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# TPM Implementation in Ceramic Tile Industry

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*Abstract* — *To increase industrial growth in Indonesia, especially the ceramic tile industry, it must increase productivity on production floors. The purpose of this study is, firstly, to find out the causes of the Overall Equipment Effectiveness (OEE) level in a company that does not meet the expected standards. Second, to determine what improvements should be made to increase the OEE on the packing machine. This research uses a case study in a tile manufacturing industry located in Cikarang, Indonesia. The focus of this research is on packing machines using pneumatic and electric systems. The analysis was carried out by applying Failure Mode and Effect Analysis (FMEA) with the support of other tools such as Cause and Effect Diagrams (CED), and 6 big losses analysis. By adhering to the entire research framework, find the reasons why OEE does not meet the target. From these results, it can be concluded that the application of these methods has a positive impact on the company. The OEE rate increased from an average of 72.5% to 94.5%. It means the OEE level has reached the standard of world-class manufacturing.*

**Keywords** — *Overall Equipment Effectiveness, company productivity, Packing machine, Ceramic tile manufacturing industry.*

## I. INTRODUCTION

A country's economic prosperity and growth indeed depend on the prosperity of its industrial sector. However, as a result of globalization, the manufacturing industry is under constant pressure due to increased competition. To maintain and further develop their competitiveness in the global market, manufacturers develop innovative, high-quality products in the shortest possible time, and robust industrial plants that provide efficient conditions for excellent operation. It is necessary to design a flexible production system (Herlambang, 2020). Due to common challenges, manufacturing companies must continuously improve the performance of their production systems to reduce production costs. This is due to customer demand for year-on-year declines in product prices and increasing cost competition as products gradually mature towards the maturity stage of the product lifecycle. Production services in terms of quality, cost, reliability, and flexibility are defined as performance goals (Febriana et al., 2020). Therefore, it is necessary to flexibly design and operate the production system so that the target performance can always be achieved. Otherwise, there will be a gap between market requirements and manufacturing companies' production capacity, leading to a loss of competitiveness and thus a loss of market share and profitability (Hasbullah et al., 2017). In addition, production approaches should consist of long-term considerations of developing the potential of production systems and assets in conjunction with corporate and business strategy. As the focus on financial, environmental, and social sustainability increases, it becomes increasingly challenging to design and operate production systems more efficiently. Lean manufacturing is a term used by some researchers and companies to describe the goals and means related to resource efficiency in manufacturing (Babu et al., 2016; Seifermann et al., 2018).

In today's production environment, where high-tech and expensive machines/equipment with computer controls and advanced manufacturing concepts are used, with little tolerance for failures of any kind, maintenance management is currently the only goal that is under the highest pressure for Zero-failure (Herlambang et al., 2021). What began as a traditional machine repair/maintenance strategy has now reached the level of Total Productive Maintenance (TPM), the concept of zero downtime. TPM is a maintenance as well as manufacturing program designed primarily to maximize the effectiveness of machinery and equipment through the participation and motivation of all staff and employees (Sukma et al., 2022). TPM itself according to (Prabowo et al., 2018) is the key to the success of each manufacturing optimization strategy because without reliable machines all production/manufacturing optimization programs will not be able to run perfectly. In the world of machine maintenance, there is the term six big losses that must be avoided by every company if it wants to maintain and increase the effectiveness of a machine. The six big losses are usually categorized into 3 main categories based on the aspect of the loss, namely Downtime, Speed Losses, and Defects (Sultoni &

Santoso Saroso, 2019). Many companies are now focused on asset optimization and more efficient use of assets. The main part of a company that has a large impact on assets is the maintenance department or maintenance manager. All machine work is characterized by high productivity and efficiency, maintenance is the employee's responsibility and aims to prevent problems before they occur (Supriyati & Hardi Purba, 2019). PT. Mulia Keramik located in Cikarang, West Java, is a company that produces ceramic tiles. One of the obstacles faced by the company in production is the high downtime of packing machines which causes production disruptions. The effect of this downtime is a decrease in engine speed and performance resulting in a low OEE value. Low OEE results in production-floor results that are not according to plan, lots of products that are rejected and reworked, and lengthy setup and adjustment times (Sunadi et al., 2021). Conversely, a high OEE will be able to increase productivity (Perdana & Santoso, 2019).

Within 3 months (January 2022 – April 2022) found indications of losses in one line (line 4) of the packing machine. This is indicated by the presence of a fairly large total downtime of 160,557 minutes. PT MK itself has only implemented the TPM strategy for several years but has never conducted an evaluation. Based on the background above, the purpose of this research is to: evaluate the application of TPM on packing machines by measuring the OEE value and six big losses and looking for the factors that most influence the high or low OEE.

## II. METHOD

This study was conducted in the ceramic tile industry. The focus of this research is on packaging machines. This type of study involves mixed methods. The design of this study aims to be both descriptive and exploratory. Identify and remediate the root causes of lost machine uptime and downtime. The types of data required for this study are primary data and secondary data. Primary data were collected by FGD by 5 experts: 2 staff engineers, 1 quality control (QC) manager, 1 packaging manager, and 1 packaging supervisor. Primary data is also obtained online from the electronic conversion of production data. Secondary data such as the number of defects, downtime, and total maintenance time were obtained from the literature, previous studies, books, and company reports. This study uses a systematic procedure to ensure that the research is focused and targeted. This research step is divided into:

Step 1:

Describes the symptom of the problem that occurs on the LSP machine. Set research goals to solve the problem. Conduct a literature review on TPM approaches, FMEA, and OEE methods. The study of literature should deepen the theories used as methods of problem-solving.

Step 2:

Analysis of the six main losses for OEE calculation by measuring the loading times used during the study. The loading time formula is:

$$Working\ time = days\ x\ Working\ hours\ x \frac{Minutes}{Hours} \quad (1)$$

The next step is to calculate the base OEE before improving using the following formula:

$$Availability = A = \frac{Loading\ Time - Unplanned\ Downtime}{Loading\ Time}\ x\ 100\% \quad (2)$$

$$Performance\ rate = P = \frac{Idle\ Run\ Time\ x\ Total\ Product}{Operating\ Time}\ x\ 100\% \quad (3)$$

$$Quality\ rate = Q = \frac{Total\ parts - Total\ defects}{Total\ Parts}\ x\ 100\% \quad (4)$$

$$OEE = A\ X\ P\ X\ Q \quad (5)$$

The next step is to use the Excel software to create a Pareto chart from the results of the six major losses analysis. Next, create a fishbone diagram based on the Pareto chart to identify the root causes of the main problems caused by FGD.

Step 3:

FMEA analysis is performed by FGD with five experts. The purpose of FMEA is to determine the primary failure modes based on a Risk Priority Number (RPN) calculated based on occurrence (O), severity (S), and detection (D) risk factors. Score each on an integer scale from 1 to 10 according to expert evaluation. The calculation of RPN is done using equation (6).

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$$RPN = S\ X\ O\ X\ D \tag{6}$$

After the need positioning is known, at that point make advancements by applying the TPM column.
Step 4:

Performing OEE calculations after advancement in Jul–Oct 2021 within the same way within the moment arrange and at long last the conclusions of this inquiry about are obtained.
The modern approach to this investigation is that the sort of machine utilized in analyzing the OEE esteem is the packing machine, whereas the strategy utilized when deciding the RPN esteem with FMEA investigation employments FGD with specialists in their field. But the kaizen strategy will moreover be orderly within the Pareto chart, FMEA, and OEE strategies since it incorporates quantitative investigations and employments FGD and Fishbone graphs which are subjective inquiries. The system can be seen in Figure 1.

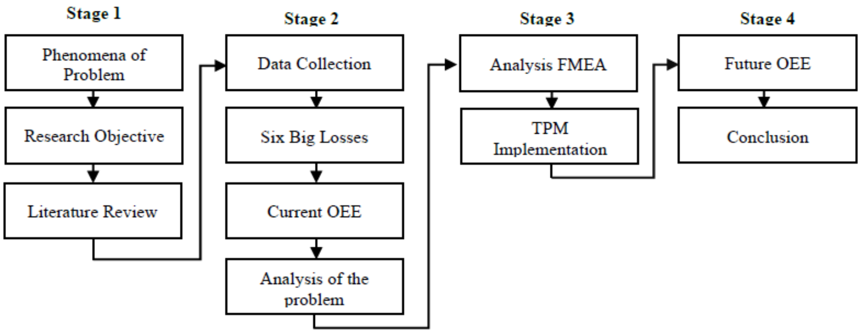


Figure 1. Frame work-study

## III. RESULT AND DISCUSSION

In this area, we'll talk about information collection beginning with estimation stacking time information as the premise for calculating six huge misfortunes. Calculation of OEE esteem information beginning from AR, PE, and QR. At that point to decide the greatest six enormous misfortunes, utilizing the Pareto chart. After the overwhelming issue is known, the Fishbone diagram is utilized to discover the main cause of an issue with FGD assembly was held to decide the need values of the RPN utilizing the FMEA strategy. At long last, the TPM strategy is utilized to decide remedial activities and avoid issues from repeating.

In this study, the six enormous misfortunes of the Packing machine are clarified concurring with the working time misfortune conditions. Breakdown misfortune on a Packing machine may be a time and amount of failure/loss caused by a defective machine that cannot be worked. Whereas the setup is the misfortune of setting and alteration time when the Packing machine warms up before use. Sitting and minor misfortune may be a misfortune when the machine is working due to a shortstop or the method is incidentally hindered. Decreased speed misfortune is the misfortune of time within the patient's treatment preparation due to extra time due to late confirmation. Dismiss misfortune is the misfortune of time due to the patient's treatment comes about being failed/rejected or canceled. Revamp misfortune is the machine working once more due to electrical issues or information isn't put away. This to begin with segment will examine the comes about of the calculation of stacking time carried out amid this inquiry. Calculation of Loading time equation (1). The comes about are summarized in Table 1.

Table I. Loading Time Before Improvement

| Month | Number of working days | Working hours/ days | Minute/ hour | Loading Time (minute) |
|---|---|---|---|---|
| Jan 22 | 20 | 8 | 60 | 10,600 |
| Feb 22 | 19 | 8 | 60 | 10,120 |
| Mar 22 | 22 | 8 | 60 | 10,560 |
| Apr 22 | 20 | 8 | 60 | 10,600 |
| **Total** | **81** | **8** | **60** | **41,880** |

Table II. Six big losses data before improvement

| Month | Downtime Losses | Speed Losses | Quality Losses |
|---|---|---|---|

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| | Breakdown | Setup | Total | Idling & Minor | Reduce speed | Total | Reject | Rework | Total |
|---|---|---|---|---|---|---|---|---|---|
| Jan 22 | 1,765 | 230 | 1,995 | 200 | 125 | 325 | 0 | 0 | 0 |
| Feb 22 | 1,965 | 215 | 2,180 | 210 | 125 | 335 | 0 | 0 | 0 |
| Mar 22 | 1,875 | 245 | 2,120 | 240 | 140 | 380 | 0 | 0 | 0 |
| Apr 22 | 1,670 | 225 | 1,895 | 190 | 115 | 305 | 0 | 0 | 0 |
| **Total** | **7,275** | **915** | **8,190** | **840** | **505** | **1,345** | **0** | **0** | **0** |

Table 1 shows that the packaging machine works 81 days, 8 machine hours, and 60 minutes/hour. The total load time before remediation was 41,880 minutes. Next, we will analyze the six major losses that emerge from the check sheet created by the packaging machine operator. The results of the report are shown in Table 2. Table 2 shows that downtime loss includes a total of 8,190 minutes of downtime loss and setup loss. The speed loss includes idling and minor losses for a total of 1,345 minutes. In the meantime, lost scrap or lost rework means no lost time. Based on the data of 6 severe losses, the data are processed using a Pareto chart. Looking at the Pareto chart in Figure 2, we can see that loss/time loss is the highest breakdown, at 76.3%. Therefore, this default loss is evaluated for improvement. Table 2 means a quality factor of 0 and no scrap. Figure 2 shows that the main problem is downtime, with a very high percentage of 76.3%.

In this section, OEE baselines are calculated using secondary data, i.e. medical annual report data. The data used is from January to April 2021. Using formulas (2), (3), (4), and (5), the OEE before improvement (January sample) is calculated as follows.

$$A = \frac{(10{,}600 - 2{,}995)}{10{,}600}\ x\ 100\% = 71.7\%$$

$$P = \frac{15\ X\ 465}{7605}\ x\ 100\% = 91.7\%$$

$$Q = \frac{640 - 0}{640}\ x\ 100\% = 100\%$$

$$OEE = 79.2\%\ X\ 91.7\%\ X\ 100\% = 65.7\%$$

When calculated using formulas (2), (3), (4), and (5), the OEE value is 72.71%. The values for this calculation are performed using the January sample. A summary of OEE values from January to April 2021 (before improvements) is shown in Table 3.

Table III. OEE Data Before Improvement

| | Jan 22 | Feb 22 | Mar 22 | Apr 22 |
|---|---|---|---|---|
| **AR** | 94.3% | 95.1% | 99.1% | 97.5% |
| **PE** | 71.7% | 77.1% | 77.4% | 77.4% |
| **QR** | 98.7% | 95.8% | 95.2% | 99.5% |
| **OEE** | 65.7% | 70.3% | 73.0% | 75.1% |

The fishbone diagram brainstorming results are discussed with the participation of machine operators, inspectors, and other Engineer staff. The fishbone diagram results are shown in Figure 3.

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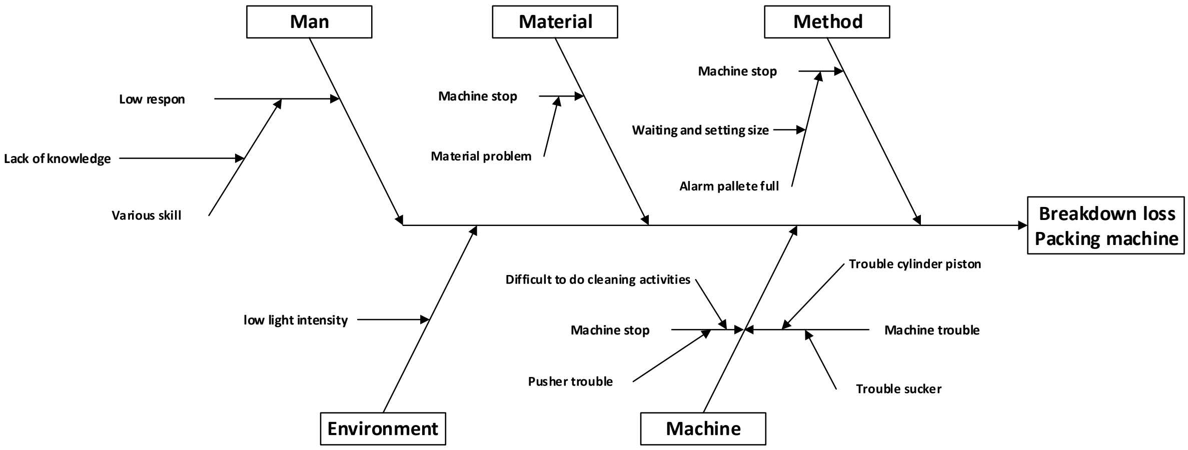


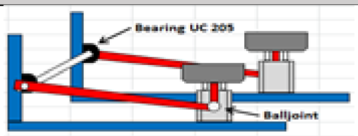
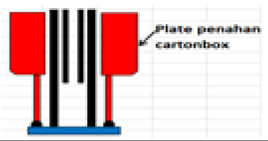

Figure 2. Cause Effect Diagram (CED)

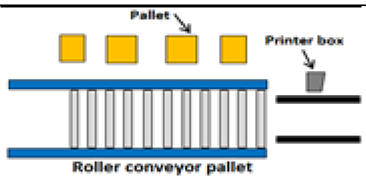
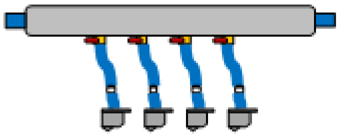
Table IV. FMEA Analysis

| Potential Failure Mode | Sev | Potential Failure Effect | Occ | Potential Cause of Failure | Det | RPN | Rank |
|---|---|---|---|---|---|---|---|
| Piston cylinder trouble | 8 | Unbalance cylinder motion | 9 | Machine stop frequently | 7 | 504 | 1 |
| Sucker cylinder leakage | 9 | Failure pickup carton | 8 | Machine stop frequently | 7 | 504 | 2 |
| Pusher trouble | 8 | Material transfer unsmooth | 9 | Box damage | 7 | 504 | 3 |
| Difficult cleaning nozzle activities | 7 | Stuck glue supply | 8 | Nozzle dirty | 9 | 504 | 4 |
| Alarm pallet full | 5 | Remote operator range | 7 | Machine stop | 7 | 245 | 5 |
| Various skill Operator | 4 | Human error | 6 | Poor knowledge | 5 | 120 | 6 |
| Low light intensity | 4 | Human error | 5 | wrong decision making | 6 | 120 | 7 |

This FMEA analysis is performed to prioritize issues to be fixed. The FMEA analysis is based on the RPN calculation and the scorer is performed by his 5 experts. FGD was run to determine this Prioritization and determination of corrective actions by applying the TPM column, the expected Improvements have been made. Maintaining OEE values in packaging machine control. The results of the FMEA analysis are shown in Table 4. The next stage is to develop an improvement plan as shown in table 5.

Table V. Action plan

| No | Cause | Why | What | When, Where, Who | How | How many | How much |
|---|---|---|---|---|---|---|---|
| 1 | Piston cylinder trouble | Unbalance motion | Change to flexible motion | May 2022 |   | Shaft 25mm X 850 mm, 1 pc | IDR 225,500 |
| 2 | Sucker cylinder trouble | Frame sucker dirty | Change supply sucker frame | May 2022 |  | Tubing 4 X 6 mm | IDR 155,000 |
| 3 | Pusher trouble | Material tranfer unsmooth | Additional plate for lifting | May 2022 |   | Plate 5mm x 200 mm x 250 mm, 2 pc | IDR. 135,500 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4 | Alarm Pallet full | Remote operator range | Change layout | May 2022 |  | 1 set | IDR. 750,000 |
| 5 | Difficult cleaning nozzle activities | Stuck supply glue | Change construction system nozzle | May 2022 |  | 1 set | IDR. 4,000,000 |

Repairs were carried out in May 2022 with a total cost of IDR 5,000,000. Then an evaluation is carried out by comparing the OEE values before and after the improvement as shown in table 6.

Table VI. Evaluation OEE After Improvement

| | **Jan 22** | **Feb 22** | **Mar 22** | **Apr 22** | **May 22** | **Jun 22** | **Jul 22** |
|---|---|---|---|---|---|---|---|
| **AR** | 94.3% | 95.1% | 99.1% | 97.5% | **Kaizen Implementation** | 99.1% | 97.5% |
| **PE** | 77.2% | 77.1% | 77.4% | 77.4% | | 98.8% | 98.8% |
| **QR** | 98.7% | 95.8% | 95.2% | 99.5% | | 95.2% | 99.5% |
| **OEE** | **71.8%** | **70.3%** | **73.0%** | **75.1%** | | **93.2%** | **95.8%** |
| **Average OEE** | **72.5%** | | | | | **94.5%** | **Up 30.3%** |

## VI. Conclusions

The results of the study found that the causes of OEE in companies could not reach the target. First, the packing machine often stops due to three major factors, namely poor cylinder flexibility, frequent sucker cylinder trouble, and poor material pusher movement. Second, the full pallet alarm is not responded to quickly by the operator, causing the packing machine to stop. Third, from the environmental factor, namely the intensity of light in the nozzle cleaning process, the operator requires a fairly high concentration due to the complex cleaning system. In May 2022, improvements were made to these three factors and cost IDR. 5,000,000, the impact is that the company's OEE value increases by 30.3%, or the average OEE value after improvement is 94.5%. It can also be said that the company's ability is at a world-class manufacturing level. FMEA, FGD, 6 big losses analysis, and PDCA were used by researchers to complete this research. To know the capability and process variation in more depth, it is expected to use 6sigma DMAIC.

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