

Implementation of Overall Equipment Effectiveness (OEE) and Its Optimization: Data Driven Analysis of Tablet & Capsule Packaging Section

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Abstract

Pharmaceutical industry has gone through significant changes in the past decades. Competition has increased drastically. To stay competitive, improving efficiency and productivity is a key driver. Product quality also acts a major role in pharmaceutical industry as it is directly connected with the living beings. Keeping that in mind, industry should introduce OEE (Overall Equipment Effectiveness) which is a key performance indicator within Total Productive Maintenance (TPM) that weighs equipment productivity by appraising availability, performance & quality. This study possessed real-time production data of tablet and capsule packaging machines of multiple shifts and calculated the OEE scores. The resulted OEE scores falls between from 28.02% to 48.93% and was compared with the world class OEE standards, which falls significantly short. This study also pinpointed the root causes such as high breaks and idle time of workers, high breakdown and setup loss, no planned maintenance for low OEE scores through the implementation of Root Cause Analysis. Optimization recommendations using TPM schemes such as planned maintenance, quality control and operator training to gradually coincide the packaging operation with world class OEE standards was also proposed in the study.

Keywords

Overall Equipment Effectiveness, Total Productive Maintenance, Planned Maintenance, Fishbone Diagram

1. Introduction

Improving the productivity of a production company is indispensable to obtain higher profits and cope up with demands in such a competitive market. Equipment is an important part of a production system and its efficiency directly affects the quality and overall productivity of a production plant. All the equipment must operate efficiently in order to manufacture high quality products and cope with the demands(MAJUMDAR, 2017). The ultimate goal of every manufacturing firm is to produce quality goods and gain high profit through cost reduction. It can be achieved through implementation of an effective maintenance system. This maintenance system should be able to maximize availability of equipment by minimizing the machine downtime(Zubair et al., 2021).

Most of the pharmaceutical companies are seeking to optimize the productivity of their production. This could be made possible by identifying the production losses and applying quality standards which will certainly minimize the repairing time and other hidden operating costs such as machine breakdowns, low availability of machines.

In machine factor point of view, the measurement of machine effectiveness is very important. Thus, six big losses are introduced that relates to the machine effectiveness(Nakaiima, 1988). The 6 big losses include breakdown losses, setup and adjustment losses, idle and minor stoppage, reduced speed, rework losses and yield/scrape. In extension of 6 big losses, Overall Equipment Effectiveness (OEE) was also introduced. OEE is a measurement tool to measure machine effectiveness based on three important parameters which are; Availability (A), Performance (P), and Quality (Q)(Maideen et al., 2016). Overall Equipment Effectiveness can also be called as metric to measure the overall efficiency of the system in order to enhance the production system in more effective way. When organization uses their resources in optimum way it always reduces the end result cost. So, Overall Equipment Effectiveness is the handy tool to increase the rate of production, quality of the products and makes operations smooth during production. According to the literature, the world class Overall Equipment Effectiveness is recorded about 85%, which is considered as one of the highest recorded OEE and can be set as a standard for other organizations(Sivakumar & Manivel, 2020).

Fishbone Diagram

Fishbone diagram is also called Cause- Effect Analysis or Ishikawa Diagram and was first introduced by Dr. Kaoru Ishikawa in year 1968. This is an analysis tool designed to visually map out the causes and sub-causes leading to a particular issue or effect(Kumah et al., 2024). It helps to visualize how major causes like Man, Machine, Method, Material contribute to the problem branching into sub-causes.

2. Literature review

OEE measures the total equipment performance which is the degree to which the equipment is doing, what it is supposed to do(Williamson, 2006). OEE is an important tool which identifies areas that may have bottleneck in the production line(Omega & Andika, 2017), covering three major characteristics such as the availability, performance, and quality rate of the output of equipment. OEE is considered as one of the important contents for total productive maintenance (TPM) and lean manufacturing philosophy(Lin et al., 2017). Additionally, it is an important metric for measuring the success of manufacturing improvement approach known as Total Productive Maintenance (TPM)(Nakaiima, 1988). TPM is an innovative Japanese concept that is mostly followed for optimizing equipment effectiveness, breakdowns elimination and promoting autonomous maintenance in day to day activities involving total workforce(Mahajan et al., 2018). Three words make up TPM(Fam et al., 2018); Total: involves everyone from top to bottom in maintenance. The term "productive" refers to ensuring that an operation is efficient and that maintenance problems are reduced. Equipment maintenance: ensuring that the equipment works properly.

In any manufacturing industry it is essential to implement TPM approach due to significant impact and relationship with manufacturing performances in terms of overall equipment effectiveness (OEE)(Zubair et al., 2021).

Currently, manufacturing companies are developing alternatives to address capacity problems such as extra shifts and purchasing new equipment. An alternative approach is suggested by to enhance the performance of their existing equipment in order to improve the machine's reliability, operator's performance and eliminating or reducing idle times(Aman et al., 2017). In this regard, the Overall Equipment Effectiveness has gained much more focus in the recent past. TPM pillars were implemented for the root cause analysis of major losses related to equipment and the results showed a significant increase in the OEE level of the plant. In a study the applications of TPM principles are revealed to improve the OEE level in a pharmaceutical industry in which the ABC analysis of the equipment is

performed in order to establish the critical equipment requiring 20% attention thereby yielding 80% results(Goriwondo et al., 2011). TPM pillars were implemented for the root cause analysis of major losses related to equipment and the results showed a significant increase in the OEE level of the plant. A new performance ratio strategy has been used in a study to improve the OEE of the plant by cycle time limitation reduction(Keyser & Sawhney, 2013).

3. Methodology

First, a detailed study was conducted about the manufacturing processes of the proposed local pharmaceutical industry to know about the existing problems. The problems were identified in the packaging machine of tablet and capsule products. A detailed review was conducted and data was collected about the tablet and capsule packaging machine section for possible improvement and analyzed using the OEE calculation and compared with the world class rate of OEE.

3.1. OEE Calculation

OEE can be measured by obtaining the product of Performance(P) efficiency of the process, the Availability(A) of equipment, and rate of Quality(Q) products.

$$\text{OEE} = \text{A} * \text{P} * \text{Q}$$

- Availability (%) = $\frac{\text{Loading time} - \text{Breakdown \& setup loss}}{\text{Loading time}} * 100$

Where, Loading time= Total time- Breaks- Planned maintenance time

- Performance (%) = $\frac{\text{Quantity produced}}{\text{Time run} * (\text{Capacity} / \text{Given time})} * 100$

- Quality (%) = $\frac{\text{Amount produced} - \text{Amount defects} - \text{Amount reprocessed}}{\text{Amount produced}} * 100$

4. Data collection & analysis

Overall Equipment Effectiveness (OEE) was calculated based on the data collected for the 2 different blister packaging machines. The data was collected for the three different shifts of tablet & capsule packaging (Table 1- Table 7).

Data analysis for Hoonga HM 200R Blister Packaging Machine:

Table 1. 1st Shift Data

Total time	8 hours
Breakdown & Setup Loss	1.625 hours
Breaks & Idle time	2 hours
Machine capacity rate	1200 pcs/min
Operating Rate	800 pcs/min
Quantity produced	210000 pcs
Reprocess & Defects	6300 pcs

Loading Time= 8hrs- 2hrs= 6hrs

Availability(A)= [(6hrs- 1.625hr)/ 6hrs] * 100 = 72.92%

Performance(P)= 210000/ [4.375*(576000/8)] * 100= 66.67%

Quality(Q)= (210000-6300)/210000* 100= 97%

Overall Equipment Effectiveness (OEE)= A * P * Q
 = 72.92* 66.67* 97
 = 47.16%

Table 2. 2nd Shift Data

Total time	8 hours
Breakdown & setup loss	1.5517 hours
Breaks & idle time	2 hours
Machine capacity	1200pcs/ min
Operating rate	800pcs/ min
Quantity produced	213520 pcs
Reprocess & Defects	6173 pcs

Loading time= 8- 2= 6hrs

Availability(A)= [(6- 1.5517)/6] * 100= 74.14%

Performance(P)= 213520/ [4.4483 * (576000/8)] * 100= 66.67%

Quality(Q)= [(213520-6173)/213520] * 100= 97.11%

Overall Equipment Effectiveness (OEE)=A * P * E
 = 74.14 * 66.67 * 97.11
 = 48%

Table 3. 3rd Shift Data

Total time	8 hours
Breakdown & Setup loss	1.45 hours
Breaks & idle time	2 hours
Machine capacity	1200pcs/ min
Operating rate	800 pcs/min
Quantity produced	218370 pcs
Reprocess & Defects	7000 pcs

Leading time= 8- 2= 6 hours

Availability(A)= [(6- 1.45)/ 6] * 100= 75.83%

Performance(P)= [218370/ {4.55 * (576000/ 8)}] * 100= 66.66%

Quality(Q)= [(218370- 7000)/218370] * 100= 96.79%

Overall Equipment Effectiveness (OEE)= A * P * Q
 = 75.83 * 66.66 * 96.79

= 48.93%

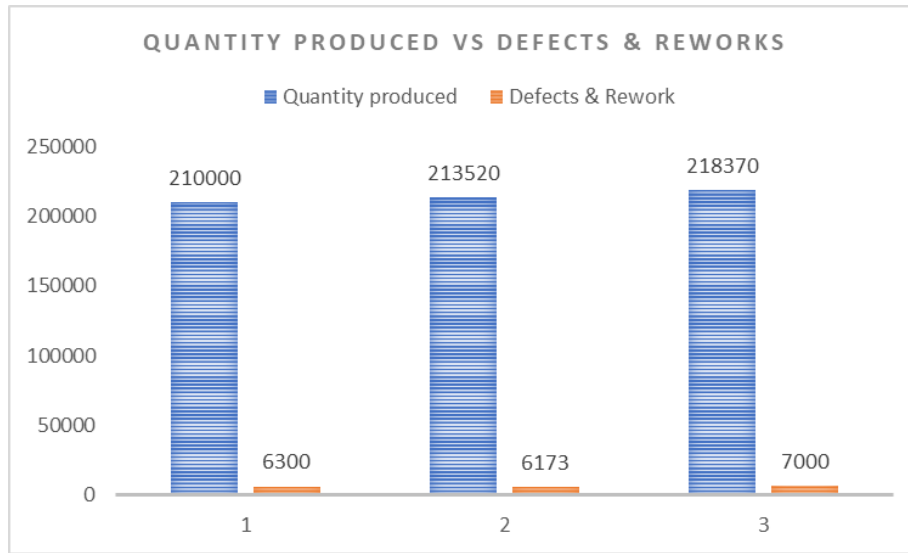


Figure 1. Quantity produced vs defects and rework produced in 3 shifts

If we look at the data, it shows that the OEE level of the machine of the 3 shifts are very much lower than the world class rate of 85% (Figure 1).

Data analysis of Horn Noack N-740 Blister Packaging Machine:

Table 4. 1st Shift Data

Total time	8 hours
Breakdown & Setup loss	2 hours
Breaks & idle time	2 hours
Machine capacity	1000 pcs/ min
Operating rate	440 pcs/ min
Quantity produced	105635 pcs
Reprocess & Defects	2112 pcs

Loading time= 8- 2= 6 hours

Availability(A)= [(6-2)/ 6] * 100= 66.67%

Performance(P)= [105635 / {4 * (480000/ 8)}] * 100= 44.01%

Quality(Q)= [(105635- 2112)/ 105635] * 100= 98%

Overall Equipment Effectiveness (OEE)= A * P * Q

= 66.67 * 44.01 * 98

= 28.75%

Table 5. 2nd Shift Data

Total time	8 hours
Breakdown & Setup loss	2.10 hours
Breaks & idle time	2 hours
Machine capacity	1000 pcs/ min
Operating rate	440 pcs/ min
Quantity produced	102930 pcs
Reprocess & Defects	2060 pcs

Loading time= 8- 2= 6 hours

Availability(A)= $[(6-2.10)/ 6] * 100= 65\%$

Performance(P)= $[102930/ \{3.90 * (480000/ 8)\}] * 100= 43.99\%$

Quality(Q)= $[(102930- 2060)/ 102930] * 100= 98\%$

Overall Equipment Effectiveness (OEE)= A * P * Q

$$= 65 * 43.99 * 98$$

$$= 28.02\%$$

Table 6. 3rd Shift Data

Total time	8 hours
Breakdown & Setup loss	1.88 hours
Breaks & idle time	2 hours
Machine capacity	1000 pcs/ min
Operating rate	440 pcs/ min
Quantity produced	108665 pcs
Reprocess & Defects	2175 pcs

Loading time= 8- 2= 6 hours

Availability(A)= $[(6- 1.88)/ 6] * 100= 68.67\%$

Performance(P)= $[108665/ \{4.12 * (480000/ 8)\}] * 100= 43.96\%$

Quality(Q)= $[(108665-2175)/ 108665] * 100= 97\%$

Overall Equipment Effectiveness (OEE)= A * P * Q

$$= 68.67 * 43.96 * 97$$

$$= 29.28\%$$

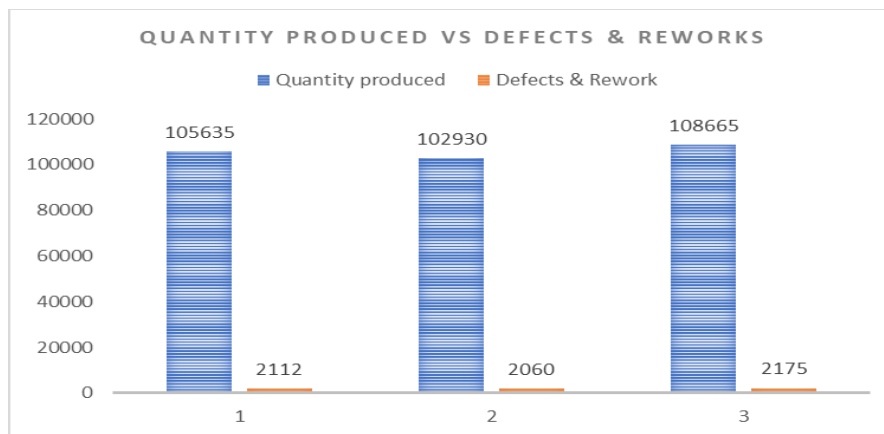


Figure 2. Quantity produced vs defects and rework produced in 3 shifts

5. Results & Discussion

In Table 7, we can see that there is a very significant gap between the OEE of our observed equipment and the world class OEE benchmark (Figure 2 and Figure 3).

Table 7. Shift-wise OEE Performance and Gap Analysis for Machines

Machine	Shifts	Availability (%)	Performance (%)	Quality (%)	OEE (%)	Benchmark OEE (%)	Gap (%)
Hoonga HM 200R	1 st	72.92	66.67	97	47.16	85	37.84
	2 nd	74.14	66.67	97.11	48	85	37
	3 rd	75.83	66.66	96.79	48.93	85	36.07
Horn Noack N-740	1 st	66.67	44.01	98	28.75	85	56.25
	2 nd	65	43.99	98	28.02	85	56.98
	3 rd	68.67	43.96	97	29.28	85	55.72

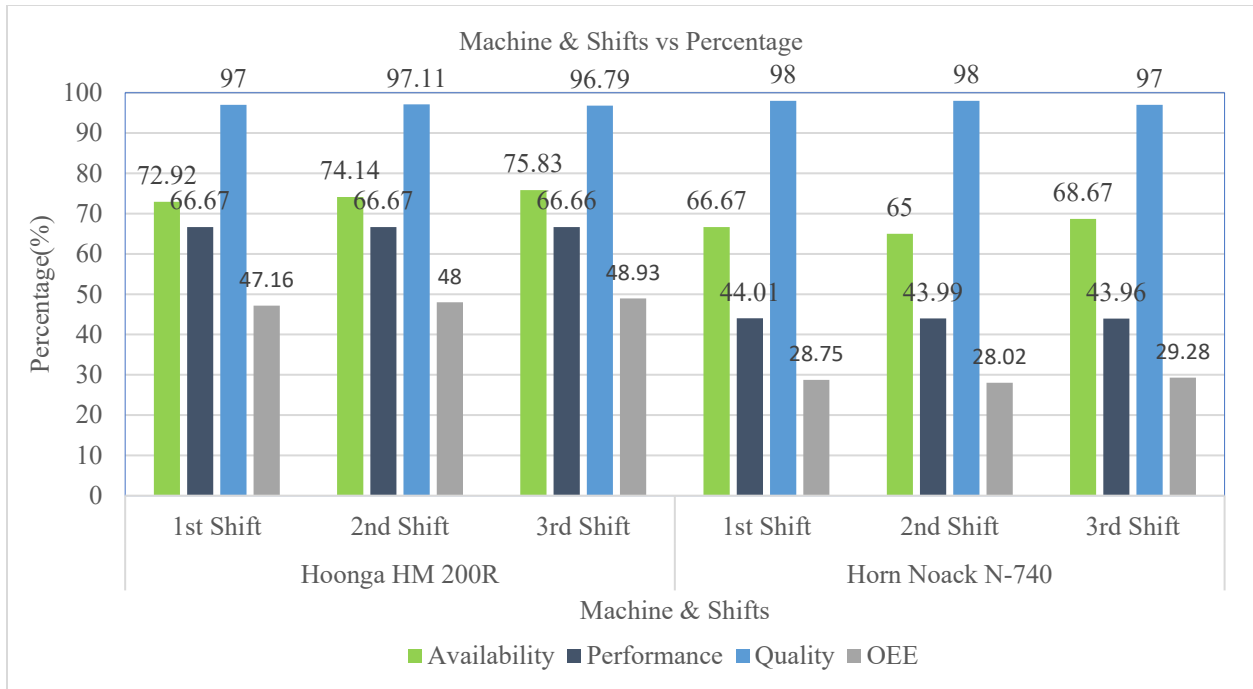


Figure 3. Availability, Performance, Quality and OEE scores of machines across multiple shifts

Fishbone Diagram:

Factors that affect in OEE measurement are showed in the fishbone diagram in Figure 4-

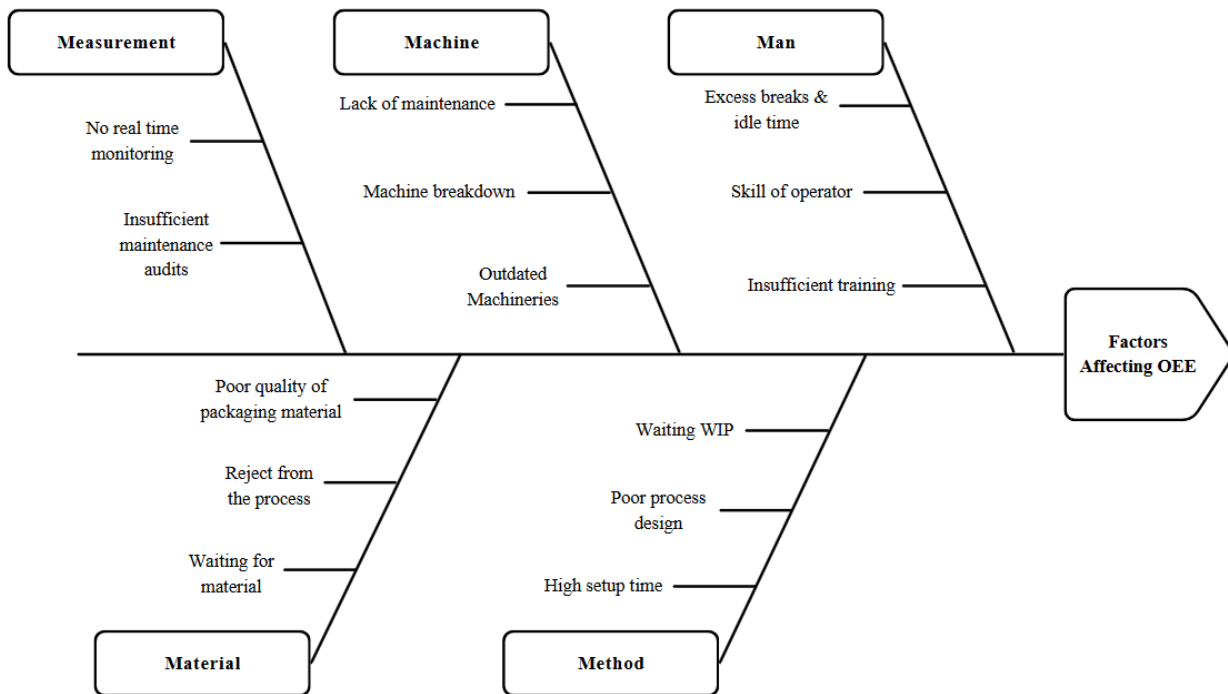


Figure 4. Fishbone Diagram

5.2 Proposed Recommendations

Observing the following data, there are several reasons for the low level of availability, performance, and quality of blister packaging process of tablet and capsule products. Firstly, the breaks and idle time of workers are very much higher which is the cause of low productivity and performance. Secondly, breakdown and setup loss of the machine and components are also very high which is the cause for the low level of availability and performance. There is also no planned maintenance system for the equipment which leads to the production of unacceptable and rework quality products. There is also constant machine breakdown during the production process which not only hampers the production but also causes bottlenecks.

It is recommended that the industry should develop a planned and proactive maintenance system rather than a breakdown maintenance. This maintenance system will improve the performance, availability, safety and lifetime of the equipment. Thus, the breakdown time of the machines can be decreased. It also lowers the defective and reprocessed units. Total Productive Maintenance (TPM) programs such as planned maintenance, quality maintenance, 5S, office TPM, training should also be introduced from the top officials to all kinds of employees. These programs could improve productivity and reduce waste. Industry should be more strict in workers breaks and idle time. Right person should be employed at the right place because it ensures skills, personality, and goals align with needs, leading to peak performance, efficiency, and positive outcomes.

6. Conclusion

The Overall Equipment Effectiveness was implemented on a local pharmaceutical industry in the tablet and capsule packaging section. Data was collected and analyzed based on three parameters. The results show that the OEE level are very much lower than the world class rate of OEE. Data driven analysis identified various key inefficiencies such as equipment downtime, reduced speed, excess breaks and idle time, low quality products. Optimizing OEE will not only enhance the packaging section's overall performance but also a more develop packaging process and ensuring higher quality products. In addition, TPM approach like planned maintenance should also be introduced in the industry which will reduce the breakdown maintenance time enhancing higher quality products, safety and lifetime of the equipment.

References

- Aman, Z., Ezzine, L., Fattah, J., Lachhab, A., & Moussami, H. E., Improving efficiency of a production line by using overall equipment effectiveness: A case study. *Proceedings of the International Conference on Industrial Engineering and Operations Management, Rabat, Morocco*, 1048–1057, 2017.
- Fam, S.-F., Loh, S. L., Haslinda, M., Yanto, H., Khoo, L. M. S., & Yong, D. H. Y. , Overall equipment efficiency (OEE) enhancement in manufacture of electronic components & boards industry through total productive maintenance practices. *MATEC Web of Conferences*, 150, 05037
- Goriwondo, W. M., Mhlanga, S., & Kazembe, T. , Optimizing a production system using tools of total productive maintenance: Datlabs pharmaceuticals as a case study. *International Conference on Industrial Engineering and Operations Management*, 1139–1144, 2011.
- Keyser, R. S., & Sawhney, R. S. , Reliability in lean systems. *International Journal of Quality & Reliability Management*, 30(3), 223–238, 2013.
- Kumah, A., Nwogu, C. N., Issah, A. R., Obot, E., Kanamitie, D. T., Sifa, J. S., & Aidoo, L. A. , Cause-and-Effect (Fishbone) Diagram: A Tool for Generating and Organizing Quality Improvement Ideas. *Global Journal on Quality and Safety in Healthcare*, 7(2), 85–87, 2014. <https://doi.org/10.36401/JQSH-23-42>
- Lin, L., Xiu, H., Yunfei, W., & Guangchao, W. , Research on overall equipment effectiveness for cigarette equipments based on data mart and data mining. *DEStech Transactions on Engineering and Technology Research*
- Mahajan, U. K., Adatiya, P., Badhe, P., Patsute, A., & Bhusnar, A. , Total productive maintenance to improve overall equipment effectiveness. *Global Journal of Research in Engineering*, 18(3), 16–57, 2018.
- Maideen, N. C., Sahudin, S., Yahya, N. H. M., & Norliawati, A. O, Practical framework: Implementing OEE method in manufacturing process environment. *IOP Conference Series: Materials Science and Engineering*, 114(1), 012093, 2016.
- MAJUMDAR, S. Nallusamy. G. , Enhancement of overall equipment effectiveness using total productive maintenance in a manufacturing industry. *International Journal of Performability Engineering*, 13(2), 173. , 2017.
- Nakaiima, S., *Introduction to total productive maintenance (TPM)*. Cambridge, MA: Productivity Press. 1998.

- Omega, D., & Andika, A., Improving overall equipment effectiveness using CPM and MOST: A case study of an Indonesian pharmaceutical company. *IOP Conference Series: Earth and Environmental Science*, 101(1), 012039, 2017
- Sivakumar, R., & Manivel, R. , Analysis on overall equipment effectiveness of a PEMAMEK panel processing machine. *Materials Today: Proceedings*, 21, 367–370, 2020.
- Williamson, R. M. , Using overall equipment effectiveness: the metric and the measures. *Strategic Work System, Inc*, 1–6,2006.
- Zubair, M., Maqsood, S., Habib, T., Usman Jan, Q. M., Nadir, U., Waseem, M., & Yaseen, Q. M. , Manufacturing productivity analysis by applying overall equipment effectiveness metric in a pharmaceutical industry. *Cogent Engineering*, 8(1), 2021. <https://doi.org/10.1080/23311916.2021.1953681>

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