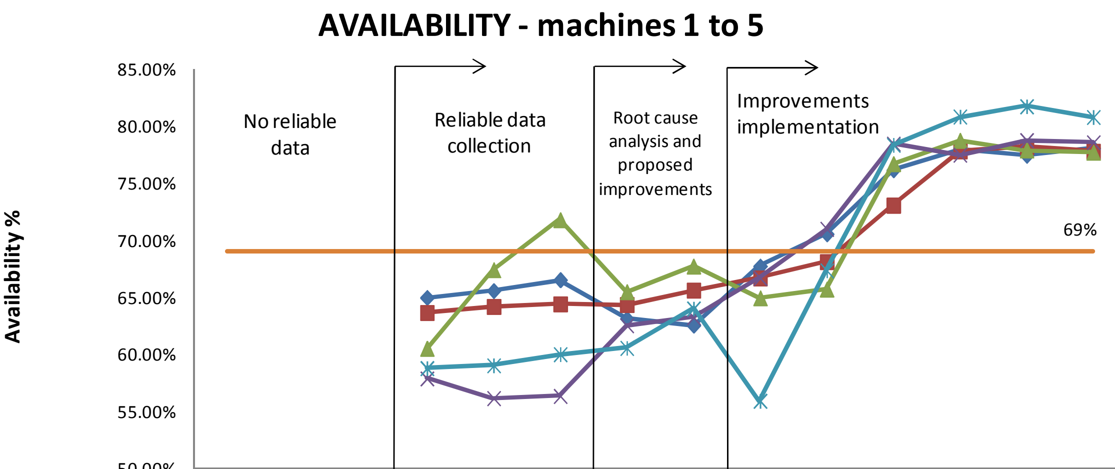
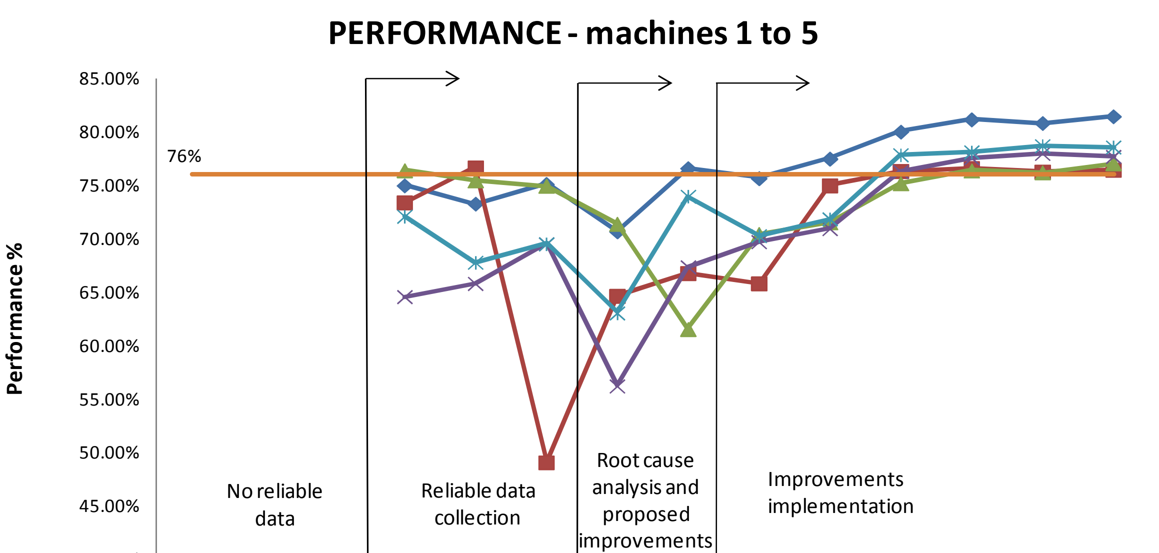


Figure-5
Pareto diagram of filling failure



	month 1	month 2	month 3	month 4	month 5	month 6	month 7	month 8	month 9	month 10	month 11	month 12	month 13	month 14
Machine 1				64.96%	65.56%	66.52%	63.11%	62.54%	67.71%	70.54%	76.16%	77.96%	77.42%	78.07%
Machine 2				63.64%	64.18%	64.40%	64.34%	65.61%	66.67%	68.09%	73.05%	77.79%	78.16%	77.78%
Machine 3				60.51%	67.39%	71.77%	65.47%	67.72%	64.92%	65.70%	76.69%	78.73%	77.89%	77.68%
Machine 4				57.87%	56.14%	56.33%	62.52%	63.23%	66.68%	70.98%	78.44%	77.48%	78.74%	78.56%
Machine 5				58.77%	59.01%	59.99%	60.55%	63.99%	55.91%	67.33%	78.33%	80.82%	81.72%	80.78%
availability goal	69%	69%	69%	69%	69%	69%	69%	69%	69%	69%	69%	69%	69%	69%

Figure-6
Availability indicator



	month 1	month 2	month 3	month 4	month 5	month 6	month 7	month 8	month 9	month 10	month 11	month 12	month 13	month 14
Machine 1				74.96%	73.25%	75.09%	70.67%	76.58%	75.64%	77.47%	80.00%	81.14%	80.81%	81.43%
Machine 2				73.37%	76.64%	49.04%	64.62%	66.75%	65.79%	74.97%	76.31%	76.59%	76.25%	76.43%
Machine 3				76.38%	75.43%	74.93%	71.37%	61.52%	70.42%	71.51%	75.16%	76.36%	76.18%	77.03%
Machine 4				64.56%	65.79%	69.50%	56.19%	67.34%	69.70%	70.92%	76.26%	77.56%	77.96%	77.67%
Machine 5				72.08%	67.77%	69.49%	63.03%	73.95%	70.26%	71.83%	77.83%	78.10%	78.68%	78.56%
perf. goal	76%	76%	76%	76%	76%	76%	76%	76%	76%	76%	76%	76%	76%	76%

Figure-7
Performance indicator

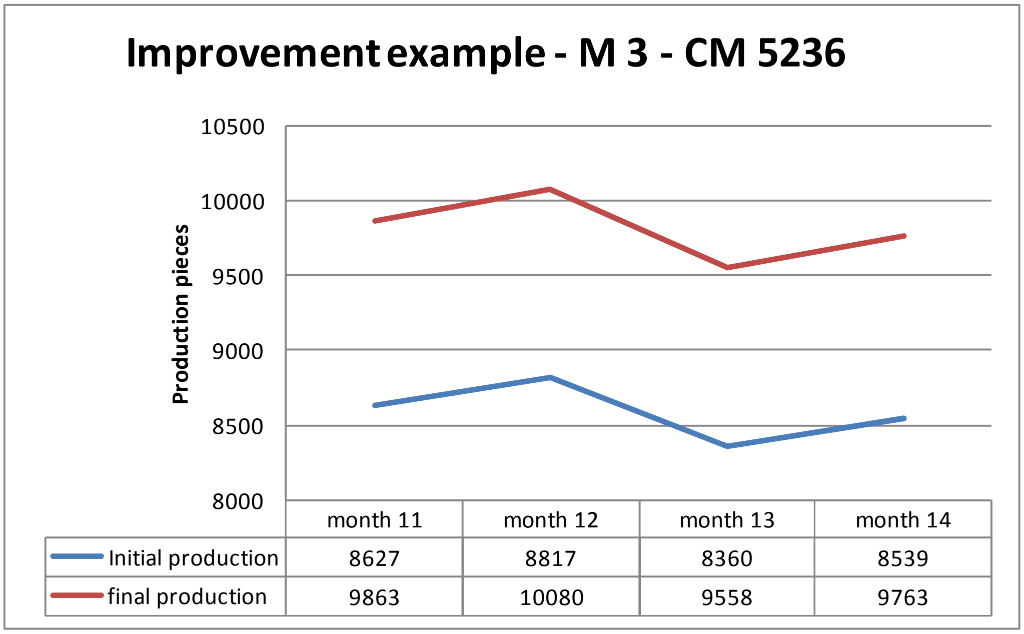


Figure-8
Production of machine 3 after improvements

References

1. Sharma R. and Trikha V., TPM Implementation in Piston Manufacturing Industry for OEE, *Inter. J. Current Engineer Technol*. **1**, 118-125 **(2011)**

2. Dheeraj N. and Vishal N., An Overview of Green Supply Chain Management in India, *Res.J.Recent Sci*., **1(6)**, 77-82 **(2012)**

3. Nikhil D., Rajesh A., Vijay M., Sandeep K., Mohit Satyapal and Pardeep K., Strategic Supply Chain Management: Perception versus Reality - A Review, *Res. J. Recent Sci.,* **1**(**5**), 83-86 (**2012**)

4. Chand G. and Shirvani B., Implementation of TPM in cellular manufacture, *J. Mater. Proces. Technol.,* **103**, 149-154 **(2000)**

5. Elevli S. and Elevli B., Performance Measurement of Mining Equipments by Utilizing OEE, *Acta Montanistica Slovaca*, **15**, 95-101 **(2010)**

6. Almeanazel O.T.R., Total Productive Maintenance Review and Overall Equipment Effectiveness Measurement, *Jordan J. Mech. Ind. Engineer,* **4**, 517-522 **(2010)**

7. Droudi H. and Farkoosh F.D., An Investigation on the Relation between Human Resources Management and Organizational Developments, *Res. J. Recent Sci.,* **2**(**2**), 50-53 (**2013**)

8. Tahere N., Zahra G.T., Fateme D. and Asma Y., Investigating the Effects of Job Experience, Satisfaction, and Motivation on Organizational Commitment Case Study, *Res. J. Recent Sci.,* **1**(**7**), 59-67 (**2012**)

9. Jeong K.Y. and Phillips D.T., Operational efficiency and effectiveness measurement, *Int. J. Operat.Product. Manag*., **21**, 0144-1416 **(2001)**

10. Carrizo-Moreira A. and Silva-Pais G.C., Single Minute Exchange of Die. A Case Study Implementation, *J. Technol. Manag. Innov*., **6**, 129-146 **(2011)**

11. Nystha B., Rao S.U. and Sharath D., Overcoming Additional Investment to Meet Customer Needs by Applying Smed/Qco Tool - A Study, *Res. J. Recent Sci.,* **1**(**11**), 59-63 (**2012**)

12. Michalska J. and Szewieczek D., The 5´s methodology as a tool for improving the organization, *J. Achiev. Mater. Manufact. Engineer,* **24**, 211-214 **(2007)**