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Improved YM Laser Machine Performance with Overall Equipment Effectiveness and Fault Tree Analysis Methods Implementation at PT. XYZ

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Abstract. In the development of the shoe-making industry, demanding companies continue to improve the quality and quality of production. PT. XYZ responded by improving the performance of the YM Laser machine which is the main engine in the sports shoe production line. The approach is carried out using the entire Equipment Effectiveness Method and Error Tree Analysis. The purpose of this study is to measure the ratio of value availability, performance ratio, quality ratio, total value of OEE on YM Laser machines, identify the root causes of problems and make improvement plans to improve machine performance. YM Laser Machines have a Overall Average Equipment Effectiveness Value of 75.89%. After researching with the OEE method, it was found that the root of the problem was to reduce speed. Furthermore, the investigation using a cause and effect diagram, obtained the main cause is a machine factor. All problems found were solved using Fault Tree Analysis on engine factors and their improvement efforts to make standard lens replacement so that the lens is always in optimal condition, changing the quality of the switch so that it is not easily damaged again, and regularly updating software and replacing standard bolts.

Keywords: Overall Equipment Effectiveness, Performance Ratio, YM Laser Machines, Fault Tree Analysis

1. Introduction

In the development of industrial world in the era of globalization, Indonesia's increasing economy has built a climate of increasingly fierce competition between companies. Every company is required to be able to survive and have the ability to compete [1].

Along with the times, the industrial world is also growing rapidly. Productivity is a benchmark to improve company performance. To maintain and improved productivity, the maintenance of production facilities needs to be considered. The intended facility is machine's component that must be maintained so that conditions are always optimal. Machine is one of important component in production process, if the machine stops due to damage, it will produce defect product and energy waste will occurs because the machine operates but doesn't produce product.

The purpose of this research is to measure the performance of the production line, including:

- Calculating the value of the availability ratio, performance ratio, quality ratio and OEE (Overall Equipment Effectiveness) YM Laser machines in the production line at PT. XYZ.
- Look for factors that cause a decrease in overall equipment effectiveness performance.



- Identify the root cause of the problem of lower OEE values compared to its ideal value and cause that dominate the problem and provide improvement suggestion to increase the machine's performance.

1.1 Overall Equipment Effectiveness

OEE value is obtained from the multiplication of the three OEE factors, namely availability, performance and quality.

Availability Ratio (AR) aims to measure overall time with unoperated system due to equipment damage, production preparation and adjustment of the machine or component.

$$\text{Availability} = \frac{\text{Operating Time}}{\text{Loading Time}} \times 100\% \quad (1)$$

Performance Ratio is measured with actual operation time ratio from the machine or component with ideal cycle time based on its capacity. The ratio of comparison between the current production level with the planned production level or the ratio of machine capability that obtained from multiplication of the production result with the theoretical cycle time that divided by operation time or multiplication result from operating speed rate and net operating time. The calculation for PR is as follows:

$$\text{Performance} = \frac{\text{Production total} \times \text{Ideal Cycle Time}}{\text{Operation Time}} \times 100\% \quad (2)$$

Quality Ratio (QR) is a quality loss in the form of number of products that have experienced damage that is related to the equipment. Which is then converted to time by how much time is spent to produce the product that is damaged. The calculation for QR is as follows :

$$\text{Quality} = \frac{\text{Production total} - \text{Total Defect}}{\text{Production Total}} \times 100\% \quad (3)$$

$$\text{OEE (\%)} = (\text{Availability} \times \text{Performance} \times \text{Quality}) \quad (4)$$

1.2 Six Big Losses

In the world of machine's maintenance, known as the six big losses, this is something that every company should avoid. Six big losses are six losses that must be avoided by every company that can reduce the level of effectiveness of a machine. Six big losses are usually categorized into 3 main based on aspects of loss, namely downtime, speed losses and defects. What it meant by downtime is time wasted, where the production process doesn't run as usual due to machine's damage [2]

Downtime consists of two types of losses, namely breakdown and setup and adjustment. Speed losses is a condition where the speed of the production process is interrupted, so the production doesn't reach the expected level. Speed losses consists of two types of losses, namely idling and minor stoppages and reduced speed. Defect is a condition where the product that produced doesn't meet the requested specifications (nonconformance to standards) [3]. Six big losses in question, among others is :

1. Breakdown

Machine's or equipment damaged will cause time wasted resulting in losses for the company due to lack of production volume or material loss due to defective product.

$$\text{Breakdown losses} = \frac{\text{Total Trouble}}{\text{Loading Time}} \times 100\% \quad (5)$$

2. Setup and adjustment

The time that spent on preparing equipment that can't be spent on producing and this is considered a loss. Unnecessary adjustments are also included below.

$$\text{Setup losses} = \frac{\text{Total Setup}}{\text{Loading Time}} \times 100\% \quad (6)$$

3. Idling and Minor Stoppages

Small stops usually refer to the length of the stop and are a means of classifying stops that are often not noticed (until measured) but the cumulative effect has a very large effect and directly reduces operating time (and increases worker frustration).

$$\text{Idling and minor stoppage} = \frac{(\text{Loading time} - \text{Net operating time})}{\text{Loading time}} \times 100\% \quad (7)$$

4. Reduce speed

There is often a heated debate about how fast the process can run and what are the standards to calculate the performance.

$$\text{Reduce Speed Losses} = \left(\frac{\text{average actual cycle time} -}{\text{average ideal cycle time}} \right) \times \left(\frac{\text{total production}}{\text{loading time}} \right) \times 100\% \quad (8)$$

5. Quality Defect and Rework

The most part of reduction in organizational quality defect is a great opportunity to increase productivity and reduce costs. The true cost of poor quality is usually large although most defects can be prevented by using focused techniques and operators [4]. The aim of each repair team must therefore include zero defects.

$$\text{Defect Losses} = \frac{\text{Total defect} \times \text{rata-rata actual cycle time}}{\text{Loading time}} \times 100\% \quad (9)$$

6. Reduced Yield or Other Losses

Reduced Yield accounts for defective parts produced from startup until stable (steady-state) production is reached. Reduced Yield can occur after any equipment startup, however, it is most commonly tracked after changeovers. Reduced Yield is a Quality Loss.

$$\text{Yield atau scrap loss} = \frac{\text{ideal cycle time} \times \text{scrap}}{\text{Loading time}} \times 100\%$$

2. Methods

The research method that used is overall equipment effectiveness and fault tree analysis.

2.1 Overall Equipment Effectiveness

OEE is a main calculation to measure the success of the implementation of Total Productive Maintenance Program. Valuations relating to OEE follow the global standard, namely 90% for the availability rate value, 95% for the performance rate value and 99% for the quality rate value. The total for OEE value must be 85% from a machine or component. This OEE measurement is very important to identify the machine or equipment that need to be improved the level of productivity or efficiency [5].

Availability Ratio (AR) aims to measure the overall time if there is damage to equipment, production preparation and adjustment of machines or equipments. So, the availability ratio requires value from operating time, loading time and downtime.

Performance Ratio (PR) is measured by the ratio of actual the actual operating speed of a machine or component to an ideal speed based on its capacity. The ratio is obtained from comparison between current production level with planned production level or machine's capability ratio that obtained from multiplication of produced product with theoretical cycle time that divided by operating time or multiplication from operating speed rate and net operating time.

Quality Ratio is the quality loss in the form of the number that have experienced damage that is related to the equipment, which is then converted to time by how much time is spent to produce the product that is damaged.

2.2 Fault Tree Analysis

Fault tree analysis is a structured diagram analysis that identifies the elements that can cause system failure. This technique is based on deductive logic and can be adjusted to risk identification to analyze the impact of risks arises. Effective application of this technique requires a detailed explanation of the area under discussion. Unwanted results are first identified and then all possible conditions / failures that lead to the event can be identified too. [6].

3. Result and Discussion

The research was conducted in the production section PT. XYZ, located in Pakualam, Tangerang. The data used in this research are loading time, downtime, total production, total defects and cycle time. The research was carried out in the cutting line.

3.1 OEE Calculation

All calculations to produce OEE values can be seen in table 1. The formula that used to calculate OEE is : $OEE = \text{availability ratio} \times \text{performance ratio} \times \text{quality ratio}$.

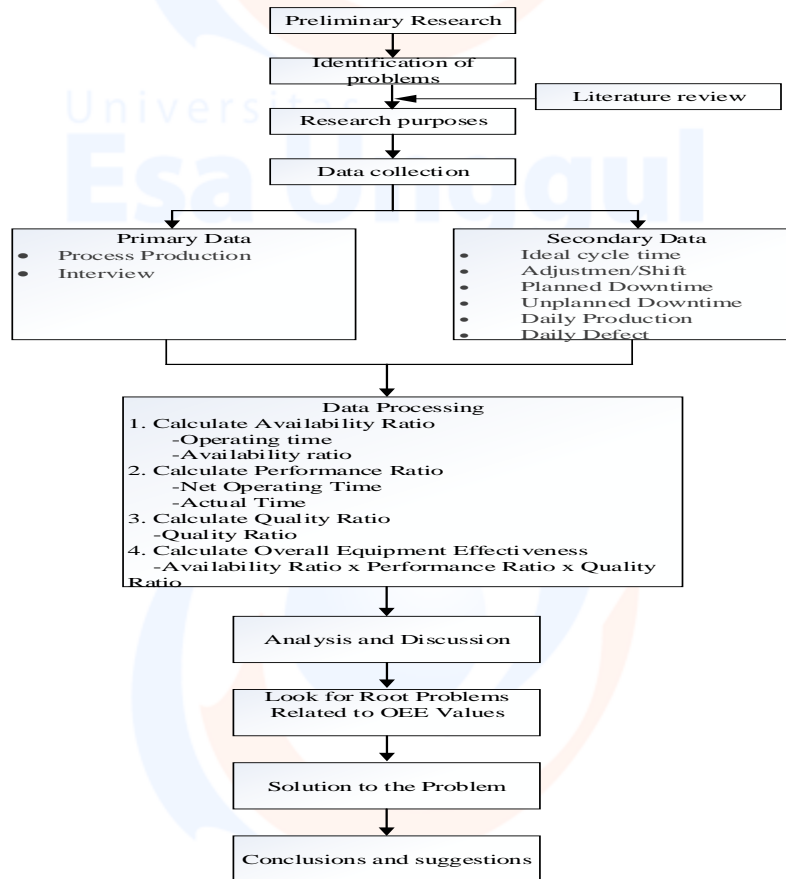


Figure 1. Research flow chart

3.2 Six Big Losses Calculation

The calculation of the value of six big losses is useful to identify how much losses caused by machine’s damage. Losses in adjusting time, defect as well as losses resulting from reduced speed and idle time & stoppage minor. The loss calculation is done because the YM Laser machine has an OEE value in March of 75,64% and in April of 76,13% meaning it must be traced and identified because the OEE value was low. There are six big losses on the YM Laser Machine. All Six Big losses calculations can be seen in table 22.

Breakdown or equipment failure is a sudden or unwanted damage to the machine or equipment that causes loss. Breakdown or equipment failure is calculated by dividing the total trouble time with loading time with loading time.

March calculation :

$$\begin{aligned}
 \text{Breakdown Losses} &= \frac{\text{Total Trouble}}{\text{Loading Time}} \times 100\% = \frac{269}{19200} \times 100\% \\
 &= 1.40\%
 \end{aligned}$$

Setup losses are losses due to installation, adjustments and also the time that required to substitute types of products to other types of products as well as time that used to change the material and do some additional adjustment. To calculate setup losses, the following are setup losses calculations in March.

$$\text{Setup Losses} = \frac{\text{Total Setup}}{\text{Loading Time}} \times 100\% = \frac{400}{19200} \times 100\% = 2.08\%$$

Table 1. Overall Equipment Effectiveness Calculation

| Overall Equipment Effectiveness Calculation in March 2019 | | | | |
|-----------------------------------------------------------|-----------------------|----------------------|------------------|--------|
| Date | Availability Ratio(%) | Performance Ratio(%) | Quality Ratio(%) | OEE(%) |
| March 1, 2019 | 96.15% | 67.96% | 99.02% | 64.71% |
| March 4, 2019 | 96.04% | 74.65% | 98.90% | 70.90% |
| March 5, 2019 | 97.92% | 86.48% | 99.61% | 84.35% |
| March 6, 2019 | 97.92% | 81.57% | 99.55% | 79.51% |
| March 8, 2019 | 97.92% | 86.72% | 99.61% | 84.59% |
| March 11, 2019 | 97.92% | 93.49% | 99.45% | 91.03% |
| March 12, 2019 | 95.94% | 82.80% | 98.96% | 78.61% |
| March 13, 2019 | 94.48% | 66.08% | 98.46% | 61.47% |
| March 14, 2019 | 96.46% | 72.44% | 98.87% | 69.09% |
| March 15, 2019 | 97.29% | 82.93% | 99.22% | 80.05% |
| March 18, 2019 | 95.83% | 72.09% | 98.94% | 68.35% |
| March 19, 2019 | 96.98% | 77.57% | 99.12% | 74.57% |
| March 20, 2019 | 93.23% | 59.78% | 98.98% | 55.17% |
| March 21, 2019 | 96.98% | 80.96% | 99.39% | 78.03% |
| March 22, 2019 | 97.92% | 91.05% | 99.60% | 88.79% |
| March 25, 2019 | 97.08% | 90.33% | 99.04% | 86.86% |
| March 26, 2019 | 95.00% | 73.33% | 98.54% | 68.64% |
| March 27, 2019 | 93.75% | 65.81% | 98.02% | 60.48% |
| March 28, 2019 | 97.60% | 84.87% | 99.06% | 82.06% |
| March 29, 2019 | 97.92% | 87.82% | 99.41% | 85.48% |
| Total | 1930.31% | 1578.72% | 1981.75% | |
| Average | | | | 75.64% |

The average of the OEE in March was 75,64%.

Table 2. Six Big Losses Calculation

| Month | Breakdown losses | setup losses | other losses | deffect losses | reduce speed | idle & stoppage minor | Total |
|---------|------------------|--------------|--------------|----------------|--------------|-----------------------|--------|
| March | 1.40% | 2.08% | 0 | 0.86% | 24.82% | 3.48% | 32.65% |
| April | 1.71% | 2.08% | 0 | 0.88% | 25.06% | 3.79% | 33.53% |
| Total | 3.11% | 4.17% | 0 | 1.74% | 49.89% | 7.27% | 66.18% |
| Average | 1.55% | 2.08% | 0 | 0.87% | 24.94% | 3.64% | 33.09% |

Defect losses is a matter that must be minimized and even must be eliminated from the production process because in addition to providing losses to the material is also detrimental in terms of time. Defect losses can be calculated using the formula.

Defect losses calculation in March,

$$Defect Losses = \frac{Total\ defect\ x\ actual\ cycle\ time\ average}{Loading\ time} \times 100\% = \frac{438 \times 0.37}{19200} \times 100\% = 0.86\%$$

Reduce speed losses is an activity caused by a machine that is less than optimal, a decrease in machine's speed occurs the actual cycle time is longer than the ideal cycle time that has been set as a standard. Reduce speed losses can be calculated using the formula.

$$\begin{aligned}
 \text{Reduce Speed Losses} &= (\text{actual cycle time average} - \text{ideal cycle time average}) \times \\
 &\quad (\text{total production}) / (\text{loading time}) \times 100\% \\
 &= \frac{(0.37 - 0.28) \times 50456}{19200} \times 100\% = 24.82\%
 \end{aligned}$$

Idle and minor stoppage are losses caused by stopping the machine without damage, machine's hour, unfocused operators and machine's idle time. Idling and minor stoppage can be measured using formulas.

Calculation in March,

$$\begin{aligned}
 \text{Idling and minor stoppage} &= \frac{(\text{Loading time} - \text{Net operating time})}{\text{Loading time}} \times 100\% \\
 &= \frac{(19200 - 17862)}{19200} \times 100\% = 3.48\%
 \end{aligned}$$

3.3 Analysis

Analysis of the results of data processing is done on the calculation of the value of availability performance, quality and overall equipment effectiveness. Based on reference source used in every calculation in OEE has different ideal values. This ideal value is used to find out whether the value is sufficient or not. If not, there must be a repair while sufficient value must only be maintained or increased.

3.3.1 Cause-Effect Analysis. Based on the data calculation of losses, the biggest loss in table 2 is on reduce speed. The results of interviews with related parties, the losses were caused by the speed of the machine is below the specified standards, lack of maintenance, lack of preventive maintenance implementation and the schedule changes of components caused the machine can't run optimally as specified. To determine the root of the problem is to use a pareto diagram.

Pareto diagram is useful for determining the priority of solving existing problems. Based on figure 2, the highest priority is on reduce speed with a value of 75,4%, it can be concluded that there is a top priority to be made, namely reduce speed. These priorities are the root of the problems that occur in the YM Laser machine which are the analyzed for the root causes.

3.3.2 Cause-Effect Diagram Analysis. To make it easier to identify six big losses, relevant tools are created, that is a cause-effect diagram that formulates an improvement plan to address the root causes. Referring to figure 2, a cause-effect diagram analysis is carried out only on the six big losses that are the priority, namely reduce speed. So that the analysis is more focused on the factors that have high priority which is the cause of the low OEE score. The following is the reduce speed analysis.

Based on figure 3, the reduce speed's cause and effect diagram that causes low productivity there are four factors that affect, among others man, method, machine and environment.

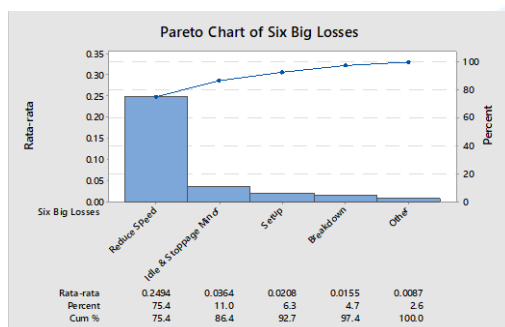


Figure 2. Six Big Losses Average in Pareto Chart

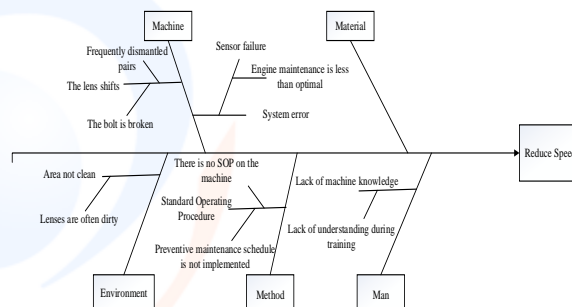


Figure 3 Reduce Speed's Cause and Effect Diagram

1. Machine

Machine system problems caused by sensors damage due to less optimal maintenance schedules resulting in losses. The machine factor also has several constraints ranging from the lens shift to lack of couplers, slack couplers that are caused by overused. Blower suction power decreases due to compressor leakage which is neglected by the operator.

2. Method

Standard Operating Procedures (SOPs) that are less socialized due to the absence of SOP sheets on several production lines that result in technicians working not in accordance with company SOPs and the lack of a preventive maintenance schedule.

3. Man

The ability of employees or operators must be in accordance with the work performed. Lack of operator knowledge of the machine can result in mishandling of small and large things. Sometimes small problems can become big because of the wrong handling.

4. Environment

Cleanliness of the work area is not get enough attention. This can cause the lens is often dirty thus slowing down machine's performance.

From the analysis of reduce speed cause and effect diagram, there are 3 dominant factors that cause losses, namely blower suction power, lens shift and problematic system.

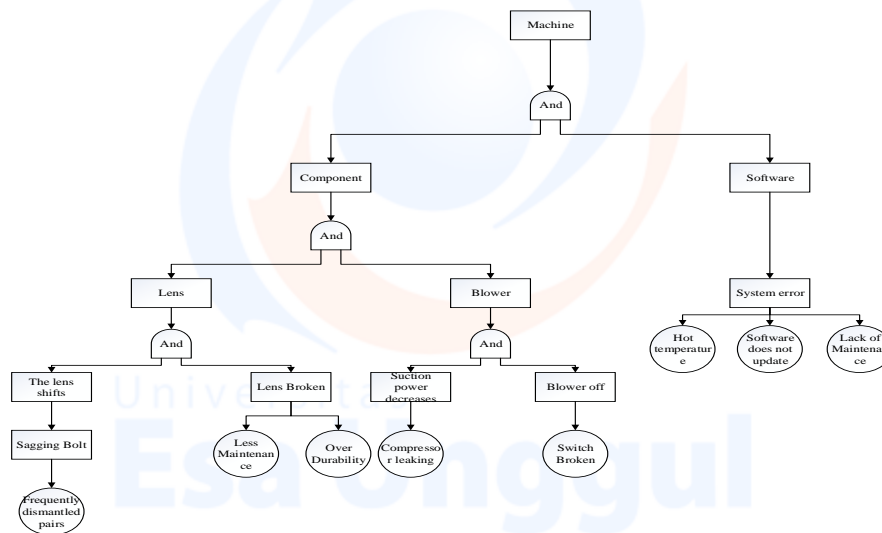


Figure 4. Fault Tree Analysis of Machine Factor

Table 3. Improvement plan to increase OEE value

| Problems | Improvement Plan |
|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| The lens is often disassembled | Make a standard bolt change so it is not too often disassembled |
| Lack of maintenance on the lens | Improved the supervision so that the preventive maintenance schedule can be well implemented and makes some work instructions. |
| Excessive lens life | Make a standard lens change so the lens will always in optimal condition |
| Compressor cleaning errors | Provide compressor cleaning procedures so the damage on the compressor will not occur again |
| Switch blower is often damaged | Change the switch blower to a better quality one so it is not too often damaged. Material must be checked first before used |
| Software is not updated | Do regular software updates |
| Software is not calibrate | Make a calibration schedule on software so it can be run optimally |

4. Conclusions

Based on the results of data processing and analysis of problems can be concluded as follows:

1. The results of the average value of the YM Laser machine availability ratio is said to be ideal with a value of 96.36%, the value of the ideal availability ratio is 90%. The value of the YM Laser machine performance ratio is 79.31% or not ideal, because the ideal value of the performance ratio is 95%. The value of the quality ratio on the YM Laser machine is 99.06%, it is ideal because the ideal quality ratio value is 99%. The result of the overall equipment effectiveness value on YM Laser machine is 75.89%, it has not been said to be ideal because the ideal value of overall equipment effectiveness is 85%, so an increase is needed to increase the OEE value.
2. Performance, availability, and quality factors are sequences of factors that cause OEE values from high to low. The cause of the large losses is the reduced speed caused by suboptimal maintenance.
3. The main cause of the problem of low OEE values on YM Laser machines is the low value of the performance ratio caused by the high reduce speed on YM Laser machines. Then the proposed improvements to the engine factor are as follows :
 - Repair plans for lenses that are often disassembled by changing standard bolts with special bolts so that they are not disassembled frequently.
 - Increase supervision so that preventive maintenance schedules for lenses can be applied and make some work instructions.
 - Make changes to the standard lens so that the lens is always in optimal condition.
 - Provide a compressor cleaning procedure so that compressor damage can be prevented.
 - Change the blower switch to a better one so it doesn't get damaged often and the material must be inspected before use.
 - Perform regular software updates and schedule calibrations in the software so that it can run optimally.

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