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# COMBINATION OF OEE AND FMEA METHODS TO ANALYZE THE EFFECTIVENESS OF PRODUCTION MACHINES

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## Abstract

Maintenance concepts are required for equipment to maintain effectiveness and quality. One of the maintenance concepts offered is total productive maintenance which connects the synergy between all functions in the organization. In tpm, there is a method to calculate the value of machine effectiveness, namely the overall equipment effectiveness method. The purpose of oee itself is to maximize the output of the results of the available capacity. In this study aims to see the value of the effectiveness of existing machines in the production process. It was found that some OEE values were still below the JIPM level. JIPM itself is the OEE benchmark standard used by the world, jipm explains that the world standard for OEE is 85%. Therefore, it is necessary to improve the maintenance system by using the TPM pillars of autonomous maintenance and training and education.

***Keywords***: *Total Productive Maintenance, Overall Equipment Effectiveness, Six Big Losses, Failure Mode and Effect Analysis, Fish Bone Diagram.*

## 1. INTRODUCTION

In today's modern world, the measurement and existence of productivity and effectiveness are so important that everyone is starting to realize these two things. They are closely related to the world of manufacturing. If we talk about today's economy, the focus is on the customer. In all sectors of activity, competitiveness and operational efficiency are improved in their production processes [1] Every manufacturing facility wants its production systems and equipment to operate and maintain in a reliable mode. However, the world is not ideal: no physical aspect runs perfectly forever in most organizations [2].

The concept of maintenance is necessary for equipment because the effectiveness and quality of production decreases over time and machines may fail more frequently [3]. Maintenance is the activity of maintaining, repairing, cleaning, adjusting, and inspecting the object being maintained [4]. Maintenance is a core function to keep a system running and avoid failures [5]. Total Productive Maintenance is a Japanese concept that extends the concept of preventive maintenance to become more like productive maintenance. TPM describes the synergy relationship between all organizational functions, especially between production and maintenance to make continuous improvement of products, quality, operating process efficiency, productivity, and safety. There are three ultimate goals of TPM, namely zero defects, zero accidents, and zero breakdowns [6].

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The principle of continuous improvement is one of the important approaches to manufacturing, but it also necessitates the application of a considerable number of tools, as shown in Figure 1 [7]. TPM is considered one of the most significant tools that can be used in lean manufacturing [8]. TPM is a maintenance plan used to reduce losses that occur, increase the service life of equipment, and ensure effective utilization of equipment [9]. In addition, TPM can reduce accidents and increase morale for all employees [10]. It is very important to implement TPM principles strategically based on analyzing the causes of equipment failure and proposing targeted improvements [11].

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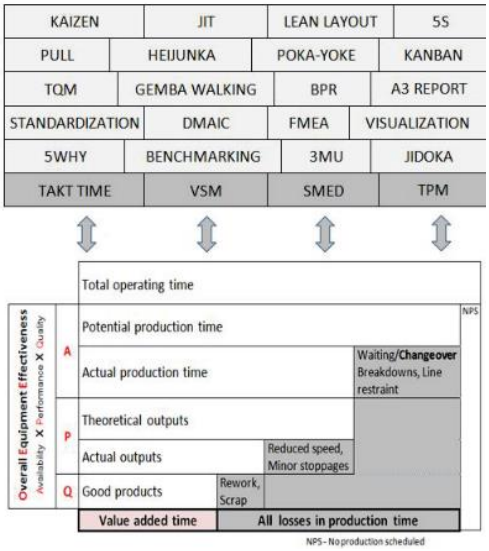


**Figure 1.** Lean Production Tools [7]

In the world of machine maintenance, there are six types of failures that exist and must be avoided by every company called six big losses. Six big losses themselves are categorized into three main categories based on aspects of failure, namely downtime, speed losses, and defects. There is a comprehensive calculation method to identify how high the level of effectiveness of a piece of equipment is called overall equipment effectiveness [12]. The purpose of OEE management itself is to maximize the output of the results of the available capacity [13].

To identify failures, evaluate the effects of failures, and prioritize failures that occur, there is a method that can be used, namely failure mode and effect analysis (FMEA). FMEA is a method used to identify and prevent problems in products and production processes [14]. There is a relationship between the RPN value in FMEA and the OEE value. When the RPN value decreases, the OEE value will increase so that there is a negative change in the RPN value and its parameters lead to positive changes in the OEE value [15]. This study aims to measure the value of machine effectiveness at the NPK fertilizer manufacturing company and identify failures that affect the value of machine effectiveness that occur in the company. it is expected that by knowing the cause of failure, it will be known to suggest improvements in the form of TPM implementation at the company.

# 2. METHODS

## 2.1. Total Productive Maintenance

Total productive maintenance is one of the maintenance strategies originating from Japan. TPM considers all aspects in making efforts to minimize problems in production by involving all parties in the company from top to bottom. TPM itself emphasizes independent maintenance that involves production operators to carry out daily repairs such as cleaning, lubrication, and checking [6]. To achieve its goal of reaching "zero", TPM has eight pillars that can be used or applied to company practices [16]. The eight-pillar strategy motivates workers to apply the concept of zero production losses, zero breakdowns, and minimize production losses by maximizing the effectiveness of equipment, and improving the skills of operators and maintenance personnel [17]. TPM is said to be successful if it can improve the efficiency and effectiveness of the results of maintenance activities in increasing the availability value of equipment and can reduce downtime [18].

## 2.2. Overall Equipment Effectiveness

There are three classifications of losses in OEE, namely downtime losses, speed losses, and quality losses. Each classification of losses is divided into two categories consisting of breakdown losses, setup and adjustment, idling and minor stoppages, reduced speed losses, reduced yield, and defects in process. To find the effectiveness value of the machine, there is a matrix that can be used, namely overall equipment effectiveness (OEE). OEE is a key performance indicator to measure the level of TPM effectiveness in a system [5]. OEE is measured based on the six biggest losses by considering the three OEE parameters, namely availability, performance, and quality [19].

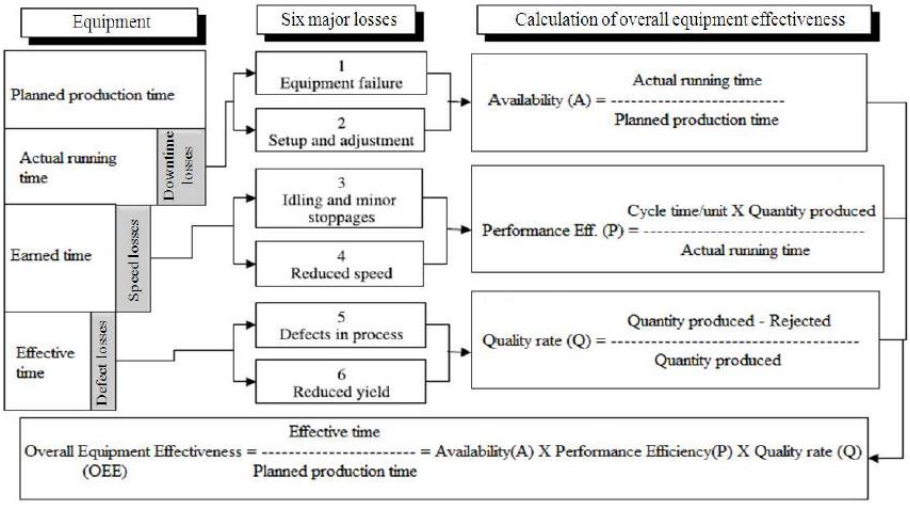


**Figure 2.** Concept of OEE [20]

Figure 2 presents the concept of OEE. Availability considers losses that can cause the stoppage of planned production for a long period of time which includes damage repair, replacement, adjustment, and setup time. Performance considers losses caused by the performance of the production process speed less than the maximum that can be run [5]. For quality is the ability to produce a product that meets the standards [21]. Figure 2 shows the calculation of OEE. In addition, Figure 2 also shows how the relationship between six big losses and OEE, so that if the calculation of six big losses shows a value, the OEE value will also be affected.

## 2.3. Failure Mode and Effect Analysis

FMEA is a systematic mode used to identify and prevent problems in products and production processes [14]. There are three parameters for measuring FMEA, namely severity, occurrence, and detection, which later the three parameters will be multiplied to produce the value of FMEA. Severity represents the magnitude of failure that occurs in an observed system. Occurrence is the probability of a failure occurring [22]. Baghbani et al. [15]conducted research on the relationship between OEE and FMEA output values. It is found that the value of the OEE parameter and the RPN value owned by FMEA have an inversely proportional correlation or negative relationship. This means that a decrease in the value of the RPM parameter owned by FMEA causes an increase in the value of the OEE parameter owned by the machine.

$$RPN = severity\ x\ occurrence\ x\ detection \quad (1)$$

## 2.4. Research Methodology

Observations were made at a company that produces NPK fertilizer where the demand for fertilizer is very high due to high demand. The initial step of the research was carried out by observing the production process of making NPK fertilizer in the Company in order to see the actual conditions that exist in the Company. Taking historical data from the Company needs to be done at this stage for calculations in the next step. Then the data that has been obtained is used as input to calculate the six big losses in order to find out whether there are failures that occur in the production process. If the calculation of six big losses generates an output in the form of a value then there is an indication of a failure that affects the value of machine effectiveness. This shows that it is necessary to calculate the effectiveness value using the OEE method.

Before calculating the OEE value, it is necessary to calculate the three OEE parameters first, namely availability, performance, and quality. The values of the three parameters will be multiplied to produce an OEE value. The value obtained will be compared with the world standard owned by JIPM to find out whether the results obtained are lower or have met the predetermined standard. When the result is below the JIPM value, it is necessary to find the root cause of the failure on the machine. From the causes of failure that occur will be given a weighted value using the FMEA method where each cause of failure will be ranked from three parameters namely severity, occurrence, and detection. Giving this weight score is to see which causes are most influential on the value of machine effectiveness. The last step is to make improvements to the causes of failure that occur using the application of TPM as an improvement plan. Figure 3 shows how the steps are carried out in processing the data in this paper.

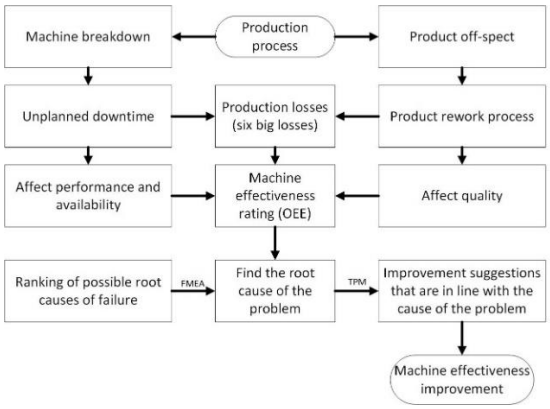


**Figure 3.** Research Flowchart

## 3. RESULTS AND DISCUSSION

The first step is to calculate the value of the six main failure categories. The data needed are loading time, operating time, breakdown, setup time, ideal cycle time, process amount, defects and scrap. Loading time is all the available time that can be used to carry out the production process. Meanwhile, operating time is the time used to carry out production.

**Table 1.** Results of six big losses of rotary dryer

| Year | Month | Breakdown Losses | Setup and adjustmen | Idling and minor stoppages | Reduced speed | Reduced yield | Defect in process |
|---|---|---|---|---|---|---|---|
| 2022 | January | 0,00% | 0,00% | 0,00% | 33,91% | 2,55% | 2,55% |
| 2022 | February | 0,00% | 0,00% | 0,00% | 33,95% | 1,19% | 1,19% |
| 2022 | March | 0,00% | 0,00% | 0,00% | 33,94% | 1,61% | 1,61% |
| 2022 | April | 0,00% | 0,00% | 0,00% | 33,89% | 0,00% | 3,19% |
| 2022 | May | 1,08% | 0,00% | 0,00% | 36,30% | 3,90% | 3,90% |
| 2022 | June | 0,56% | 0,00% | 0,00% | 33,28% | 4,86% | 4,86% |
| 2022 | July | 0,13% | 1,34% | 0,00% | 33,65% | 6,85% | 6,85% |
| 2022 | October | 0,13% | 0,00% | 0,00% | 33,66% | 6,45% | 6,45% |
| 2022 | November | 1,11% | 4,31% | 0,00% | 32,69% | 6,25% | 6,25% |
| 2022 | December | 0,00% | 0,00% | 0,00% | 33,93% | 1,75% | 1,75% |
| 2023 | January | 0,00% | 0,00% | 0,00% | 33,93% | 2,96% | 2,96% |
| 2023 | February | 0,15% | 0,00% | 0,00% | 33,77% | 2,38% | 2,38% |
| 2023 | March | 0,07% | 0,00% | 0,00% | 36,49% | 2,96% | 2,96% |
| 2023 | April | 0,00% | 0,00% | 0,00% | 33,84% | 5,00% | 5,00% |
| 2023 | May | 0,40% | 0,00% | 0,00% | 33,51% | 2,42% | 2,42% |
| 2023 | June | 0,00% | 0,00% | 0,00% | 33,93% | 1,81% | 1,81% |
| 2023 | July | 0,00% | 0,00% | 0,00% | 33,92% | 2,15% | 2,15% |
| Rata-rata | | 0,21% | 0,33% | 0,00% | 34,03% | 3,43% | 3,43% |

Table 1 shows the results of the values obtained from the calculation of the six big losses. From the calculation it can be seen that in the production process failures occur. From the failures that occur, the reduced speed losses category has the largest average of 34,03%. The second largest failure that occurs is reduced yield. Reduced speed occurs because the machine is operated slower than the maximum speed that can be run. Reduced speed is related to machines, people, and the environment. A possible cause is that the operator does not understand the machine settings. Speed losses are related to the performance factors in OEE. The results from Table 1 are made into cumulative percentages and pareto diagrams to see which contribution of losses is the biggest that occurs. The percentage obtained in Table 1 is then multiplied by the existing loading time value to produce a total time value for each loss that occurs. The results are presented in Table 2 and Figure 4 which show that the largest losses that occur are in reduced speed losses.

**Table 2.** Cumulative percentage of six big losses

| No | Six Big Losses | Total Time | Percentage | Cummulative Percentage |
|---|---|---|---|---|
| 1 | Reduced speed losses | 252943,2 | 82,10% | 82,10% |
| 2 | Defect in process | 25557,984 | 8,30% | 90,39% |
| 3 | Reduced Yield | 25557,984 | 8,30% | 98,69% |
| 4 | Setup and adjustment | 2460,096 | 0,80% | 99,48% |
| 5 | Breakdown losses | 1589,904 | 0,52% | 100,00% |
| | Total | 308109,168 | 100,00% | |

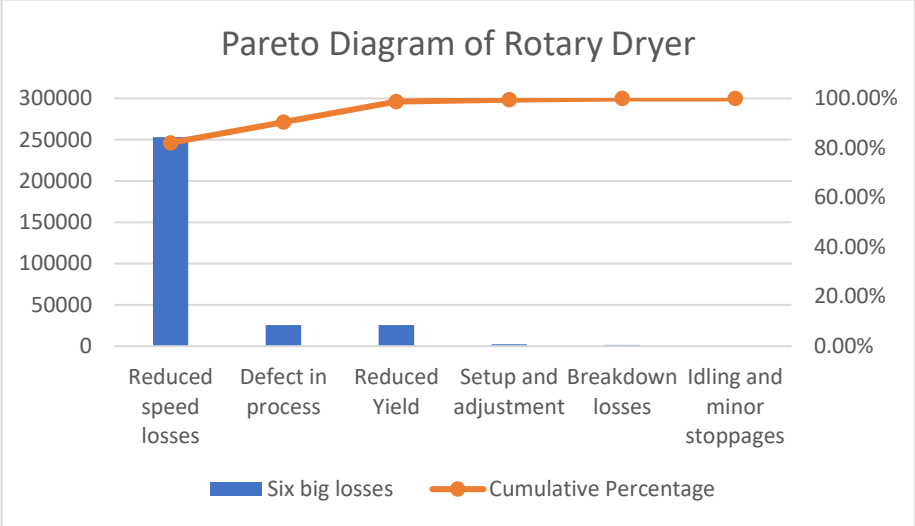


**Figure 4.** Pareto diagram of rotary dryer

Due to the losses that occur so that it can be indicated that there is a disturbance to the value of effectiveness. Under these circumstances, the OEE calculation is carried out by finding the value of the three parameters owned by OEE using the formula listed in Figure 2. Some of the data that are required are loading time, unplanned shutdown, operating time, ideal cycle time, quantity processed, and number of defects. Table 3 presents the data needed to calculate the OEE value parameters.

**Table 3.** Historical data of companies

| Year | Month | Loading time | Unplanned shutdown | Operating time | Ideal cycle time | Processed amount | Defect amount |
|---|---|---|---|---|---|---|---|
| 2022 | Januari | 44640 | 0 | 44640 | 0,4 | 73757 | 2850 |
| 2022 | Februari | 40320 | 0 | 40320 | 0,4 | 66578 | 1200 |
| 2022 | Maret | 44640 | 0 | 44640 | 0,4 | 73725,5 | 1800 |
| 2022 | April | 43200 | 0 | 43200 | 0,4 | 71398,5 | 3450 |
| 2022 | Mei | 44640 | 480 | 44160 | 0,4 | 69887 | 4350 |
| 2022 | Juni | 43200 | 240 | 42960 | 0,4 | 71452,5 | 5250 |
| 2022 | Juli | 44640 | 60 | 44580 | 0,4 | 73901 | 7650 |
| 2022 | Agustus | 44640 | 60 | 44580 | 0,4 | 73880 | 7200 |
| 2022 | September | 43200 | 480 | 42720 | 0,4 | 71497,5 | 6750 |
| 2022 | Oktober | 44640 | 0 | 44640 | 0,4 | 73730 | 1950 |
| 2022 | November | 44640 | 0 | 44640 | 0,4 | 73734,5 | 3300 |
| 2022 | Desember | 40320 | 60 | 40260 | 0,4 | 66614 | 2400 |
| 2023 | Januari | 44640 | 30 | 44610 | 0,4 | 70800,5 | 3300 |
| 2023 | Februari | 43200 | 0 | 43200 | 0,4 | 71457 | 5400 |
| 2023 | Maret | 44640 | 180 | 44460 | 0,4 | 73752,5 | 2700 |
| 2023 | April | 43200 | 0 | 43200 | 0,4 | 71353,5 | 1950 |
| 2023 | Mei | 44640 | 0 | 44640 | 0,4 | 73743,5 | 2400 |
| 2023 | Juni | 44640 | 0 | 44640 | 0,4 | 73757 | 2850 |
| 2023 | Juli | 40320 | 0 | 40320 | 0,4 | 66578 | 1200 |

The formula in Figure 2 is used to find the three parameters, here is an example calculation for January.

$$Availability\ rate = \frac{44640-0}{44640}\ x\ 100\% = 84{,}19\% \qquad (2)$$

$$Performance\ rate = \frac{73757\ x\ 0{,}4}{44640}\ x\ 100\% = 66{,}09\% \quad (3)$$

$$Rate\ of\ quality = \frac{73757-2850}{73757}\ x\ 100\% = 96{,}14\% \quad (4)$$

Furthermore, after the value of the three parameters is known, it will be multiplied to generate the OEE value. Table 4 presents the values of quality, performance, availability, and OEE values resulting from calculations on rotary dryer machines. Figure 5 shows a comparison between the OEE values obtained (red line) and JIPM (blue line). JIPM is a world-class OEE benchmark standard that has been established where the threshold value is at 85%. It can be seen in Figure 5 that some OEE values are still below the JIPM standard value, indicating that the company has problems with its effectiveness value.

**Table 4.** Availability, performance, quality, and OEE values of rotary dryer machines

| Year | Month | Availability (A) | Performance (P) | Quality (Q) | OEE (AxPxQ) |
|---|---|---|---|---|---|
| 2022 | January | 100,00% | 66,09% | 96,14% | 63,54% |
| 2022 | February | 100,00% | 66,05% | 98,20% | 64,86% |
| 2022 | March | 100,00% | 66,06% | 97,56% | 64,45% |
| 2022 | April | 100,00% | 66,11% | 95,17% | 62,92% |
| 2022 | May | 98,92% | 63,30% | 93,78% | 58,72% |
| 2022 | June | 99,44% | 66,53% | 92,65% | 61,30% |
| 2022 | July | 99,87% | 66,31% | 89,65% | 59,36% |
| 2022 | October | 99,87% | 66,29% | 90,25% | 59,75% |
| 2022 | November | 98,89% | 66,95% | 90,56% | 59,95% |
| 2022 | December | 100,00% | 66,07% | 97,36% | 64,32% |
| 2023 | January | 100,00% | 66,07% | 95,52% | 63,11% |
| 2023 | February | 99,85% | 66,18% | 96,40% | 63,70% |
| 2023 | March | 99,93% | 63,48% | 95,34% | 60,48% |
| 2023 | April | 100,00% | 66,16% | 92,44% | 61,16% |
| 2023 | May | 99,60% | 66,35% | 96,34% | 63,67% |
| 2023 | June | 100,00% | 66,07% | 97,27% | 64,26% |
| 2023 | July | 100,00% | 66,08% | 96,75% | 63,93% |
| Rata-rata | | 99,79% | 65,89% | 94,79% | 62,32% |

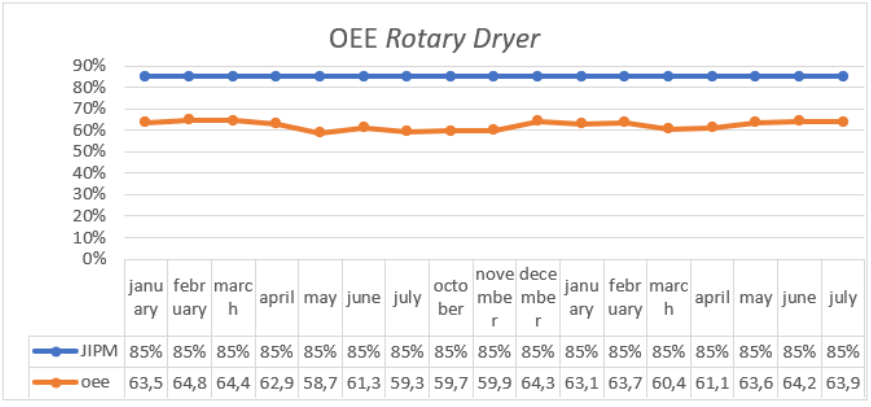


**Figure 5.** OEE rotary dryer

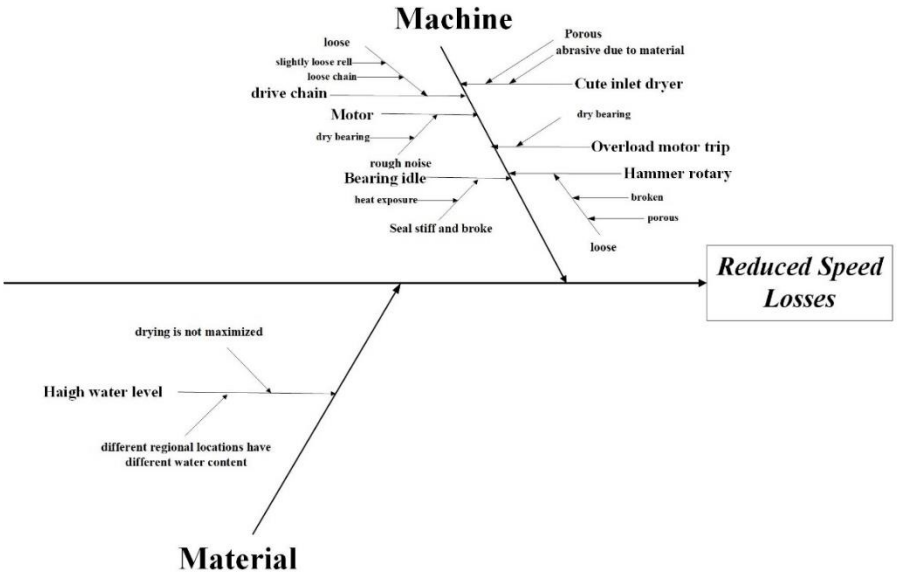


**Figure 6.** Fishbone diagram of rotary dryer

Due to the failure that occurred, it is necessary to find the root cause of the failure to find the main cause that affects. In Figure 6, it is stated that what affects the water level in the final product is the water content of the raw materials at the beginning of production, it is very possible that each raw material received by the Company has a different quality. The quality here is intended to be seen from the water level of the raw material. Because the material has a different water level from each region of origin of the material. This is certainly also a challenge for the Company so that there are no off-spect products from the moisture parameter. The company must do an initial check when the initial raw material is received in order to further monitor if the raw material is processed whether there is special treatment that must be done by the Company. The company must also apply a quality threshold limit for incoming materials. This is done to maintain product quality and avoid the occurrence of off-spect products. The step that can be taken is to make quality standards and acceptable allowances for the quality of raw materials.

From the failures depicted in Figure 6, it shows that there are two things that are the root cause, first from the material factor and the second is the machine factor. From the material factor there are two things that cause. The first is that the water level in the raw material is already high, which will affect the water level in the final product. The second cause is that during the drying process in the dryer, the heat received is not maximized, causing the water shrinkage that occurs is not maximized. This results in the moisture level in the material still being high. In the machine factor that causes the cessation of the production process is the loose drive chain due to the loose chain and slightly loose rell. Another cause is the cute inlet dryer which is porous due to corrosion caused by urea. The heat from the dryer itself also caused bearing damage where the seal became stiff and broke. In the dryer there is also damage to the hammer which is loose due to porous which is finally broken.

From the existing problems, an analysis is needed to assess which root causes most affect the value of OEE. This article uses the FMEA method to see the value of severity, occurrence, and detection of each failure. Table 5 presents the results of the FMEA assessment. The reason for combining the FMEA method here is to give weight to the root cause of failure generated by the fishbone in Figure 6. The highest RPN value indicates the root cause of failure that most affects the production process.

**Table 5.** FMEA result of rotary dryer

| Unit | *Failure mode* | *Effect* | *Potential cause* | *Downtime* | | S | O | D | RPN |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Min | Frequency | | | | |
| Drive chain | loose | Rough noise | Loose chain | 120 | 2 | 3 | 2 | 6 | 36 |
| | | | Loose rell | 60 | 1 | 2 | 2 | 6 | 24 |
| *Cute inlet dyrer* | porous | many materials fall to the floor | porous due to corrosion | 480 | 1 | 8 | 2 | 7 | 112 |
| *Bearing* | *Idle* | Rough noise | seals stiffen and break due to heat | 240 | 1 | 4 | 2 | 6 | 48 |
| Motor | Undue sound | Rough noise | *Drye bearing* | 480 | 1 | 8 | 2 | 6 | 96 |
| *Overload* motor | *Trip* | the drive motor in the engine gets hot | dust ingress | 30 | 1 | 1 | 2 | 5 | 10 |
| *Hummer rotary* | loose | material in the dryer is slightly lumpy | broken, porous | 180 | 1 | 3 | 2 | 7 | 41 |

In Table 5, it is known that the damage with the largest weight value is in the cute inlet dryer unit where the damage is porous due to corrosion. Corrosion itself is caused by the nature of the raw material that is processed corrosive in the form of urea. Due to the corrosiveness of urea causes corrosion. In addition, the company should emphasize preventive maintenance by making an inspection schedule. This is intended to prevent and detect if a problem will occur. Predictive maintenance can also be applied because the situation that occurs is that the machine is used to operate for 24 hours in 7 working days. From the detection value in Table 3, it can be seen that the detection capability in the company indicates that the lack of ability of workers or operators who use the machine to recognize the symptoms of damage.

In a survey conducted at several manufacturing-based companies, it was shown that not only do they not perform the necessary diagnostic of manufacturing equipment as part of maintenance so that they cannot find the types of failures and incidents that will occur but sometimes they do not even make a preventive maintenance schedule. But there are cases where companies have made schedules but are not carried out or do not keep to the planned schedule according to the age of the equipment [23]. Therefore, most companies do not deliberately deal with prevention or diagnostics and keep the maintenance management system at a lower level. The main goal of TPM is to enable companies to be able to use machinery and equipment at 100% for production needs, which represents the perfect condition of production processes and manufacturing devices, where there are no failures, defective products, and no accidents [7].

The long-term goals to be achieved in the application of TPM are to achieve the goals of zero breakdown, zero defect, and zero accident. In addition, it also wants to increase the productivity and stability of the production process, to increase the value of equipment effectiveness and if it can be achieved, it can make cost savings. But for the initial implementation and development of TPM methods in the company, it is necessary to set short-term goals, especially in maintaining the motivation of the employees involved [7]. The short-term goal to be achieved is to reduce downtime and also keep the applied improvements running and carried out by workers so that the improvements made can become a culture that can be consistently carried out with the aim of continuous improvement. In this paper, the pillars applied are autonomous maintenance and training and education in order to reduce downtime and increase the knowledge of workers.

| **Form TPM** | No | |
|---|---|---|
| Machine: | Part: | Name: |
| **Identification card** | Date: | Time: |
| Identification: | | |
| Describtion: | | |

| **Form TPM** | No | |
|---|---|---|
| Machine: | Part: | Date: |
| **Maintenance card** | Start: | End: |
| Identification: | | |
| Describtion: | | |
| Action: | | |
| Name | Management | |

**Figure 7.** Example of TPM card

The first step that can be taken is to clean up the work environment using 5S so that the work environment is not disturbed by materials or tools that should not be in the work environment. The application of 5S itself is also to train workers to organize their work area environment to reduce work accidents. A simple step that can be done is to clean up items in the work environment and eliminate unused objects or tools, besides that, it is done by arranging similar objects or tools so that it does not spend time in searching for tools if needed. In addition, it is also done by returning the tools that have been used to the initial place.

The next step is to conduct training and education regarding the importance of implementing TPM as well as explanation and training about the equipment used by each operator. Detection of the tools that are used is very important if there are early symptoms of failure. In addition to training, operators and employees involved in the production floor are required to know and understand the machines and tools they use so that they can carry out minor repairs and checks that can be carried out every day without exception in order to implement the autonomous maintenance pillar. In the training on detection, it is necessary to conduct training along with how to respond. How to overcome here means that if the abnormality that occurs is a minor disturbance and can be repaired by the operator based on the knowledge gained, it can be handled immediately. But if it is an indication of damage that can lead to severe damage, the operator must directly contact the relevant parties. If there is a characteristic of abnormality that occurs, the operator is required to fill out the form in Figure 7 in the identification card section. And for steps at the time of maintenance, it is hoped that the operator or maintenance party will fill in the maintenance card which will later become a report to management. this can be a record of repairs and can be further analyzed in the future.

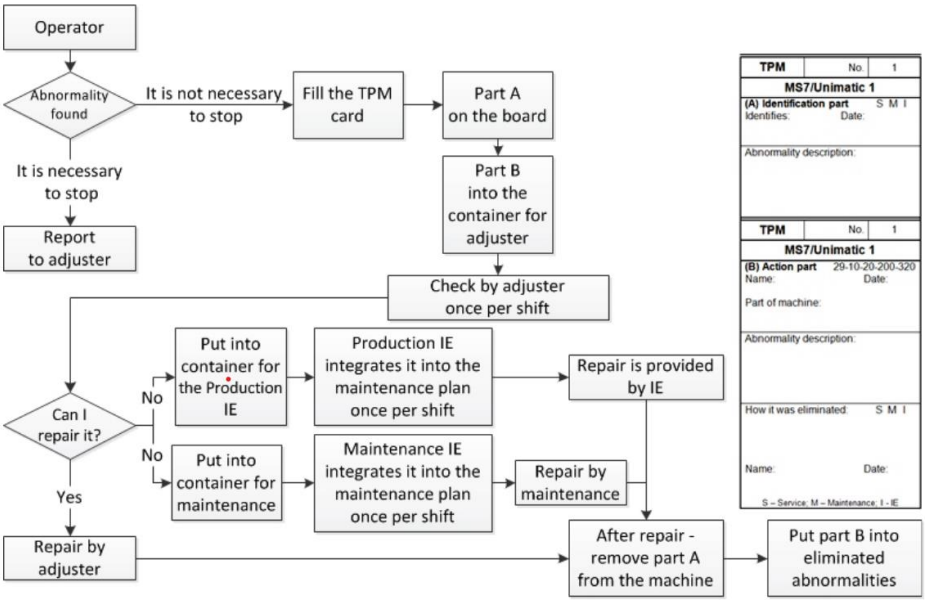


**Figure 8.** Diagram for detecting abnormalities and examples of TPM cards [7]

Research that has proven this was successfully conducted by Schindlerová [7] who implemented TPM with (1) kick-off, (2) TPM workshops, (3) autonomous maintenance settings, (4) TPM device cards and abnormal control, and (5) education training. In the context of maintenance, emphasis is placed on control activities and early recognition of risks based on autonomous maintenance principles. Early detection and documentation of abnormalities that occur can use the TPM card system in Figure 8. By archiving everything that happens, TPM cards can be used as a database of abnormalities that can be further analyzed or tracked in the future. The end result can be reduced technical downtime, improved staff morale, but also their awareness of the effective use of maintenance. n addition, research conducted by [11] states that basic training is carried out with the aim of reviewing the basis of TPM (TPM pillars), managing machine cleaning: handling areas that are difficult to reach, managing small failures such as registration, classification, pareto, root cause problems, and fishbone diagrams, and autonomous maintenance such as 5S, inspection, lubrication, and basic settings.

## 4. CONCLUSION

In the observations made, it was found that there were indications of failure in the rotary dryer machine, this was characterized by the presence of losses in the six big losses. This affects the OEE value of the rotary dryer machine where the OEE results show that the value is below the JIPM standard. Losses with the largest percentage that occur on the machine are the reduced speed losses category. The cause of losses when viewed from the fishbone diagram is due to two factors, namely the machine and material factors. What needs to be done is to provide improvements that can be applied, by applying the TPM pillars. The pillars to be applied are autonomous maintenance and training and education. The purpose of applying the two pillars is to reduce downtime by including operators to participate in maintaining the machine. It is expected that operators can perform simple maintenance on machines such as lubrication, cleaning, and checking. With training and education, operators will be trained to better recognize and understand the machines they use so that if there are symptoms of abnormalities that occur they can detect damage early.

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## REFERENCES

[1] C. Jorge and V. Carvalho, "Plano Estratégico De Manutenção ? Implementação Da Metodologia TPM," 2019. *Accessed*: Dec. 21, 2023. [Online]. Available: https://recipp.ipp.pt/handle/10400.22/14865

[2] L. R. Higgins *et al*., "*Maintenance Engineering Handbook R. Keith Mobley Editor in Chief Seventh Edition*," 2008, doi: 10.1036/0071546464.

[3] Xh. Mehmeti, B. Mehmeti, and Rr. Sejdiu, "The equipment maintenance management in manufacturing enterprises," *IFAC-PapersOnLine*, vol. 51, no. 30, pp. 800–802, Jan. 2018, doi: 10.1016/j.ifacol.2018.11.192.

[4] A. Budi Sulistyo and T. Zakaria, "*Analisis Overall Equipment Effectiveness Mesin Vertical Roller Mill (Vrm) Di Pt. Cemindo Gemilang*," 2019.

[5] A. Zarreh, H. Da Wan, Y. Lee, C. Saygin, and R. Al Janahi, "Cybersecurity concerns for total productive maintenance in smart manufacturing systems," *in Procedia Manufacturing, Elsevier* B.V., 2019, pp. 532–539. doi: 10.1016/j.promfg.2020.01.067.

[6] M. Ben-Daya, S. O. Duffuaa, J. Knezevic, D. Ait-Kadi, and A. Raouf, "*Handbook of maintenance management and engineering*". Springer London, 2009. doi: 10.1007/978-1-84882-472-0.

[7] V. Schindlerová, I. Šajdlerová, V. Michalčík, J. Nevima, and L. Krejčí, "Potential of Using TPM to Increase the Efficiency of Production Processes," *Tehnicki vjesnik - Technical Gazette*, vol. 27, no. 3, pp. 737–743, Jun. 2020, doi: 10.17559/TV-20190328130749.

[8] M. Jasiulewicz-Kaczmarek and A. Saniuk, "How to make maintenance processes more efficient using lean tools?," *in Advances in Intelligent Systems and Computing, Springer Verlag*, 2018, pp. 9–20. doi: 10.1007/978-3-319-60828-0_2.

[9] S. Nallusamy and G. Majumdar, "*Enhancement of Overall Equipment Effectiveness using Total Productive Maintenance in a Manufacturing Industry*," 2017.

[10] Z. T. Xiang and C. J. Feng, "Implementing total productive maintenance in a manufacturing small or medium-sized enterprise," *Journal of Industrial Engineering and Management*, vol. 14, no. 2, pp. 152–175, 2021, doi: 10.3926/jiem.3286.

[11] J. D. Morales Méndez and R. S. Rodriguez, "Total productive maintenance (TPM) as a tool for improving productivity: a case study of application in the bottleneck of an auto-parts machining line," *The International Journal of Advanced Manufacturing Technology*, vol. 92, no. 1–4, pp. 1013–1026, Sep. 2017, doi: 10.1007/s00170-017-0052-4.

[12] O. Taisir and R. Almeanazel, "Total Productive Maintenance Review and Overall Equipment Effectiveness Measurement," 2010. [*Online*]. *Available*: www.jjmie.hu.edu.jo

[13] Y. H. Hung, L. Y. O. Li, and T. C. E. Cheng, "Uncovering hidden capacity in overall equipment effectiveness management," *Int J Prod Econ*, vol. 248, Jun. 2022, doi: 10.1016/j.ijpe.2022.108494.

[14] R. E. McDermott, R. J. Mikulak, and M. R. Beauregard, The basics of FMEA. CRC Press, 2009.

[15] M. baghbani, S. Iranzadeh, and M. Bagherzadeh khajeh, "Investigating the relationship between RPN parameters in fuzzy PFMEA and OEE in a sugar factory," *J Loss Prev Process Ind*, vol. 60, pp. 221–232, Jul. 2019, doi: 10.1016/j.jlp.2019.05.003.

[16] D. Stamatis, "*The OEE Primer: Understanding Overall Equipment Effectiveness, Reliability, and Maintainability*," 2010.

[17] S. Kigsirisin, S. Pussawiro, and O. Noohawm, "Approach for Total Productive Maintenance Evaluation in Water Productivity: A Case Study at Mahasawat Water Treatment Plant," *in Procedia Engineering*, Elsevier Ltd, 2016, pp. 260–267. doi: 10.1016/j.proeng.2016.07.472.

[18] J. W. Tsal, "*Operator Empowerment For Total Prodvcfive Maintenance*," 1996.

[19] C. P. Ahire and A. S. Relkar, "Correlating failure mode effect analysis (FMEA) & overall equipment effectiveness (OEE)," *in Procedia Engineering, Elsevier* Ltd, 2012, pp. 3482–3486. doi: 10.1016/j.proeng.2012.06.402.

[20] K. G. Eswaramurthi and P. V. Mohanram, "Improvement of manufacturing performance measurement system and evaluation of overall resource effectiveness," *Am J Appl Sci*, vol. 10, no. 2, pp. 131–138, Mar. 2013, doi: 10.3844/ajassp.2013.131.138.

[21] R. C. Hansen, Overall equipment effectiveness: a powerful production/maintenance tool for increased profits. Industrial Press, 2002.

[22] M. Catelani, L. Ciani, and M. Venzi, "Failure modes, mechanisms and effect analysis on temperature redundant sensor stage," *Reliab Eng Syst Saf*, vol. 180, pp. 425–433, Dec. 2018, doi: 10.1016/j.ress.2018.08.013.

[23] V. Schindlerová, I. Šajdlerová, and P. Zmeškal, "Implementation of the Principles of Tpm in Field of Maintenance Preparations," *Transactions of the VŠB - Technical University of Ostrava, Mechanical Series,* vol. 62, no. 1, pp. 51–57, Sep. 2016, doi: 10.22223/tr.2016-1/2010.

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