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Impact of Cleaning Inspecting Lubrication & Tightening (CILT) on Overall Equipment Effectiveness for Sustainable Production

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ABSTRACT

Operating the equipment at its full capacity is one of the core objectives of every organization for sustainable production. OEE determines the actual amount of the product to be produced. This study was carried out to investigate the impact of Cleaning, Inspection, Lubrication, and Tightening (CILT) on Overall Equipment Effectiveness (OEE). OEE matrix was used to determine the utilization of the line before and after the implementation of CILT. It was found that after the implementation of CILT, OEE has increased by 12% so the availability (3.12%), performance (16. %), and quality (0.44%). Results of the study confirm that CILT can bring a notable change in the OEE and has the potential to achieve substantial improvement in the production, not limited to the pharmaceutical industry only, if it is implied for the autonomous maintenance of machines used in production lines.

Keywords: OEE; CILT; Autonomous Maintenance, Sustainable Production, Pharmaceutical

1. INTRODUCTION

Operating the equipment, process or system at its full capacity is a crucial matter for every organization. Moreover, to stay competitive, every company tries to improve the effectiveness of the machinery to a higher level. Additionally, it also provides a basis for smooth and sustainable production. One of the pharmaceutical companies located in Jamshoro, Sindh, Pakistan was also facing the same issue in achieving the required production target. Nevertheless, it has the capacity to meet the target. Not reaching the capacity implied that there were some bottlenecks in the line.

Overall equipment effectiveness (OEE) is a matrix that explores and depicts the effectiveness of the system (Dobra & Jósvai, 2023). Overall equipment effectiveness helps in identifying and achieving this by providing quantitative measures of equipment and process performance, allowing for the identification of bottlenecks, downtime issues, or quality concerns (Chong et al., 2016). By monitoring OEE, companies can identify the areas for improvement, optimize equipment utilization, reduce downtime, and enhance overall productivity (Freiheit, 2019). It also enables proactive maintenance and troubleshooting, leading to improved equipment reliability and reduced risk of unexpected breakdowns during operations (Zuashkiani et al., 2011).

To improve OEE, total productive maintenance (TPM) is widely used by industries to reduce unwanted downtime and uplift the productivity of the machines (Pinto et al., 2020). It constitutes of eight pillars, each of which would have a prominent role in the improvement of the operational time for the machines(Pinto et al., 2020). Autonomous maintenance (AM) is one of the prominent of them because it is less costly and has substantial potential for achieving the objective of TPM. Autonomous maintenance involves cleaning, inspection, lubrication, and tightening activities which are carried out by the workers (Marinho et al., 2021). It is a technique used for autonomous maintenance in which operators perform certain maintenance tasks for the smooth operations of the machines (Marinho et al., 2021).

Many studies have reported the positive impact of autonomous maintenance on the availability, performance, quality, and overall equipment effectiveness in general. Gurpreet Singh Bali et al., (2022) have reported that autonomous maintenance has increased the OEE by approximately 14%. It could be possible by reducing the breakdown time. This study was carried out in an automotive filter manufacturing unit to improve the OEE using autonomous maintenance. Autonomous maintenance was carried out on the machines which were identified as critical to downtime after the collection of required data.

Another study conducted by Mohamad et al., (2020) was carried out to improve the OEE of bottle filling line keeping the focus on reducing the planned and unplanned downtime. DMAIC (Define, Measure, Analyze, Improve, and Control) approach along with the Lean Six Sigma methodology of manufacturing was used to

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achieve the objective of the study. Data for the downtime and change over time was collected and measured in defining and measuring phase. Further, root and potential causes were analyzed with the use of cause and effect and FMEA (failure mode and effect analysis) respectively. SMED (Single Minute Exchange Die), along with autonomous maintenance was taken into consideration to reduce the changeover time and machine downtime respectively. In the end phase of control, the whole process was standardized, and a dashboard was developed to control and monitor the OEE performance. It was improved by 17.7 percent (48.8% to 66.5%) OEE when compared to the OEE calculated before the implementation of the DMAIC framework of the Six Sigma Lean Manufacturing methodology. In addition to this lean and six sigma are widely used techniques to reduce the defects in the production (Wassan et al., 2022).

Similarly, Ravjibhai, (2017) has also used autonomous maintenance to enhance the OEE of a Pharmaceutical company. After finding the causes of machine downtime, CILT as an autonomous maintenance strategy was used to bring the machine to optimum condition. Availability and performance factors of the machine were improved hence resulting in the 5.52 percent improvement of OEE.

Another study conducted by Al-Amin & Khalil, (2015) has also reported the role of autonomous maintenance in the enhancement of the effectiveness of the equipment. The study was conducted in Bangladesh in the apparel industry. The relation between the ratio of autonomous maintenance and the percentage of OEE increase was measured before and after the implementation. It was reported that Autonomous maintenance holds a substantial potential to enhance the OEE.

Similar type of study was conducted Hadisaputra & Hasibuan, in (2022) with the objective of improving the efficiency of the packaging line of a plastic manufacturing company. The main losses were identified as breakdown, setup, and adjustment losses in decreasing values respectively. With the use of autonomous maintenance and changes in the frequency of preventive maintenance, 10.6 percent of the OEE was increased.

The advantage of autonomous maintenance has been reported by the above studies as follows. Autonomous maintenance has the potential to uplift the effectiveness of the equipment, process, or system when unplanned breakdown wastes time in production. To validate the claims for the TPM, AM and CILT, this study has been carried out to know the impact of CILT on the OEE.

2. MATERIALS AND METHODS

Figure 1. shows the steps of the research methodology. Research methodology starts with problem identification, collection of data, OEE calculation, identification of losses and areas, development of maintenance plan, and OEE calculation to compare before and after the implementation of maintenance plan.

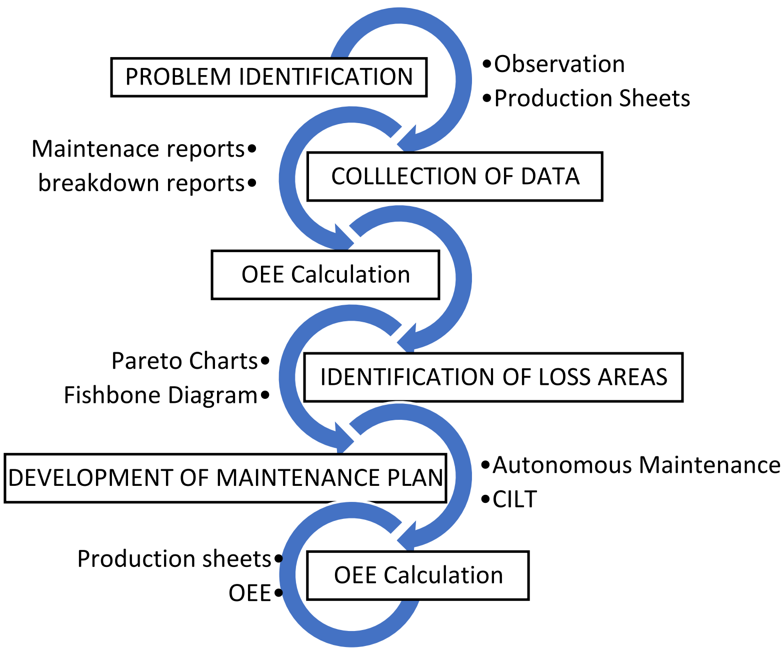

Figure 1: Schematic of Research Methodology

The first step was problem identification which involved the observation of the operations and production sheets. The second step was a collection of the data of maintenance and breakdown reports. Data included planned and unplanned downtime, machine running speed, monthly production data, and machine set-up data. The third step was the calculation of OEE. The fourth step was the identification of loss and pin areas which had created hurdles for working the system smoothly. The fifth step involved the development of an autonomous maintenance plan considering Cleaning Inspecting Lubrication and Tightening (CILT) for the identified areas. In the sixth step again OEE was calculated and compared with the earlier calculated OEE to compare the impact of CILT on OEE. Cost-benefit analysis was carried out.

2.1 OEE and its Calculation

OEE is a performance matrix that is commonly used in industries to evaluate and improve the efficiency and productivity of equipment or processes. It provides a comprehensive picture of how effectively equipment is used (Mutiara Sandy et al., 2022). The OEE is calculated by multiplying three variables i.e., availability, performance, and quality (Bamber et al., 2003).

The formula for calculating OEE is:

$$OEE = Availability\ X\ Performance\ X\ Quality \tag{1}$$

Availability: This factor compares the actual operating time of the equipment to the planned or scheduled operating time. It considers factors such as equipment failures, setup time, changeovers, and any other unplanned downtime that may reduce equipment availability.

$$Availability = \frac{loading\ time - downtime}{loading\ time}\ X\ 100 \tag{2}$$

Performance: Performance measures the speed or rate at which the equipment operates in comparison to its designed or optimal speed. It considers factors such as shorter cycle times, minor stoppages, and speed losses that may have an impact on the overall performance of the equipment.

$$Performance = \frac{processed\ amount\ X\ cycle\ time}{operating\ time}\ X\ 100 \tag{3}$$

Quality: This factor compares the proportion of high-quality products or output to the total output of the equipment. It considers defects, rework, scrap, and any other quality-related issues that may affect the overall quality of the output.

$$Quality = \frac{processed\ amount - defect\ amount}{processed\ amount}\ X\ 100 \tag{4}$$

3. RESULTS

Operating the equipment, process or system at its full capacity is one of the core objectives of every organization. One of the pharmaceutical companies located in Jamshoro, Sindh, Pakistan was also facing the issue of achieving the required production target. Nevertheless, it has the capacity to meet the target. Not reaching the capacity denoted that there are some bottlenecks in the line. Overall equipment effectiveness is a matrix that explores and depicts the effectiveness of the system.

This research therefore investigates the bottlenecks/key factors that occur at the production packaging line during normal production time and overtime and suggests a Cleaning Inspecting Lubrication &Tightening (CILT) plan for improvement. To validate the effectiveness of CILT, a case study is presented, so that the increase of equipment availability, performance and quality can be directly reflected in the increase of the company’s OEE indicator.

Table 1 contains information about a month's production data, such as available time, planned and unplanned downtime, actual production time, pack production estimates, and the number of products produced and reprocessed. These metrics are critical for determining production efficiency and pinpointing areas for improvement. As shown in Table 1 the packaging line runs for two shifts of eight hours for a whole month, which is calculated as 480 hours of availability of the line. Planned downtime is calculated as 91.2 hours for the same month. By subtraction, the planned downtime from the total available hours in both shifts resulted in total production time i.e., 388.8 hours. Nevertheless, there were certain unplanned events occurred which resulted in the stoppage of the line. This time is calculated as unplanned downtime i.e., 71 hours. This unplanned downtime has cut the production time to 317.8 hours. As per the total production time available after subtracting the planned downtime, the number of packets produced must be 4,665,600, when the line runs at maximum speed i.e., 200 packets per minute. However, the line could only produce 2,860,200 bottles while running at the speed of 150 bottles per minute. From the produced units 572,040 bottles were reprocessed because they could not pass the quality standards of the company.

Table 1. Production data for a month before CILT

Parameters	Values
Total available time per month in hours for two shifts of eight hours	480
Planned downtime in hours	91.2
Total Production Time in hours	388.8
Unplanned downtime in hours	71
Actual production time in hours	317.8
Packs to be produced in planned production time at maximum speed 200 per minute	4,665,600
Total packs produced at the speed of 150 products per minute	2,860,200
Products used to reprocess	85,811 (3.00017481%)
Good Products	2,774,389

3.1 Calculation of OEE Before CILT

After observing that the current packaging line is not running at its capacity, to trace the bottleneck OEE was carried out. Table 1 demonstrates that the OEE of the packaging line was 39.368%. Factors contributing to the OEE i.e., availability measured at 66.21%, performance resulted at 61.30%, quality valued at 96.999%. It is observed that OEE was lagging from the world-class standard benchmark.

Table 2. Results of OEE and its components before CILT

Parameters	Formula	Values	Comparison operators	WCS
Availability (A)	*A= Run Time / Planned Production Time.*	66.21%	<	90%
Performance (P)	*P= (Ideal Cycle Time x Total Count) / Run Time.*	61.30%	<	95%
Quality (Q)	*Q= Good Count / Total Count.* *= Total Count -defective Count / Total Count.*	96.999%	<	99%
OEE	OEE = (A*P*Q)	39.368%	<	85%

The value of OEE equal to 40% is the bottom line for the manufacturing companies. This is amendable by focusing on the leading causes of downtime one after another (Singh et al., 2021). To increase the OEE, it was observed that there was an unplanned breakdown which resulted in less availability of equipment. Moreover, they also remained the reason for the lower speed of the line. Not only this, but such complications also remain a reason for the defective products.

After calculating the OEE, the reason for the unplanned downtime in the shape of six big losses was explored to track their time losses and causes were found with the help of the cause-and-effect tool. It was found that most of the time loss problems were related to maintenance. In line with the problems, cleaning, inspection, lubrication, and tightening (CILT) plan of autonomous maintenance was proposed and implemented.

Table 3. Production data for a month after CILT

PARAMETERS	VALUES
Total available time per month in hours for two shifts of eight hours	480
Planned downtime in hours (2 hours addition of CILT)	93.2
Total Production Time in hours	386.8
Unplanned downtime in hours	54
Actual production time in hours	332.8
Packs to be produced in planned production time at maximum speed 200 per minute	4,641,600
Total packs produced at the speed of 180 products per minute	3,594,240
Products used to reprocess	92,017 (2.56012398%)
Good Products	3,502,223

Table 3 represents the values of different parameters for two shifts of a month after the implementation of CILT. The total available time for production for the two shifts of a month is 480 hours. The planned downtime is 93.2 hours. After subtracting the planned downtime from total available time, the remaining time is 386.8 hours which is known as the total production time in hours. Unplanned downtime is 54 hours. Subtracting the unplanned downtime from the total production time gives the value of actual production time i.e., 332.8 hours. The total number of products produced in the actual production time at the speed of 180 bottles per minute is 3,594,240 bottles. However, the line could produce 4,641,600 bottles at the speed of 200 bottles per minute. Out of the produced bottles, 92,017 bottles were reprocessed, which could not pass the quality standards. Hence, good products count as 3,502,223 bottles.

3.2 Calculation of OEE After CILT

To know the impact of CILT, OEE was calculated again. Values of which are presented in Table 4. OEE of the packaging line was measured at 52.314%. Factors contributing to the OEE i.e., availability measured at 69.333%, performance resulted at 77.435%, quality valued at 97.440%. Still, the values are much lacking behind the OEE, Notwithstanding, the OEE has improved so its parameters are contributing to OEE.

Table 4. Results of OEE and its components after CILT

Parameters	Formula	Values	Comparison operators	WCS
Availability (A)	*A= Run Time / Planned Production Time.*	69.33%	<	90%
Performance (P)	*P= (Ideal Cycle Time x Total Count) / Run Time.*	77.435%	<	95%
Quality (Q)	*Q= Good Count / Total Count.* *= Total Count -defective Count / Total Count.*	97.440%	<	99%
OEE	OEE = (A*P*Q)	52.314%	<	85%

Table 5 provides a comprehensive summary of the comparison of key indicators of performance (availability, performance, and quality) that are used to measure OEE, before and after implementing CILT. This table also provides the change in percentage in each parameter of OEE and OEE itself.

Table 5. **Percent increase in the availability, performance, and quality of line.**

Parameters	Values (before CILT)	Values (after CILT)	Percent change
Availability (A)	66.21%	69.33%	3.12%
Performance (P)	61.30%	77.435%	16.14%
Quality (Q)	96.999%	97.440%	0.44%
OEE	39.368%	52.314%	12.95%

Increased values of availability, performance, quality, and OEE are presented in Table 5. After the CILT, the availability of the line has increased from 66.21% to 69.33%. The difference is 3.12%. Similarly, there is an increase in the performance of the line from 6.30% to 77.435%, and the difference is 16.14%. Another factor contributing to OEE, quality has also increased from 96.99% to 97.44%, and the difference is 0.44%. As all the factors contributing to OEE have increased therefore, OEE has also increased from 39.368% to 52.314%, and the difference is 12.95%. The major increase that has occurred is in the performance of the line, followed by availability and quality.

Figure 2 shows the indicators for OEE, availability, performance, and quality before and after a specific event called CILT, as well as the values for threshold called world-class standard. Further Figure 1 shows the comparison between World-class standards and OEE before and after CILT. It clearly shows that OEE and the parameters that contribute to it, all have increased after the implementation of the CILT plan. However, all the parameters including OEE are far away from the world-class standards except quality. OEE has increased by almost 12.94 percent, likewise, availability has increased by 3.12 percent, performance has increased by 16.14 percent, and quality has increased by 0.44 percent. The trend line shows the positive effect of CILT in all the parameters including OEE itself. Performance is the parameter that has increased the most, followed by OEE itself, availability, and quality. It is obvious that increase in parameters like availability, performance and quality contributes directly to the increase in OEE.

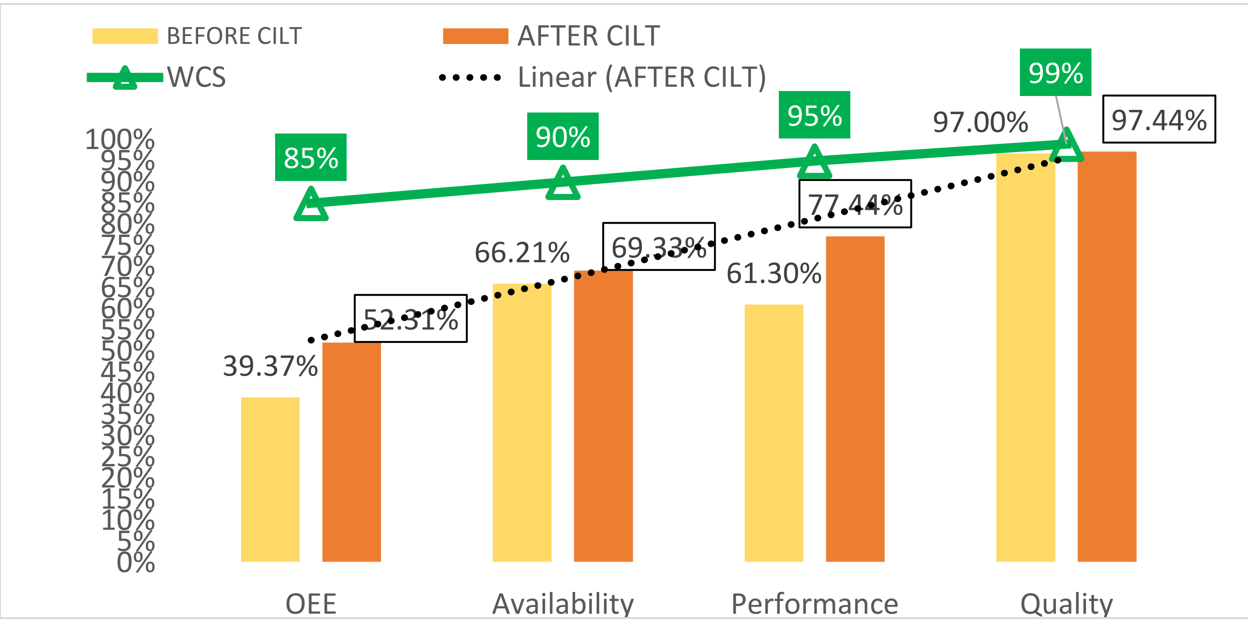

Figure 2. Comparison of OEE before and after CILT

The value of OEE before the implementation of OEE is nearly 40 percent. Such a value is considered a low value for the companies. However, this value is common for the newly and struggling companies (Thorat & Mahesha, 2020). After the implementation of CILT, an increase in all the parameters was observed. The major increase that has occurred is in the performance of the line, followed by availability and quality.

The improved OEE figure is even far away from the typical value of OEE. The typical value of OEE for manufacturing companies is 60 percent (Plinere & Aleksejeva, 2019). Such a value indicates that there is considerable room for improvement. In addition to maintenance other factors i.e., value stream mapping (VSM), methods engineering (ME), line balancing (LB), total quality management (TQM), lean manufacturing (LM), just-in-time (JIT) etc. should be considered which would have an impact on the OEE.

4 DISCUSSIONS

Running equipment, processes, or systems at full capacity is considered an optimal utilization of the available resources. To reach that level is not an easy task. Nevertheless, organizations continuously strive to achieve that milestone. Organizations adopt different strategies to cope with the problem of running machines and or systems at lower capacity. The same problem was observed and identified in one of the packaging lines of a pharmaceutical company, located at Jamshoro, Sindh, Pakistan. OEE was measured to justify the identified problem.

The value of OEE before the implementation of OEE is near 40 percent. Such a value is considered a low value for the companies. The low value of OEE is the result of several interruptions to the machines (Rabelo et al., 2023). However, this value is common for the newly and struggling companies (Thorat & Mahesha, 2020). Cleaning, Inspection, Lubrication, and Tightening (CILT), an autonomous maintenance strategy of Total Productive Maintenance (TPM) was carried out to increase the effectiveness of the line. It resulted in an improvement in performance, availability and quality written as hierarchical in increasing level.

The highest percentage of improvement was recorded in performance, with the increase of 16.14%, the value of performance has reached 77.44%. This value of performance is just 16.14% away from reaching the world-class benchmark.

Availability is the second number in the increase with a value of 3.12%. It needs an increase of 20.67% to be in line with the world-class benchmark. Other TPM pillars must be used to reduce the tile losses and enhance the availability of the line.

A very small percentage of improvement was observed in quality, which is 0.44%. It is because the quality of the products at the initial level was already very near to the World Class Standard benchmark. Furthermore, as it is a pharmaceutical company, the foremost focus of the company is on the quality of the products. Further, the products which were considered default were because of the loose caping, misprinting of labels and denting of the bottles which were recycled. Because of the CILT such problems of quality have also reduced to 1.56% from 2%. Interestingly, it requires only 1 and half percent to level the world-class benchmark.

As there was improvement in the parameters contributing to OEE as increase has been witnessed in OEE. Though CILT has improved the OEE, the improved OEE figure is far away from the typical value of OEE. AS, the typical value of OEE for manufacturing companies is 60 percent (Plinere & Aleksejeva, 2019). Despite the increase in the OEE has been recorded as 12.95%. Similar percentage of increase in OEE because of autonomous maintenance was also reported by (Gurpreet Singh Bali et al., 2022), however, it still needs 32.686% to reach the world-class benchmark. Such a value indicates that there is considerable room for improvement. In addition to maintenance other factors i.e., Single minute exchange die (SMED), value stream mapping (VSM), methods engineering (ME), line balancing (LB), total quality management (TQM), lean manufacturing (LM), just-in-time (JIT) etc. should be considered which would have an impact on the OEE.

5. CONCLUSION

This study was carried out to know the effect of Cleaning, Inspection, Lubrication, and Tightening (CILT) effectiveness of the packaging line. OEE was used to investigate the effectiveness of the equipment. OEE was measured before and after the implementation of CILT. It was found that CILT has increased the OEE. Not only OEE but CILT has improved all the parameters i.e., availability, performance, and quality. This study witnessed that the CILT technique has cut down time losses and increased the capacity of the line, which will have a notable impact on the sustainable production of the line. This can be useful insight for those industries which have machines. It is recommended that companies adopt the CILT approach to enhance the efficiency of the machines. Though this study presents the results of a pharmaceutical company, its results can be considered the positive results of implication of CILT has improved Overall Equipment Effectiveness of the packaging line of a pharmaceutical company. Results of the study confirm that the company can achieve substantial improvement in the overall effectiveness of the rest of the lines if it implements the techniques that contribute to OEE. Considering the fact of the positive impact of CILT on the OEE, practitioners can implement the CILT in other manufacturing industries because its benefits are not limited to the pharmaceutical industry only.

5.1 Limitations, Recommendations and Future work

This study was conducted on one of the packaging lines of the company. It can be carried out for other packaging lines too. Only one of the eight components of the total productive maintenance, that is autonomous maintenance in terms of CILT (cleaning, inspection, lubrication, and tightening) was considered, which has increased the OEE. However, consideration of other components may also have an impact on OEE, which could be part of future research to assess their impact on the OEE. Furthermore, this study has analyzed one-month data before and after the implementation of CILT, further data for other months may also result in more insights into the effect of CILT on OEE as a longitudinal study.

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8. COMPETING INTERESTS

The authors declare none.

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