



A Critical Estimation And Analysis Of Overall Equipment Effectiveness (OEE) Of Pick-Fill-Seal Machine In A Pesticide Manufacturing Unit

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Abstract: This research delves into the evaluation of Overall Equipment Effectiveness (OEE) in Pick-Fill-Seal machines at UPL Ltd, a leading agrochemical company. OEE stands as a pivotal metric in manufacturing, assessing equipment efficiency via availability, performance, and quality factors. The primary aim of this study is to ascertain current OEE levels and analyze operational parameters influencing efficiency. Methodology involved an exhaustive survey, gathering data from operational records and insights from UPL Ltd staff. Survey data enabled precise OEE calculation and analysis of availability, performance, and quality. Rigorous statistical analysis explored relationships between parameters such as maintenance schedules, operator efficiency, downtime, and environmental conditions, and their impacts on OEE. Results reveal acceptable OEE levels in Pick-Fill-Seal machines, with significant scope for improvement. Machine downtime and maintenance efficiency emerged as primary influencers. In conclusion, it was recommended to adopt measures like enhanced maintenance protocols, comprehensive operator training, and advanced monitoring systems implementation. This study not only evaluates Pick-Fill-Seal machine OEE but also offers actionable insights for manufacturing efficiency enhancement. The ultimate aim of the research work was to aid the plant in the enhancing manufacturing processes, fostering increased productivity and operational excellence. It emphasizes holistic equipment management and continuous optimization for superior operational performance.

Index Terms – Availability, downtime, maintenance, overall equipment effectiveness (OEE), performance quality, reliability.

I. INTRODUCTION

Machine maintenance is the essential practice of preserving and enhancing machinery functionality through comprehensive routine upkeep and strategic interventions. This vital and intricate process encompasses an extensive array of regular maintenance tasks, such as meticulous surface cleaning, precise gear lubrication, and thorough inspection of components like belts to detect and address wear and tear. Additionally, it involves proactive measures, including the continuous monitoring of equipment for potential issues, such as changes in vibration patterns, unusual temperature spikes, and abnormal increases in energy

consumption, all of which can indicate underlying problems that require immediate attention. Diving into the expansive realm of machinery maintenance reveals a variety of sophisticated strategies designed to ensure optimal performance and longevity of industrial equipment. These strategies encompass different approaches, each tailored to specific needs and operational contexts:

- a) **Reactive Maintenance:** This traditional approach involves addressing machinery issues only when they arise. Essentially, repairs and fixes are undertaken after a machine breaks down or a part fails. While this method can be cost-effective in the short term due to minimal upfront maintenance costs, it often leads to longer downtimes and potentially higher repair costs, as well as unforeseen disruptions in production schedules.
- b) **Preventive Maintenance:** This proactive approach is centered around scheduled maintenance activities. Parts and components are replaced or serviced at regular, predetermined intervals before they are likely to fail. This strategy helps in avoiding unexpected breakdowns and extends the lifespan of machinery. By adhering to a routine schedule, preventive maintenance can significantly reduce the risk of sudden failures and the associated costs of emergency repairs and downtime.
- c) **Usage-Based Maintenance:** In this method, maintenance tasks are performed based on the actual usage of the machinery. Parts are replaced or serviced after the equipment has operated for a certain amount of time or cycles. This approach takes into account the wear and tear that results from usage patterns, pre-empting breakdowns by ensuring that parts are maintained or replaced before they reach a critical point of failure. It balances the need for maintenance with the actual operational demands placed on the machinery.
- d) **Condition-Based Maintenance:** This strategy involves monitoring the actual condition of the machinery and its components to determine when maintenance is necessary. Parts are replaced or serviced only when they show signs of excessive wear or other indicators that they might compromise the functionality of the equipment. This method relies on regular inspections and the use of sensors to monitor conditions such as temperature, vibration, and pressure, ensuring that maintenance activities are carried out only when truly needed.
- e) **Predictive Maintenance:** Leveraging the power of historical data and advanced analytics, predictive maintenance aims to predict when a part is likely to fail. This approach often employs artificial intelligence and machine learning algorithms to analyse data trends and make accurate predictions about future failures. By identifying potential issues before they occur, predictive maintenance allows for timely replacements and interventions, thus minimizing downtime and enhancing operational efficiency.
- f) **Prescriptive Maintenance:** This advanced maintenance strategy goes beyond merely predicting failures. It involves sophisticated data analysis to provide actionable insights and recommendations on the best actions to take before issues arise. Prescriptive maintenance addresses potential failures, safety hazards, and quality concerns, offering guidance on the optimal timing and nature of maintenance activities. This approach helps in not only preventing breakdowns but also in optimizing the overall performance and safety of the machinery, ensuring that the right maintenance actions are implemented at the most opportune times.

By employing these diverse maintenance strategies, industries can effectively manage their machinery, reduce downtime, enhance efficiency, and ensure the safety and reliability of their operations as shown in **Figure 1**.



Figure 1. Types of maintenance

Each approach offers distinct advantages, and often, a combination of these strategies is used to achieve the best results in maintaining complex industrial systems. Data-driven maintenance enhances efficiency by optimizing part replacements and mitigating downtime. It also streamlines maintenance workload, reduces safety risks, minimizes storage needs, and improves predictability. Total Productive Maintenance (TPM) aims to maximize equipment effectiveness, promote autonomous maintenance by operators, and foster small group activities for continuous improvement. Equipment Effectiveness (OEE) is a key metric measuring equipment productivity, incorporating availability, performance, and production quality. It helps identify areas for improvement and track progress over time.

Overall Implementing TPM pillars and addressing the six major losses can significantly enhance OEE. OEE measurement is applied at startup, line level, and individual machine level to identify areas needing improvement and guide maintenance efforts effectively.

II. LITERATURE REVIEW

In order to look at performance enhancement using the analytical hierarchy approach and overall equipment effectiveness (OEE), **Muataz et al. (2021)** carried out a case study. They discovered that a company's productivity and resource utilization can be greatly increased by applying OEE as a metric. Through the identification and resolution of the underlying causes of losses, OEE acts as a tangible framework and stimulant to promote improvements in efficacy and efficiency. In order to optimize productivity and efficiency, **Tsarouhas (2012)** carried out a case study in the beverage industry on the limoncello manufacturing line, emphasizing the necessity to enhance Performance Efficiency (PE) and Quality Rate (QR). These results show that machinery makers and producers of bottled products might use these insights to improve the design and operational management of bottling production lines, thereby driving continuous improvement in the beverage industry. These findings have wider implications for the industry. In order to increase overall equipment effectiveness (OEE), **Aseem et al. (2019)** carried out a case study on specialized autonomous maintenance training for a pilot crew, emphasizing the Education and Training pillar. The goal of the study was to increase operator proficiency and promote OEE measurement ownership. The results highlight OEE as a crucial KPI that greatly enhances plant efficiency and operational success. This methodology may have consequences for other sectors seeking to improve their competitiveness by means of worker training programs and strategic performance assessment. **Chong et al. (2014)** carried out a case study in order to apply the Six Sigma Methodology to increase overall equipment effectiveness (OEE), in a semiconductor company. They emphasized the significance of describing and addressing the problem early on using the DMAIC (Define, Measure, Analyze, Improve, Control) approach. This approach offered a

thorough, methodical investigation to identify underlying issues and deliver long-lasting, workable remedies. Pin shaft instability during flipper arm turning was specifically found in the study to be the reason for unit misplacement in the pick-up arm, which resulted in equipment failures and low OEE. Implementing Overall Equipment Effectiveness (OEE) in manufacturing is a simple technique to measure equipment effectiveness, according to **Sowmya and Chetan (2016)**. Three things determine an equipment or company's total performance: performance, quality, and availability. OEE is economical since it concentrates on evaluating machine performance as opposed to making an instantaneous investment in new machinery. By focusing on major causes of loss through continual improvement, this approach encourages growth in overall productivity. According to **Tsarouhas (2018)**, academics connects theoretical ideas with real-world applications to address difficulties in implementing Overall Equipment Effectiveness (OEE) as an improvement technique. Three components make up OEE, which is commonly used in industry to evaluate the performance of equipment: availability, performance, and quality. These components are targeted at particular process elements. Calculating these, however, necessitates a significant amount of historical data, which presents problems such as uncommon occurrences, human error, financial limitations, and obstacles in gathering data from particular plants over long periods of time. According to **Lisbeth et al. (2020)**, OEE gauges the efficiency of warehouse equipment used for cargo movement in supply chains. In the service industry, it evaluates customer satisfaction with reference to service performance, availability, and quality. A balanced scorecard that incorporates OEE provides a visual representation of overall business productivity. These metrics provide a comprehensive perspective that is in line with production goals, increasing efficiency and decreasing waste. OEE's many uses demonstrate how important it is as a flexible instrument for accomplishing and displaying important production goals in a range of corporate settings. In a case study, **Ali and Changiz (2017)**, explored the impact of value stream mapping (VSM) on overall equipment effectiveness (OEE). They found that VSM in lean production enhances value-creating time by reducing errors, losses, and lead times, enabling better risk control, cost reduction, and product quality improvement. A survey evaluated factors affecting OEE and VSM, showing that VSM improvements positively impacted OEE. Implementing and adjusting suggested changes improved production processes, reduced costs, and enhanced quality, satisfying customers. When reviewing OEE measurement, **Muchiri and Pintelon (2008)**, noted how it evolved to include terminology like TEEP, PEE, OPE, OAE, and OFE to account for additional production losses. To bring theory and practice into line, they put forth a three-level framework: equipment-level effectiveness (OEE), operational-level effectiveness (TEEP), and business-level effectiveness (OAE/OPE). This paradigm takes into account non-operational causes, external variables, business difficulties, and planned downtime in addition to availability, performance, quality, and planned downtime. It gives you the freedom to customize particular losses and gives you all the information you need to make wise decisions. **Jaquin et al. (2020)** used the plan-do-check-act cycle in a case study to raise OEE on a progressive press machine. They discovered that the 600T press machine's initial OEE was 60.7%, 9.3% below the company's aim of 70% and the World Class Manufacturing norm of 85%. Since availability (AV) accounted for 63.3% of the total, efforts were directed at improving AV. Following the adjustments, OEE rose to 65.3% and AV reached 67.8%. This illustrates how well-targeted initiatives can solve problems and improve the overall effectiveness of equipment. The study emphasizes a strategic approach to problem-solving, with a focus on identifying the underlying causes of issues and developing specialized fixes to maximize machine performance and fulfill organizational goals.

In their study on maximizing OEE, **Relkar and Nandurkar** emphasized the value of dependable machinery in the cutthroat industry of today. They calculated and examined OEE for vital equipment that makes vehicle parts. The study emphasizes the significance of OEE as a crucial indicator of machinery efficacy and the effects of its constituent parts. Noteworthy OEE improvement is possible if performance rate enhancement is the primary goal. Availability (95%), Performance Rate (77%), and Quality Rate (99%) are the optimized values for 72.41% OEE. For industry practitioners seeking to maximize equipment performance and overall effectiveness, these studies offer practical insights. OEE and process capability (PC) indicators were analyzed in connection to each other by **Reyes et al. (2010)**. Their results show a direct and positive relationship between PC and OEE, highlighting the favorable influence of PC improvements on overall efficiency. But the analysis shows that PC's impact on the quality factor only becomes noticeable when the Cp/Cpk ratio is less than 0.8. Beyond 0.8, Cp/Cpk improvement actions have little effect on machine quality or overall efficacy. The study challenges the widely accepted belief that 1.33 is the "ideal" OEE target and suggests a Cp/Cpk value of 0.8 as the appropriate goal for production or process managers.

In a case study published in **2019**, **Richa Sharma** examined OEE measurement of TPM manager model machines in a flexible production setting. OEE was highlighted in the study as a critical indicator of overall operational performance. In a semi-automated machine shop that adhered to the TPM Master Plan, it analyzed three TPM manager model machines and found losses that had an impact on productivity. OEE increased

from 63% to 74.3% as a result of successful TPM activities that addressed problems including small stoppages and CNC machine updates. The research successfully reduced the main causes of OEE decline—set-up adjustment loss, alignment issues, and minor stoppages—by collaborating with TPM pillars and using systematic procedures. In a variable manufacturing setting, OEE monitoring and loss assessment were useful for starting improvements and improving overall plant efficiency. OEE and Equipment Effectiveness (E) in the semiconductor sector were assessed by **RON and Rooda (2006)**. Although they acknowledged that OEE was widely used, they emphasized that E was a deliberate technique designed to address OEE's faults. Unlike OEE, which utilizes total time, E bases its assessment of availability, speed, and quality losses on available effective time. It is not impacted by equipment utilization like OEE and is specifically created for standalone equipment that is independent of the environment. It is measured directly by production and effective time. Crucially, E correctly captures the effects of rework and downtime—areas in which OEE is deficient.

Dorota and Katarzyna (2018) looked at advancements in OEE calculation techniques. They came to the conclusion that making internal improvement comparisons easier is possible by using a standard computation approach. Though most firms find it difficult to achieve perfection in OEE models that put it at over 85% techniques such as TPM can improve OEE. Comparing your company to competitors becomes more difficult when you play about with the OEE calculation by factoring losses into the planning process. The method is made more complicated by the authors' suggestion of using a weighted OEE calculation.

Gabahne et al. (2014) carried out a case study at Narke Electricals case study, a plastic manufacturing firm, for OEE improvement in case of injection moulding machine and the result showcases a Lean Six Sigma project significantly enhancing an injection molding machine's OEE by 5% to reach 67%, leading to an annual earnings boost of Rs.2.04 lakhs. The company gained a competitive edge by systematically focusing on OEE parameters—Availability increased from 82% to 87%, Performance from 77% to 79%, and Quality held steady at 98%, collectively contributing to the OEE increase. The increased OEE resulted in significant annual savings of approximately Rs.2.04 lakhs.

III. METHODOLOGY

Determining Overall Equipment Effectiveness (OEE) involves systematic consideration of Availability, Performance, and Quality factors. Data collection encompasses parameters like Operating time, Downtime, Working Shift, Working Speed, Actual Output, Good Output, and Rejected Output. Implementation of OEE methodology follows a structured approach involving:

1. Theoretical Platform:

- (a) It includes data collection and defining parameters such as Planned production time, Actual operating time, Downtime reasons, Production counts, Ideal cycle time, Good and defective units produced etc.
- (b) Utilize tools like Manufacturing Execution Systems (MES), sensors, or manual logs for accurate real-time data capture.

2. Experimental Research:

- a) Employ a quasi-experimental research design to assess the impact of OEE implementation.
- b) Conduct baseline measurements of critical operational metrics before OEE practices implementation.
- c) Introduce OEE methodology systematically into production processes, including personnel training and performance monitoring.

3. Finding OEE:

It involves identification of vital parameters machine component which clearly define the specific equipment OEE calculation which includes:

- a) **Availability (A):** Calculate operating time and downtime.

$$A = \frac{\text{Operating Time} - \text{Down Time}}{\text{Operating Time}} \times 100\%$$

- b) **Performance (P):** Assess actual output compared to rated output. It is expressed as

$$P = \frac{\text{Actual Output}}{\text{Rated Output}} \times 100\%$$

- c) **Quality (Q):** Evaluate good count compared to total count. It is calculated by formula

$$Q = \frac{\text{Good Count}}{\text{Total Count}} \times 100\%$$

- d) **Total Count Calculation:** Sum total production units during a specified time period.

- e) **Good Count Calculation:** Assess units meeting quality standards

- f) **Overall Equipment Effectiveness (OEE) Calculation:** Use the calculated values of Availability (A), Performance (P), and Quality (Q) to find the Overall Equipment Effectiveness using the formula:

$$OEE = A \times P \times Q$$

Where A= Availability,
P= Performance
Q= Quality

IV. OBSERVATIONS

During the thesis research, data pertaining to industrial equipment was provided, which invoked first hand insights into pick fill seal machines used in agrochemical packaging. The visit revealed the technological sophistication and operational versatility of these machines. Data was collected during the visit from the production line for analysis.

Table 1 Machine Operational Information

Machine Name	PFS Machine (Pick- Fill- Seal Machine)
Machine Rated Speed-	20 Pouches per Minute @ 1Kg (SKU) Pouch
Operating Time	20 Hours/Day
Timing	10 Hours (Day- Shift) + 10 Hours (Night- Shift)
Downtime Category	Planned/Unplanned
OEE	Availability (%) × Performance (%) × Quality (%)
Availability Factor	$\frac{\text{Operating Time} - \text{Downtime}}{\text{Operating Time}} \times 100$
Performance Factor	$\frac{\text{Actual Output}}{\text{Rated Output}} \times 100$
Quality Factor	$\frac{\text{Total Output} - \text{Rejection}}{\text{Total Output}} \times 100$

Table 2: Machine data and calculation of PFS of 1 Kg

Time Period	Operating Time (min)	Downtime Planned (DP) (min)	Downtime Unplanned or Breakdown maintenance (DU) (min)	Total Downtime (D) D=DP+DU (min)	Rated Output (R) (pouches)	Total Output (T) (pouches)	Rejection (R) (pouches)	Actual Output (G) T - R (pouches)	Availability (A) (%)	Performance (P) (%)	Quality (Q) (%)	OEE (%)
Jan to June 21	180000	5760	1200	6960	3600000	3001300	800	3000500	96.13	83.347	99.973	80.102
July to Dec 21	180000	5760	1190	6950	3600000	3001250	900	3000350	96.14	83.343	99.974	80.077
Jan to June 22	170000	5000	1170	6170	3600000	3001400	750	3000650	96.37	83.351	99.975	80.305
July to Dec 22	170000	5000	1160	6160	3600000	3001420	740	3000680	96.38	83.352	99.976	80.315
Jan to June 23	170000	5000	1100	6100	3600000	3001420	720	3000700	96.41	83.353	99.976	80.34
July to Dec 23	170000	5000	1090	6090	3600000	3001440	710	3000730	96.42	83.361	99.977	80.358

V. GRAPHS

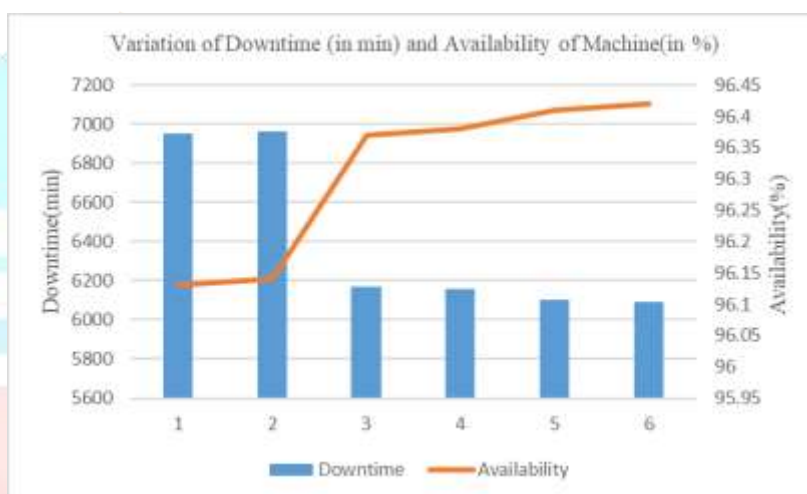


Figure 2 Graph showing variation of Machine downtime with its availability

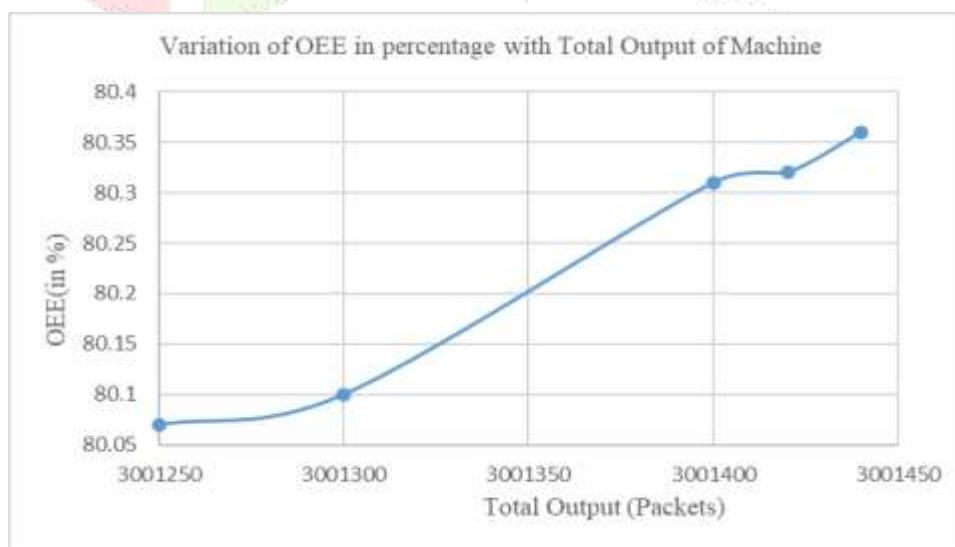


Figure 3 Graph showing variation of OEE in percentage with the total machine output

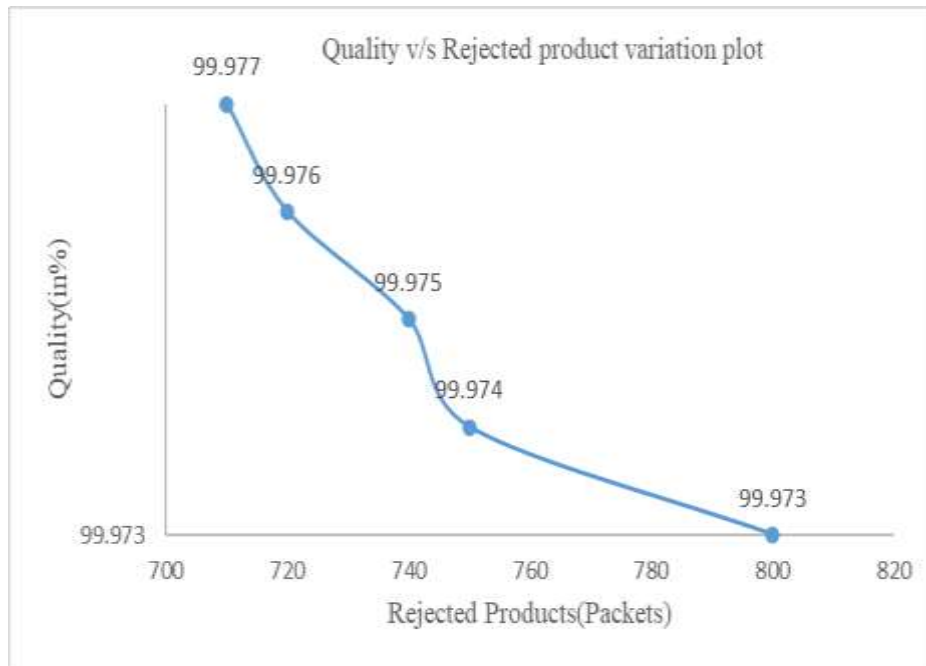


Figure 4 Graph showing variation of Quality produced in percentage with the total amount of rejected products.

VI. CONCLUSIONS

The research work primary focused on finding overall equipment effectiveness of sealing machine issues were frequent unplanned downtimes and suboptimal operating speeds. Implementing preventive maintenance and optimizing operating parameters are recommended to improve efficiency. From the calculations it was revealed that

1. The availability increases with the decrease in the downtime.
2. Low the rejection rate, more is the quality achieved in the final product
3. Performance of the machine was also enhanced with the deduction in rejected products.
4. It was revealed that with change in the total downtime, the output was enhanced.
5. OEE depends on the availability and the performance along with quality of products produced by machines.

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