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The Role of Total Productivity Maintenance In Improving The Overall Equipment Efficiency: A Case study

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Abstract

The study's purpose is to analyze the working efficiency of the machines and determine the proposed improvement. This study was conducted using four steps, namely, determining the level of machine effectiveness , determining the value of losses affecting the low level of effectiveness, using Pareto schemes to determine the most widespread losses, identifying the proposed improvements, and then calculating the value of the six losses again and analyzing them through the Pareto chart. From this study, the effectiveness of the machine is still below the global level, which is 32.87%, as the most common losses are Breakdown Losses 39,40%, and the problems that were found are caused by non-adoption of preventive maintenance, lack of operator skills, and the proposed improvement is through the adoption of maintenance programs Preventive, cleaning and continuous inspection of machines, and increasing the skill of workers through training programs and adoption of continuous improvement teams.

Introduction

To gain competitive advantages, industrial companies are interested in providing excellent reliability and quality of their equipment at competitive prices, in order to own highly reliable machines to make manufacturing processes smooth. Many organizations have implemented Total Productive Maintenance (TPM) as a tool that enables them to maximize equipment efficiency. Maintenance and its management have moved from being a "necessary evil "to being of strategic importance to most competitive organizations around the world (Tsarouhas, 2018(

Total Productivity Maintenance (TPM) is widely recognized as a strategic instrument to improve production performance and increase the efficiency of its facilities. TPM was originally introduced as a set of practices and methodologies aimed at producing performance optimized equipment that improves productivity, as maintenance is an essential and necessary part of the job. TPM describes the synergistic relationship between all organizational functions, especially between production and maintenance, to continuously improve product quality, operational efficiency, productivity and safety. It is an indispensable strategic initiative, as it meets the requirements of customers concerned with price, quality and delivery time. Almost all industrial production processes are carried out with the help of machines, and as a result every production organization depends to a large extent on its mechanisms, for when there is a breakdown or long-term stoppage of important machinery, equipment or tools, this will have far-reaching consequences for the total production (Ahuja, 2006: 581-582 .(

Methodology

1. Study Problem

The presence of many unplanned stops in the smoothing section, for a period of seven days from a month, was chosen randomly.

2. Study Importance

This study derives its importance from the fact that it focuses on improving the overall equipment efficiency (OEE) in the smoothing department of the Modern Paints Company using TPM approach. The focus will be on the product of oily paints, where the process of producing oily paints goes through four main stages: (milling, Smoothing, mixing and coloring, filtering and filling.(

3. Study Objectives

The main objective of the study is to determine the main stopping losses in order to examine and improve OEE of the smoothing phase in the oil paints industry, by applying TPM approach based on one of its pillars, Kaizen, which is a strategic instrument for continuous improvement, and the main contributions of the current study can be identified: .

- Calculating OEE in the current situation, through which it is possible to determine the main stoppage losses in the smoothing stage.
- Improving OEE by determining the main stoppage losses through the application of Kaizen, which is one of the important pillars of TPM. Then the main stoppage losses were evaluated again and presented through Pareto analysis before and after Kaizen.
- The contribution of this study is an input to organizations regarding OEE, machine maintenance, and improving the skill of operators.

.4 Study Limitations

Spatial Limitations: The study is limited to Al-Zafaraniya Modern Dyes Company.

Scientific Limitations: The study is limited to the role of comprehensive TPM in improving OEE.

- **Theoretical Framework**
- **Total Productivity Maintenance (TPM(**
- **Conceptualization**

TPM represents one of the methods of critical importance in order to improve performance in a manner that ensures the progress of the production process by maintaining the organization's equipment in order to provide the required performance, as well as achieving the expected quality of the product, and reducing production costs and equipment failures to the lowest level (Kiki, 2011). Nakajima (1988) Defines it as an innovative maintenance approach that improves equipment efficiency, eliminates faults, undertaken by all working personnel. Rhyne (1990) indicated that it is a link between maintenance and productivity functions in the organization to improve product quality, reduce waste, reduce manufacturing costs, continue equipment work, and improve maintenance in the organization. Ginder et al. (1995) said that it is an improvement methodology based on production, namely designed to improve equipment reliability and ensure effective management of factory assets. TPM can be viewed as a philosophy that includes the entire organization, which increases levels of knowledge, performance, efficiency and teamwork in every area (Sun et al. 2003). Stephens (2004) determines that TPM is not a maintenance program in itself, but rather a team management program through the collection and development of concepts of continuous improvement and total quality in addition to empowering working personnel to achieve defects and zero stoppages. Das et al. (2014) points out that maintenance management approach focuses on engaging all members of the organization in improving equipment, and it consists of a variety of methods, known for the experience of effective maintenance management in improving reliability, quality and production. Arslankaya and Atay (2015) define it as a combination of preventive maintenance activities and a comprehensive quality management philosophy to create a comprehensive productive maintenance culture by providing integration with maintenance, engineering and management units to ensure that individuals protect the equipment and machinery they use and ensure that the machines work is always correct. Jin et al. (2016) view TPM as one of the ways to preserve equipment or machines in cooperation with OEE. Some researchers regard it as a strict maintenance strategy, to be used as an approach to improving equipment performance by avoiding equipment failure and achieving communication between operators, maintenance staff and engineers is very important (Ahmad et al., 2018: 32). Pascal (2019: 86) notes that TPM aims to “bring the two functions (production and maintenance) together through a set of good business practices, teamwork, and continuous improvement”. Its promise (Díaz-Reza et al., 2019: 5-6) is a philosophy, because it requires full commitment from all hierarchical levels of the organization, which symbolizes teamwork and high coordination of activities between management, production and maintenance areas, where TPM represents the result of effort, teamwork, communication and technology. Thorat and Mahesha (2020: 1508) indicate that it is an approach that aims to increase access to existing tools and thus reduce the need for capital participation in the future. The investment in human assets shows better hardware consumption, better product quality and lower labor costs. Meca et al. (2020: 1) explain that TPM focuses on increasing equipment performance to the maximum, establishing a productive maintenance system that improves its life cycle, contributes to continuous improvement and availability, and avoids early equipment failure and contributes to keep it running. Based on the above definitions and opinions of researchers of the concept TPM, it can be defined as “one of the lean production tools, which is a methodology for continuous improvement and a systematic approach to managing machines and equipment, focusing on the participation of individuals at all levels in the organization in diagnosing and solving problems, as it creates flexibility in work by eliminating all equipment faults and interruptions, as well as reducing production time and improving OEE.

- **TPM Objectives**

TPM focuses on achieving several goals: (Abdelali, 2011: 102(

- Maximizing OEE
- Implementing a comprehensive planned maintenance system over the life of the equipment
- Engaging all departments of maintenance, operation and engineering affairs in the comprehensive productive maintenance operations

- •Engaging all levels of workers, engineers and managers
- •Encouraging self-maintenance and small group activities.

Poduval et al. (2015: 310) see it as eliminating machinery breakdowns, unplanned downtime, waste, workforce inefficiency and accidents. It defines OEE losses and classifies them into three factors: quality, availability, and performance.

•TPM Advantages

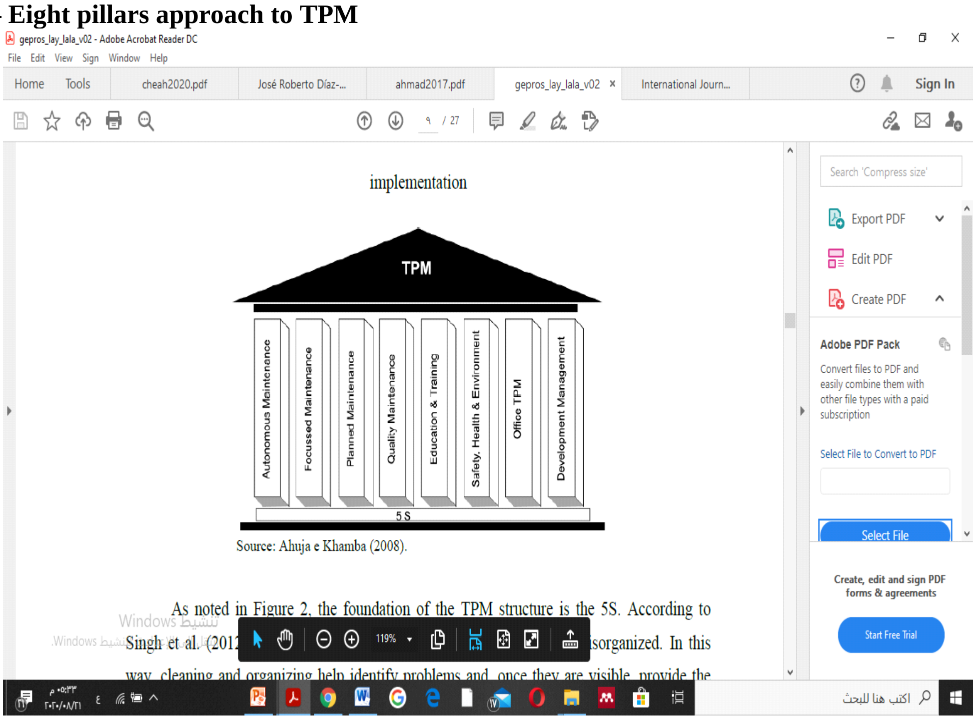
Hart (2010: 1) and Panerue (2011: 23) see that its application includes several benefits, including:
-Reducing operating costs
-Reducing machine faults to a minimum
-Achieving the optimum use of equipment and machinery
-Increasing equipment reliability
-Engaging workers in implementing maintenance work and increasing output
-Focusing on preventive maintenance and avoid unexpected time wastes

TPM can be referred to as a manufacturing strategy that includes the following steps: (Nakajima, 1989:(

- •Maximizing equipment efficiency by improving equipment availability, performance, and product quality
- •Establishing a strategy for preventive maintenance for the entire equipment life cycle
- •covering all departments such as planning and maintenance departments
- •Engaging all staff, from senior management to store workers
- •Promoting maintenance improvement through small group with self-government activities

Through the in-depth study conducted by Ahuja and Kahmba (2008) about TPM, the program was represented in eight basic pillars in line with what is proposed and promoted by the Japan Institute of Plant Maintenance (JIPM), as shown in Figure 1 below:

Figure 1 – Eight pillars approach to TPM



Source :Ahuja, I. P. S &,.Khamba, J. S., (2008), Total productive maintenance: literature review and directions .*International journal of quality & reliability management* ,v. 25, n. 7, p. 721

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TPM substrates can be illustrated by the following:

- •Autonomous Maintenance (AM): It is based on the concept that operators taking care of the small maintenance tasks, with technical maintenance personnel focusing on higher value activities and technical repairs. In other words, equipment maintenance enables a high level of productivity. Therefore, it is the responsibility of the operators to monitor their equipment during daily activities to prevent it from malfunctioning or stopping (da Silva & de Souza. 2020: 300). Moreover, AM aims to achieve a sense of belonging to the operator (Shinde and Prasad 2017), as this greatly reduces losses with operators being in charge of his operations since they have been trained and qualified for these jobs (Morales Méndez and rodriguez 2017). The aim of this type of maintenance is to increase the operators' awareness of their responsibility for his work equipment through independent maintenance activities. Among the activities that the operator must perform are simple tasks such as cleaning, lubrication, visual inspection, re-tightening and other things (Singh et al. 2013); so the primary goal of AM is to stimulate operation and maintenance teams, in a joint way, to reach To the common goal of restoring and maintaining the basic condition of equipment by stopping its deterioration. AM also aims to spread practical knowledge about equipment functions and common problems and to find solutions to those problems in order to find appropriate improvements. Finally, AM contributes to the operation of equipment without interruption and elimination of defects through the active participation of operators (da Silva & de Souza. 2020: 300.(

- Focused Maintenance (FM): The aim of FM is to propose improvements through managing equipment operation information by means of improvement groups to eliminate losses, as well as systematically identify and eliminate losses. Therefore, with this support, the organization is developing a loss mitigation framework by using specific tools. Improvements suggested by improvement teams contribute to increasing OEE and operations by eliminating waste. This continuous improvement cycle corresponds to two other points supported by focused maintenance which is the achievement of improving system efficiency and OEE for production systems (da Silva & de Souza. 2020: 300-301.(
- Planned Maintenance (PM): Since AM includes the simplest maintenance tasks by operators, the most complex and technical tasks are under the responsibility of maintenance through PM. It aims to make machines and equipment free from faults and production at the level of quality required to satisfy the customer (da Silva & de Souza. 2020: 301). Where a prior plan is developed to avoid the occurrence of faults by preparing technicians and operators and training them in the PM activities, which leads to the machine being in a state of readiness and in its normal condition (Raut & Raut, 2017: 1036). PM with maintenance practices and techniques such as preventive maintenance, time-based maintenance (TBM), condition-based maintenance (CBM), and corrective maintenance (CM) (Jasiulewicz-Kaczarek 2016.(
- Quality Maintenance (QM): It focuses on achieving zero defects, tracking and remedying equipment problems, root causes, and survey conditions (machine, labor and materials) that affect product quality (Ahuja and Khamba, 2008: 722). QM strives to keep equipment in good working conditions, delivering high quality products to customers through flawless manufacturing (Panneerselvam 2012). Quality management activities determine equipment conditions that prevent quality defects based on the basic concept of maintenance on ideal equipment to maintain ideal product quality (Díaz-Reza et al., 2019: 14.(
- Education & Training: This is essential as it provides an initial understanding of TPM, followed by an understanding of correct operations, operating machines, and stringent standards (Morales Méndez and rodriguez, 2017). For Netto (2008), it is responsible for controlling the knowledge of everyone involved in TPM activities, operators, supervisors, and leaders. Therefore, education and training are essential to achieve the goals proposed in TPM, as the change in the behavior of the working personnel, the increase in knowledge about the equipment and the acquisition of new skills in the implementation of the program (da Silva & de Souza. 2020: 302) were highlighted.
- Safety, Health and Environment: The purpose of this focus is to create a safe working environment and surrounding area that is not affected by the operation or any other action (Singh et al., 2012). Ahuja and Khamba (2008: 722) indicate that the objectives of this effort are to prevent accidents and avoid their occurrence, to eliminate the causes of hazards that lead to injuries in the workplace, and finally to eliminate the environmental impacts, and not to adopt unreliable equipment that poses danger to operators and environment.
- Office TPM: It is used to improve productivity and efficiency of administrative functions such as automating processes or procedures. It was developed on the basis of other concepts such as FM, IM, and education and training (da Silva & de Souza. 2020: 304). Ahuja and Khamba (2008: 722) assert that the Office TPM works to improve synergies between different business functions, eliminate procedural difficulties, address cost issues and implement 5S in offices and work areas.
- Development Management: It aims to reduce the time required to start operating new equipment. Moreover, some aspects that it aims to cover at this stage are reducing problems, implementation on time, and improving maintenance of new equipment from the experiences obtained according to the previous team (Abhishek et al. 2014). It also aims to build on previous learning in developing maintenance practices for new systems by reducing the problems that occurred in the current system to avoid their repetition for the new system. (Parikh & Mahamuni, 2015: 128.(

- **Overall Equipment Efficiency (OEE(**

OEE is a measure that supports the strategic outcome of TPM implementation by measuring the degree of waste elimination (Ahuja & Khamba, 2008). According to Domingo & Aguado (2015: 9033) TPM philosophy was launched with OEE standards, which is a tool used to measure machine productivity using three components:

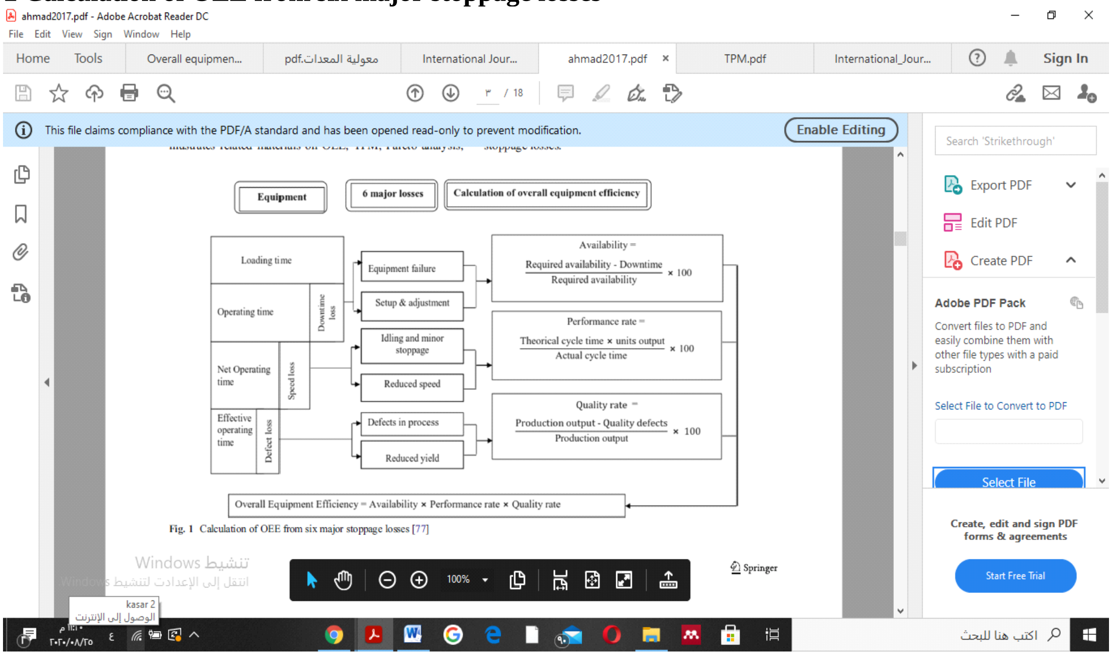
performance, availability and quality. It contributes to identifying potential losses and provides corrective actions that can be used to eliminate them. OEE can be measured on raw materials used in production, personnel and machinery. Williamson (2006) asserts that it is a measure of overall equipment performance, that is the degree to which the equipment does what it is supposed to do, and reveals the hidden costs associated with OEE. It has been widely used in industry for measuring equipment performance (Kumar et al, 2013). According to McDowell & Michaletz (2017), it was introduced with the aim of eliminating all defects and faults in industries, where the intended benefits were higher production, high quality, lower inventory cost, increased workforce efficiency and availability, and it is a measure that uses numbers to measure the productivity of manufacturing machines. This tool measures unknown costs and those that do not apply to machinery (Baumers et al., 2016: 198). OEE is used to determine the efficiency of device operation, and it is one of the most effective measures for the success of the factory improvement process. For the purpose of evaluating the effectiveness of equipment, OEE was developed to be involved TPM. OEE sheds light on the hidden energy in the organization, measures both" doing the right thing "and" doing the right things ,"and can be considered as combining the operation, maintenance and management of manufacturing equipment and resources (Ahmad et al., 2018). Cochran (2017) notes that the OEE is a standardized measurement hierarchy that has been developed to assess how high-volume manufacturing processes can use machines and raw materials effectively in manufacturing processes, which depends on work efficiency, availability, performance and quality. OEE determines how well a production system will perform according to its designed capacity, during the period of operation (Tsarouhas, 2019.(

The evaluation TPM application is done by using the value of the OEE as an indicator and searching for the reasons for the ineffectiveness of the machine by calculating the six large losses to determine the factors affecting the six big losses. By doing OEE calculations, companies will know where they are, their weaknesses, and how to make improvements (Anthony, 2019: 30). Nakajima (1988) has classified losses that reduce equipment efficiency into six major categories:

- •Equipment failure losses: This includes the failure patterns of the normal operation of the equipment and reduce its production rate
- •Setup and adjustment losses: This is the time losses that occur when one item is finished producing and the equipment is modified to meet the requirements of another
- •Losses of minor stoppage and idle: They occur when production is interrupted due to temporary failure or when the machine is idle
- •Losses of reducing speed: They happen because the speed is lower than the nominal speed of the equipment
- •Losses of defect: They include defect losses (or rework) in the process
- •Reduced yield: It is the losses of materials due to differences in the weight of input and output.

Figure (2) illustrates OEE calculation of six major stoppage losses

Fig. 2 Calculation of OEE from six major stoppage losses



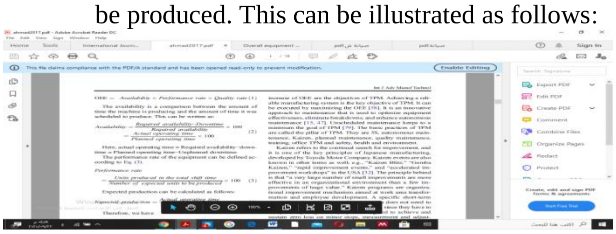
Source- :Ahuja, I. P. S & ,.Khamba, J. S., (2008), Total productive maintenance: literature review and

directions .*International journal of quality & reliability management* ,v. 25, n. 7, p. 725 .

OEE provides quantitative measure to measure efficiency of the performance of individual equipment or entire processes. It is the true measure of value-added production by equipment. OEE is a function of a number of mutually exclusive properties such as availability (A), performance efficiency (PE) and quality rating (Q). It is a three-part analysis tool for performing equipment based on availability, performance and quality. OEE is used to quantify equipment related losses, with the purpose of improving the overall performance and reliability of the assets (Tsarouhas, 2019). Therefore:

OEE = Availability x **Performance** x **Quality**(1)..…..

- Availability is a comparison of time amount a machine produces and time amount that was planned to be produced. This can be illustrated as follows:



OEE = Availability × Performance rate × Quality rate (1)

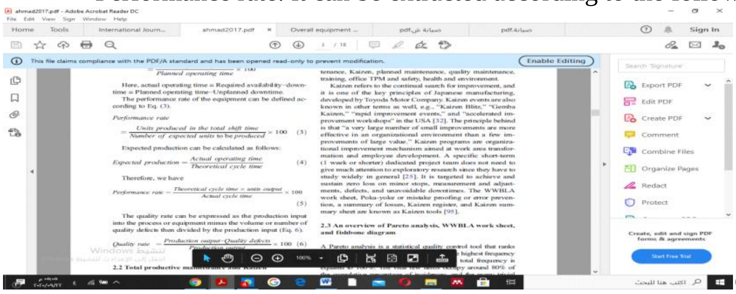
The availability is a comparison between the amount of time the machine is producing and the amount of time it was scheduled to produce. This can be written as:

$$Availability = \frac{Required\ availability - Downtime}{Required\ availability} \times 100 = \frac{Actual\ operating\ time}{Planned\ operating\ time} \times 100 \quad (2)$$

(1) ……………………………………

whereas, Actual Uptime = Required Availability - Downtime = Planned Uptime - Unplanned Downtime.

- Performance rate: it can be extracted according to the following equations:



Here, actual operating time = Required availability−downtime = Planned operating time−Unplanned downtime.

The performance rate of the equipment can be defined according to Eq. (3).

$$Performance\ rate = \frac{Units\ produced\ in\ the\ total\ shift\ time}{Number\ of\ expected\ units\ to\ be\ produced} \times 100 \quad (3)$$

Expected production can be calculated as follows:

$$Expected\ production = \frac{Actual\ operating\ time}{Theoretical\ cycle\ time} \quad (4)$$

Therefore, we have

$$Performance\ rate = \frac{Theoretical\ cycle\ time \times units\ output}{Actual\ cycle\ time} \times 100 \quad (5)$$

The quality rate can be expressed as the production input into the process or equipment minus the volume or number of quality defects then divided by the production input (Eq. 6).

$$Quality\ rate = \frac{Production\ output - Quality\ defects}{Production\ output} \times 100 \quad (6)$$

2.2 Total productive maintenance and Kaizen

tenance, Kaizen, planned maintenance, quality maintenance, training, office TPM and safety, health and environment.

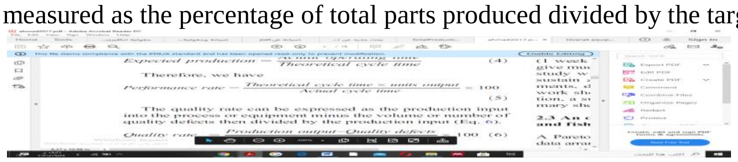
Kaizen refers to the continual search for improvement, and it is one of the key principles of Japanese manufacturing, developed by Toyoda Motor Company. Kaizen events are also known in other terms as well, e.g., "Kaizen Blitz," "Gemba Kaizen," "rapid improvement events," and "accelerated improvement workshops" in the USA [32]. The principle behind is that "a very large number of small improvements are more effective in an organizational environment than a few improvements of large value." Kaizen programs are organizational improvement mechanism aimed at work area transformation and employee development. A specific short-term (1 week or shorter) dedicated project team does not need to give much attention to exploratory research since they have to study widely in general [25]. It is targeted to achieve and sustain zero loss on minor stops, measurement and adjustments, defects, and unavoidable downtimes. The WWBLA work sheet, Poka-yoke or mistake proofing or error prevention, a summary of losses, Kaizen register, and Kaizen summary sheet are known as Kaizen tools [95].

2.3 An overview of Pareto analysis, WWBLA work sheet, and fishbone diagram

(2) ……………………..

Therefore, performance is measured as the percentage of total parts produced divided by the target output.

(3) ………………………



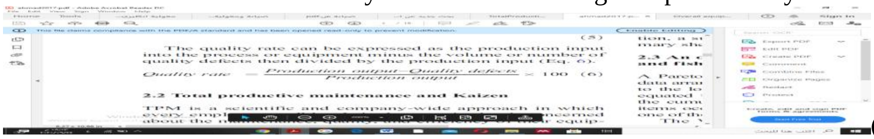
$$Expected\ production = \frac{Actual\ operating\ time}{Theoretical\ cycle\ time} \quad (4)$$

Therefore, we have

$$Performance\ rate = \frac{Theoretical\ cycle\ time \times units\ output}{Actual\ cycle\ time} \times 100 \quad (5)$$

The quality rate can be expressed as the production input into the process or equipment minus the volume or number of quality defects then divided by the production input (Eq. 6).

- Quality rate: Quality is measured based on the percentage of good parts out of the total parts produced on the machine divided by the total number of goods produced by the machine.



The quality rate can be expressed as the production input into the process or equipment minus the volume or number of quality defects then divided by the production input (Eq. 6).

$$Quality\ rate = \frac{Production\ output - Quality\ defects}{Production\ output} \times 100 \quad (6)$$

2.2 Total productive maintenance and Kaizen

(4) ………………

- **Study Applications**

The study was conducted in Al-Zafaraniya Modern Paints Company, for high volume machines and semi-automatic machines in the smoothing department using the TPM approach. The main objective of this study was to improve OEE through TPM. To measure OEE, six major stopping losses across the company were examined. Based on the measured main stopping losses, OEE was calculated and the smoothing section containing the lowest OEE was chosen. Pareto analysis was used to analyze data on stoppage losses and OEE to find out the reasons behind those large losses and the basic steps of the methodology are as follows:

- Calculating OEE characteristics, i.e. Availability, Performance, Quality in addition to OEE from the data. It should be possible to determine the main loss by examining the losses for each of the six classes of losses related to OEE separately.
- Determining the main causes of the six stoppage losses and then making improvements through Kaizen and evaluating the losses before and after the improvement.

- **Results and Discussion**

Information collected about the paint manufacturing processes is used for a 7-day OEE analysis for a period of 7 days in January 2019, which changes with different values of the variables for availability, performance, and quality. OEE here is widely adopted and proven scale is used to monitor the efficiency of pigment manufacturing processes. Factor availability, performance, quality and OEE are calculated for the manufacturing activities for January 2014 using equations (1, 2, 3 and 4) respectively, and OEE results are collected in Table 1.

Table 1: OEE results

Day	1	2	3	4	5	6	7
A Time for each shift (min(	360	360	360	360	360	360	360
B Shift Downtime (min(	0	0	0	0	0	0	0
C Charge time per shift (A − B) (min(	360	360	360	360	360	360	360
D Losses by shift stop (min(	60	30	50	30	40	60	32
E Operating time per shift (C − D) (min(	300	330	310	330	320	300	328
Defective amount (number(	98	108	106	106	110	97	106
F Output per shift (number(	3710	3609	3703	3710	3655	3706	3790
G Quality rates of products(%)	97.36	97	97.14	97.14	97	97.38	97.13
H Ideal cycle time (min(	0.033	0.033	0.033	0.033	0.033	0.033	0.033
I Actual cycle time (min(	0.051	0.053	0.048	0.051	0.053	0.051	0.048
J Actual time (I * F) (min(	189.21	191.28	177.74	189.21	193.72	189	177.12
K speed rate (H/I * (%) (100	64.71	62.26	68.75	64.71	62.26	64.71	68.75
L Net operating rate (J/E * (%) (100	63.07	57.96	57.34	57.34	60.54	63.0	54.0
M Availability (E/C) * (%) 100	83.33	91.67	86.11	91.67	88.89	83.33	91.11
N Performance efficiency (K * L * (100 (%)	40.81	36.09	39.42	37.11	37.69	40.77	37.13
OEE = M * N * G * (%) 100	33.11	32.09	32.97	33.05	32.50	33.08	32.86
Average OEE(%)	32.87						

Table 2 shows availability, performance, and quality values and rates, to be then compared with the global standard, to know the rate achieved by the company, and to determine the main reasons for the company's failure to meet the global standard.

Table 2. Availability, performance, and quality value

Day	**Availability(%)**	**Performance(%)**	**Quality(%)**
1	83.33	40.81	97.36
2	91.67	36.09	97
3	86.11	39.42	97.14
4	91.67	37.11	97.14
5	88.89	37.69	97
6	83.33	40.77	97.38
7	91.11	37.13	97.13
Average	88.02	38.43	97.16

Table 3. OEE value

OEE Factors	Actual Value(%)	World Class Standard (%)
Availability	88.02	90≤
Performance	38.43	95≤
Quality	97.16	99≤
Overall Equipment Effectiveness (OEE(	32.87	85≤

Note from Table 3 that OEE value does not reach the overall level. The low performance value (38.43%) indicates that the performance factor is the furthest factor from the global standard in terms of percentage. It turns out that the performance factor contributes more to the decline in OEE value, so we will calculate the six large losses corresponding to knowing and diagnosing the final causes, as six large losses represent an attempt to determine the factors that provide the largest loss of equipment, as shown in Table 4 and Figure 3. Each factor of the six major losses provides information on downtime, speed and quality losses. Based on Table 4, the value of damage losses is 39.40%, which indicates that the company needs adequate maintenance to overcome the collapse, as shown in Table 4 below.

Table 4. Six big losses value before applying Kaizen

Six Big Losses Factors	Total loss (min(	%	Com. R
Breakdown Losses(%)	119	%39,40	%39.40
Idle and Minor Stoppage(%)	51	%16,89	%56.29
Setup and Adjustment Losses(%)	39	%12,91	%69.20
Rework Losses(%)	35	%11,59	%80.79
Reduced Speed Losses(%)	33	%10,93	%91.72
Yield/Scrap Losses(%)	25	%8,3	%100
Total	302	100.0	

Fig. 3 Pareto diagram for six major stoppage losses before applying Kaizen

By reviewing workflow in the company and interviews with maintenance manager and personnel working in the maintenance division, it became clear that machine maintenance takes place after the occurrence of the failure, which led to the occurrence of many unplanned stops. Therefore, in order to reduce machines stoppage, the company must change its maintenance policy by following preventive maintenance to avoid sudden stops, which leads to work stoppage and the inability of the company to fulfill its obligations towards customers. The company must also prepare a program for education and training for working personnel that enables them to quickly deal with sudden interruptions at work, which contributes to their participation in quality activities through optimization, as operators will be able to improve their skills in basic maintenance tasks such as machine parts cleaning, lubrication, tensioning, checking and basic routine work; as both preventive maintenance program and trained personnel contribute to reducing downtime and work completion times. With all the above steps taken, data were collected again from the smoothing section on the six major stop losses for measurement, analysis, and comparison with the previous setting. Table 5 and Figure 4 illustrate downtime and losses after analyzing the data using Kaizen tools and by developing the training program for operators.

Table 5. Six big losses value after applying Kaizen

Six Big Losses Factors	Total loss (min(	%	Com. R
Breakdown Losses(%)	71	%50.71	%50.71
Idle and Minor Stoppage(%)	22	%15.71	%66.42
Setup and Adjustment Losses(%)	20	%14.28	%80.7
Rework Losses(%)	11	%7.86	%88.56
Reduced Speed Losses(%)	10	%7.14	%95.7
Yield/Scrap Losses(%)	6	%4.29	%100
Total	140	100.0	

Fig. 4 Pareto diagram for six big stop losses post - Kaizen application

Pareto analysis before and after kaizen application helped us to determine the contribution of different factors to OEE of products in the smoothing section. Figure 5 compares stoppage losses in two scenarios, namely, before and after they were reduced. Before and after applying Kaizen, the downtime losses were 302 minutes. Losses reduced to 140 minutes for 7 days.

Fig. 5 Six major losses status pre and post applying Kaizen

Conclusions and Recommendations

Conclusions

1. TPM system doesn't focus only on machinery, but also on workers.
2. Adopting TPM system is both PM and CM policy.
3. OEE section is still below the global standards of efficiency, as it was 32.87%. This proves that machines have not yet reached optimum operation. It can be seen that the obtained OEE value is still below standards (85%.(.
4. By calculating the six losses, the most common loss affecting OEE is Breakdown (39,40%) due to maintenance programs and operator skills lack.

Recommendations

1. The improvement proposal presented by the company's researchers is to make improvements to the approved maintenance programs in the company by adopting preventive maintenance instead of curative maintenance, adopting intensive training programs to improve the skills of operators in each part, adopting quality improvement teams, and reviewing the machine specifications document so that it can be checked before it crashes and stops working.
2. Disseminating TPM principles and concepts among workers with the aim of establishing this philosophy as business strategy needs to established.
3. Training of workers and their participation in specialized courses is key.
4. The research conducted in this study can be applied to other categories of manufacturing industries that can provide them with basic foundations and ideas, as well as practical and management insights for applying TPM approach to improving productivity in the manufacturing setting.

References

Abdul-Aali N. M., (2011), TPM role in Lean manufacturing support. Tikrit magazine of economy and management sciences. Vol 3, issue 21.

Ahmad, N., Hossen, J & ,.Ali, S. M., (2018), Improvement of overall equipment efficiency of ring frame through total productive maintenance: a textile case. The international journal of advanced manufacturing technology, 94(1-4), 239-256.

Ahuja, I. P. S & ,.Khamba, J. S., (2008), Total productive maintenance: literature review and directions. International journal of quality & reliability management ,v. 25, n. 7, p. 709-756.

Ahuja, I.P.S., Khamba, J.S. and Choudhary, R., (2006), Improved organizational behavior through strategic total productive maintenance implementation, Paper No. IMECE2006-15783, ASME International Mechanical Engineering Congress and Exposition (IMECE), November 5-10, Chicago, IL, pp. 1-8.

Al-Kiki M. G. (2011), improving equipment reliability by TPM in Badosh cement factory, Iraqi magazine for management sciences, 7, 70-73.

Anthony, M. B., (2019), Analysis Penerapan Total Productive Maintenance (TPM) Menggunakan Overall Equipment Effectiveness (OEE) Dan Six Big Losses Pada Mesin Cold Leveller PT. KPS. JATI UNIK: Jurnal Ilmiah Teknik dan Manajemen Industri, 2(2), 94-103.

Baumers, M., Dickens, P., Tuck, C., Hague, R.J.T.f & .change, s., (2016),The cost of additive manufacturing: machine productivity, economies of scale and technology-push: 102:193-201.

Cochran, D.S., Foley, J.T. and Bi, Z., (2017), Use of the manufacturing system design decomposition for comparative analysis and effective design of production systems. International Journal of Production Research, 55(3), pp.870-890.

da Silva, R. F & ,.de Souza, G. F. M., (2020), Asset management system (ISO 55001) and Total Productive Maintenance (TPM): a discussion of interfaces for maintenance management. Gepros: Gestão da Produção, Operações e Sistemas, 15(2), 288.

Das B, Venkatadri U, Pandey P., (2014), Applying lean manufacturing system to improving productivity of air conditioning coil manufacturing. International Journal Advanced Manufacturing Technology, 71(1):307–323.

Díaz-Reza, J. R., García-Alcaraz, J. L & ,.Martínez-Loya, V., (2018), Impact Analysis of Total Productive Maintenance: Critical Success Factors and Benefits. Springer.

Domingo, R & .Aguado, S.J.S., (2015), Overall environmental equipment effectiveness as a metric of a lean and green manufacturing system. 7(7):9031-9047.

Ginder A, Robinson A, Robinson CJ, (1995), Implementing TPM: The North American experience. Taylor & Francis.
https://doi.org/10.1007/s00170-013-5407-x

Jasiulewicz-Kaczmarek M., (2016), SWOT analysis for planned maintenance strategy—a case study. IFAC-Papers OnLine 49(12):674–679. https://doi.org/10.1016/j.ifacol.2016.07.788.

Jin, X., Siegel, D., Weiss, B. A., Gamel, E., Wang, W., Lee, J & ,.Ni, J., (2016), The present status and future growth of maintenance in US manufacturing: results from a pilot survey. Manufacturing review, 3.

McDowell, N.G., Michaletz, S.T., Bennett, K.E., Solander, K.C., Xu, C., Maxwell, R.M., Allen, C.D. and Middleton, R.S., (2017), Predicting chronic climate-driven disturbances and their mitigation. Trends in ecology & evolution

Meca Vital, J. C & ,.Camello Lima, C. R., (2020), Total Productive Maintenance and the Impact of Each Implemented Pillar in the Overall Equipment Effectiveness. International Journal of Engineering and Management Research, Volume- 10,Issue-2.

Morales Méndez JD, Rodriguez RS, (2017), Total productive maintenance (TPM) as a tool for improving

productivity: a case study of application in the bottleneck of an auto-parts machining line. International Journal Advanced Manufacturing Technology, 92(1):1013–1026. https://doi.org/10.1007/s00170-017-0052-4.
Nakajima S., (1988), Introduction to TPM: total productive maintenance. Productivity Press.
Nakajima S., (1989), TPM development program: implementing total productive maintenance .Productivity Press, New York
Parikh, Y & ,.Mahamuni, P., (2015), Total productive maintenance: need & framework. International Journal Innovation Res Advanced Engineering, 2(2), 126-130.
Pascal, V., Toufik, A., Manuel, A., Florent, D & ,.Frédéric, K., (2019), Improvement indicators for Total Productive Maintenance policy. Control Engineering Practice, 82, 86-96.
Poduval, P.S., Pramod, V.J.I.J.o.Q & .Management, R., (2015), Interpretive Structural Modeling (ISM) and its application in analyzing factors inhibiting implementation of Total Productive Maintenance (TPM). International Journal of Quality & Reliability Management, 32(3):308-331.
Raut, Niyati & Raut, Swapnail, (2017 ",(Implementation of TPM to Enhance OEE in A Medium Scale Industry ,"International Research Journal of Engineering and Technology (IRJET), 04(05.(
Rhyne D., (1990), Total plant performance advantages through total productive maintenance. In: Conference proceedings APICS, pp 683–686.
Rslankaya S, Atay H., (2015), Maintenance management and lean manufacturing practices in a firm which produces dairy products. Procedia Soc Behav Sci 207:214–224 .https://doi.org/10.1016/ j.sbspro.2015.10.090.
Saif A. A., (2020), Applying TPM in manufacturing performance. Magazine of Humanities and social sciences, issue 3, vol 1.
Shinde DD, Prasad R., (2017), Application of AHP for ranking of total productive maintenance pillars. Wireless Pers Commun. https://doi.org/10.1007/s11277-017-5084-4.
Singh R, Gohil AM, Shah DB, Desai S., (2013), Total productive maintenance (TPM) implementation in a machine shop: a case study. Procedia Eng 51:592–599. <https://doi.org/10.1016/j.proeng. 2013.01.084.<
Stephens MP, (2004), Productivity and reliability-based maintenance management. Prentice Hall.
Sun H, Yam R, Wai-Keung N., (2003), The implementation and evaluation of total productive maintenance (TPM)—an action case study in a Hong Kong manufacturing company. International Journal Advanced Manufacturing Technology 22(3):224–228. https://doi.org/10.1007/s00170-002-1463-3.
Thorat, R & ,.Mahesha, G. T., (2020), Improvement in productivity through TPM Implementation. Materials Today: Proceedings, 24, 1508-1517.
Tsarouhas, P., (2019), Improving operation of the croissant production line through overall equipment effectiveness (OEE). International journal of productivity and performance management.

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