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Overall Equiqpment Effectiveness Analysis to Improve Machine Effective Value for Maxibrick Machine or Interlock Brick Molding Machine

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Abstract

The MaxiBrick- RBM-02 Automatic machine is an interlock Brick- molding machine, with alternative raw materials such as concrete materials in general, soil and sand, the remains of destroyed building materials, solid industrial waste, and many other alternative raw materials. This machine works with a hydraulic press system with a pressure of up to 25 tons. To achieve the daily production target that has been set, it is necessary to have a stable and efficient engine performance, so scientific calculations must be carried out to be able to see the level of effectiveness of the MaxiBrick- RBM-02 engine, so that more accurate maintenance

planning can be carried out on the factors that often cause downtime occurs. This study aims to measure and determine the level of effectiveness of the MAXIBRICK- RBM-02 Automatic machine by using the Overall Equipment Effectiveness (OEE) method and find solution, to achieve an engine effectiveness level of more than 85% based on OEE calculations.

Keywords— Brick, OEE, control system, improvement, ladder, PLC.

Introduction

Interlock Brick-s have several advantages over conventional Brick-s, this is due to several factors, including: faster processing time and cheaper costs than conventional Brick-s (Kafrain, 2018), Interlock Brick-s are produced manually by SMEs. RIP, SIDOARJO designed a machine that produces interlock Brick-s under the name RBM-02 Maxi-Brick- Machine. The MaxiBrick- RBM-02 machine is present as a solution to problems for SMEs producing interlock Brick-s. Based on data from PT RIP, it was found that the machine's performance has not been able to reach the expected production target, which is 3000 Brick-s per day, so it is necessary to analyse the effectiveness of machine performance and repair or overhaul the system.

Previous RESEARCH

Research on the effectiveness of the machine can be done by analyzing OEE at PT. UPA and shows an increase in production effectiveness by 15% to 88% by carrying out regular maintenance of the production line (Saipudin, 2019).

Research on OEE analysis has also been carried out by Dinda Hesti Triwardani and Arif Rahman on the Dual Filters DD07 engine at PT. Filtrona Indonesia and managed to overcome frequent machine downtime by replacing the more standard timex, and sharpening the hopper knife (Triwardani et al., 2013).

Method

Overall Equipment Effectiveness as a statistical measurement of engine efficiency, it is a key metric of TPM. In addition to what comes out of the machine, the focus is also on what can come out, and where the loss of effectiveness is occurring. Overall Equipment Effectiveness offers a simple yet powerful measurement tool for extracting information about what is really going on. OEE is the result which can be expressed as the ratio of the actual output of the equipment divided by the maximum output of the equipment under the best performance conditions .

Availability is a ratio that describes the utilization of available time for machine and equipment operation activities. or the ratio of operation time, by eliminating equipment downtime to loading time (Nakajima, 1988). So, the formula used to measure availability is :

$$\text{Availability} = \frac{\text{Loading Time} - \text{Down Time}}{\text{Loading Time}} \times 100\%$$

Performance is a ratio that describes the ability of the equipment to produce goods. This ratio is the result of the operating speed rate and net operating rate (Nakajima, 1988). The formula for measuring this ratio is :

$$\text{Performance} = \frac{\text{Output}}{\text{Output Maximal}} \text{ x } 100\%$$

Rate of product quality is a ratio that describes the ability of equipment to produce products that comply with standards (Nakajima, 1988). The formula used for measuring this ratio is:

$$\text{Rate of Quality} = \frac{\text{Processed amount} - \text{Defect amount}}{\text{Processed amount}} \times 100\%$$

The OEE value is obtained by multiplying the three main ratios (Nakajima, 1988). Mathematically the formula for measuring the OEE value is:

$$\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Rate of quality}$$

Result and discussion

The initial problem with the Maxi-Brick- machine was that the production target of 3000 pcs/day was not achieved. See this data :

Table 1 *MaxiBrick- Technical Specifications*

Technical specifications		
General	Dimension	1.500 (L) x 1.500 (W) x 2.208 (H) mm
	Machine Weight	1.800 Kg (approx.)
	Production Pallet Size	750 x 600 x 30 mm
	Effective Print Area	300 x 260 mm
	Print Yield Height (max/min)	100 mm/50 mm
	Average Capacity	400 pieces/hour
Power (3 phase, 380 V)	**Component**	**Power Requirement**
	Hydraulic Oil Pump	10 HP 1500 rpm
	Gearmotor for Feeder	0.5 KW

To identify the need for overhauling the system is to calculate the level of efficiency on the machine, thus the Overall Equipment Effectiveness method was chosen to support this research.

At this stage, data is taken randomly in the period March 2021 to December 2021, with an average working hour of 7.5 hours per day. Data is taken from observations and interviews with operators in the field.

There are 3 types of bricks produced, namely Brick Penuh (Full), Brick Kanal, Brick Setengah.

Table 2 *First Sample*

Date	Brick type	Jumlah		Output
March 2021				
23/03/2021	Brick- Full	5x320	1600	1880
	Brick- Kanal	1x280	280	
24/03/2021	Brick- Full	4x320	1280	1840
	Brick- Kanal	2x280	560	
26/03/2021	Brick- Full	6x320	1920	1920
April 2021				
03/04/2021	Brick- Full	6x320	1920	1920
07/04/2021	Brick- Full	7x320	2240	2240
08/04/2021	Brick- Full	6x320	1920	2240
	Brick- Kanal	2x280	360	
24/04/2021	Brick- Full	6x320	1920	1920
29/04/2021	Brick- 1/2	3x200	600	1560
	Brick- Full	3x320	960	
30/04/2021	Brick- 1/2	8x200	1600	1600
June 2021				
07/06/2021	Brick- Full	6x320	1920	1920
11/06/2021	Brick- Full	6x320	1920	1920
11/06/2021	Brick- Full	5x320	1600	1600
23/06/2021	Brick- Full	5x320	1600	1600
September 2021				
11/09/2021	Brick- Full	6x320	1920	1920
13/09/2021	Brick- Full	5x320	1600	1600
17/09/2021	Brick- Full	3x320	960	1800
	Brick- Kanal	3x280	840	
20/09/2021	Brick- Full	3x320	960	1800
	Brick- Kanal	3x280	840	
23/09/2021	Brick- Full	6x320	1920	1920
October 2021				
11/10/2021	Brick- Full	5x320	1600	2000
	Brick- 1/2	2x200	400	
22/10/2021	Brick- Full	6x320	1920	1920
26/10/2021	Brick- Full	5x320	1600	1600
November 2021				
03/11/2021	Brick- Full	4x320	1280	1880
	Brick- 1/2	3x200	600	
04/11/2021	Brick- Full	6x320	1920	2120
	Brick- 1/2	1x200	200	
06/11/2021	Brick- Full	6x320	1920	1920
29/11/2021	Brick- Full	5x320	1600	1600
December 2021				
15/12/2021	Brick- Full	6x320	1920	1920
27/12/2021	Brick- Full	6x320	1920	1920
28/12/2021	Brick- Full	6x320	1920	1920

Figure 1 *Brick Type*

From the data (Table 2) the standard production target to be achieved, namely 3000 bricks per day has not been met. To determine the number of production targets that can be achieved by the machine, it is necessary to calculate the Relative Number of Targets, the target quantity is the maximum target that can be achieved in the available time range during the Operating Time. With the following formula :

$$\text{Output Max} = \frac{\text{Operation Time}}{\text{Ideal Cycle Time}} \text{ x output in one cycle time}$$

The previous system still uses the default settings in the PLC program system, the results of observations show that the initial standard ideal cycle time is 20 seconds, with an output of 2 bricks per cycle time and because no real Operation Time calculations have been carried out, the Operation Time value is set at 7.5 hours or 450 minutes.

Operation Time
450 Minutes
Ideal Cycle Time
20 Seconds
Output Maximum
2700

The data on the side is the initial standard data of the machine before the system overhaul is held, from here it can be concluded that the maximum output amount still touches the figure of 2700 bricks per day, if you want to reach the initial target of 3000 bricks a day, the cycle time must be increased, with the data on the side An overhaul of the system needs to be carried out by considering several aspects of production, including :

1. Operator's skill in operating the machine. If the Cycle Time is accelerated it will certainly increase the engine speed, it can increase the risk of accidents and product defects, therefore a flexible system needs to be made with a speed that can be adjusted to the operator's skills, if the operator's skills increase then Cycle Time can also be accelerated.
2. Do not change the design of the machine, With many machine products sold, of course changing the design of the machine is not possible (example: increasing the number of molds, Replacing the Electric Motor with the aim of increasing the speed of the hydraulic cylinder thrust) therefore changes to the system are most likely to conducted.

From the data (Table 2) it can be calculated Performance Ratio.

At this stage, the value of Loading Time and Downtime has not been recorded specifically because there is no realtime calculation on the system, it is necessary to add a new system to the HMI frame to perform these calculations, so that the value of the Availability Ratio can be formulated and known.

Likewise, the value of the Rate of Quality Product cannot be formulated, based on observations in the field, the operator said that the product defect was only less than 2-3%, but further data collection is needed so that the data obtained is more specific.

The basis for the changes made is Reliability Centered Maintenance, which is a flexible maintenance method that is able to adapt to existing conditions. So further evaluation is needed so that the method used remains relevant to the condition of the machine. (Zulnor, Hari, 2021) So we need a flexible system that can be changed.

Table 3 *First Performance Ratio*

Date	Output	Performance Ratio
March_2021		
23/03/2021	1880	69,60%
24/03/2021	1840	68,10%
26/03/2021	1920	71,10%
April_2021		
03/04/2021	1920	71,10%
07/04/2021	2240	82,90%
08/04/2021	2240	82,90%
24/04/2021	1920	71,10%
29/04/2021	1560	57,70%
30/04/2021	1600	59,20%
June_2021		
07/06/2021	1920	71,10%
11/06/2021	1920	71,10%
11/06/2021	1600	59,20%
23/06/2021	1600	59,20%
September_2021		
11/09/2021	1920	71,10%
13/09/2021	1600	59,20%
17/09/2021	1800	66,60%
20/09/2021	1800	66,60%
23/09/2021	1920	71,10%
October_2021		
11/10/2021	2000	74%
22/10/2021	1920	71,10%
26/10/2021	1600	59,20%
November_2021		
03/11/2021	1880	69,60%
04/11/2021	2120	78,50%
06/11/2021	1920	71,10%
29/11/2021	1600	59,20%
December_2021		
15/12/2021	1920	71,10%
27/12/2021	1920	71,10%
28/12/2021	1920	71,10%

Here is HMI default system in machine.

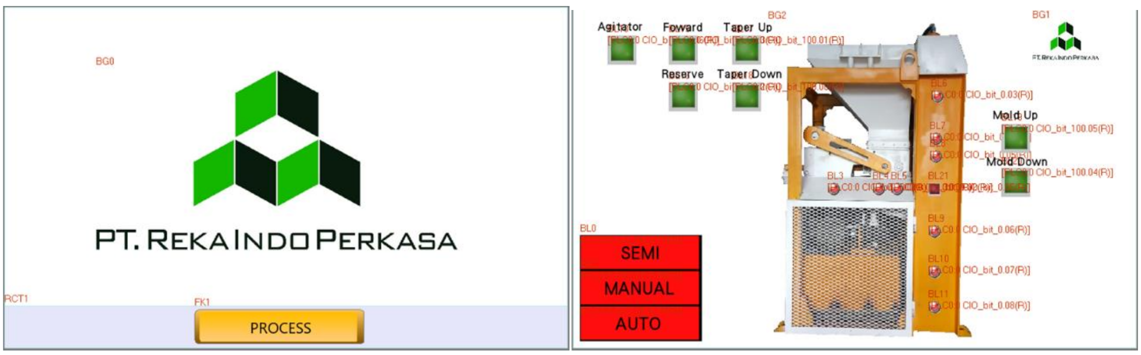

Figure 2 *Default HMI system*

Figure 2 shows the initial HMI standard display on the Maxibrick machine, there are 2 frames in this initial system, namely:

1. Frame 0 (left): The initial frame after the engine starts, there is 1 touch screen button, namely the PROCESS button, if pressed it will lead to the frame process.
2. PROCESS Frame (right): Frame that shows how the machine works, there are all indicator sensors to monitor movement and indicators of the SEMI, MANUAL, AUTO process system.

Due to consideration of several aspects above, the HMI default system must be changed. The new model for HMI uses NB_Desighner Software to support the new program on the PLC, the old HMI model can be seen in (Figure 2) as a comparison.

For system reform and research support, at this stage it is necessary to add 2 new frames, namely the Setting frame and the OEE frame.

Figure 3 *Frame 0*

When turning on the machine, the initial display that you get is Frame 0 as (Figure 3), in this frame 2 Function Keys are added to switch to frame process and frame settings. With the following explanation:

a) Frame Process, in this frame there are several sensor indicators in real time.
b) Frame Setting, this frame is used to change some process variables
c) Frame Recipe, this frame is only additional to support material differences for brick density (not needed for machine effectiveness research)

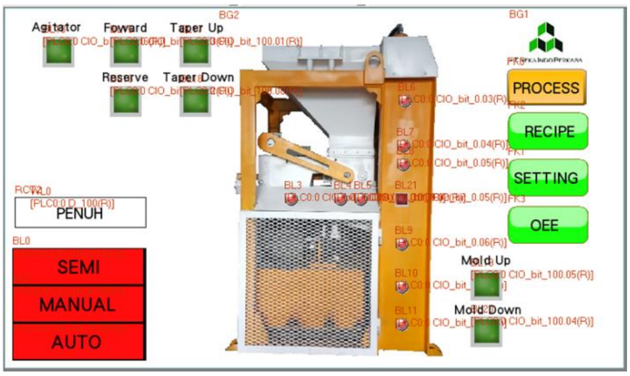

Figure 4 *New Frame Process*

There are not many changes to the frame process (for comparison see Figure 2), there is an addition to moving to another frame with a function key.

Before changes are made to the system, there is no frame setting, the variables on the machine are made static, the addition of this frame setting functions so that the variable values on the machine can be changed according to the operator's skills, the desired impact of this change is a faster cycle time, so that increased production targets.

The initial static parameter settings are:

1. CLEANING: the number of production cycles which then causes the machine to stop for mold cleaning. Value 5
2. UP MOLD: The number of down movements of the upper mold. The optimum value is
3. AGITATOR: The amount of forward motion of the agitator filler tub. Value 3.
4. LOAD TIMER: Amount of lag time after the product has been picked up. Value 5 seconds
5. FEED TIMER: The amount of time the material is filled by the fill tank. Value 3 Seconds

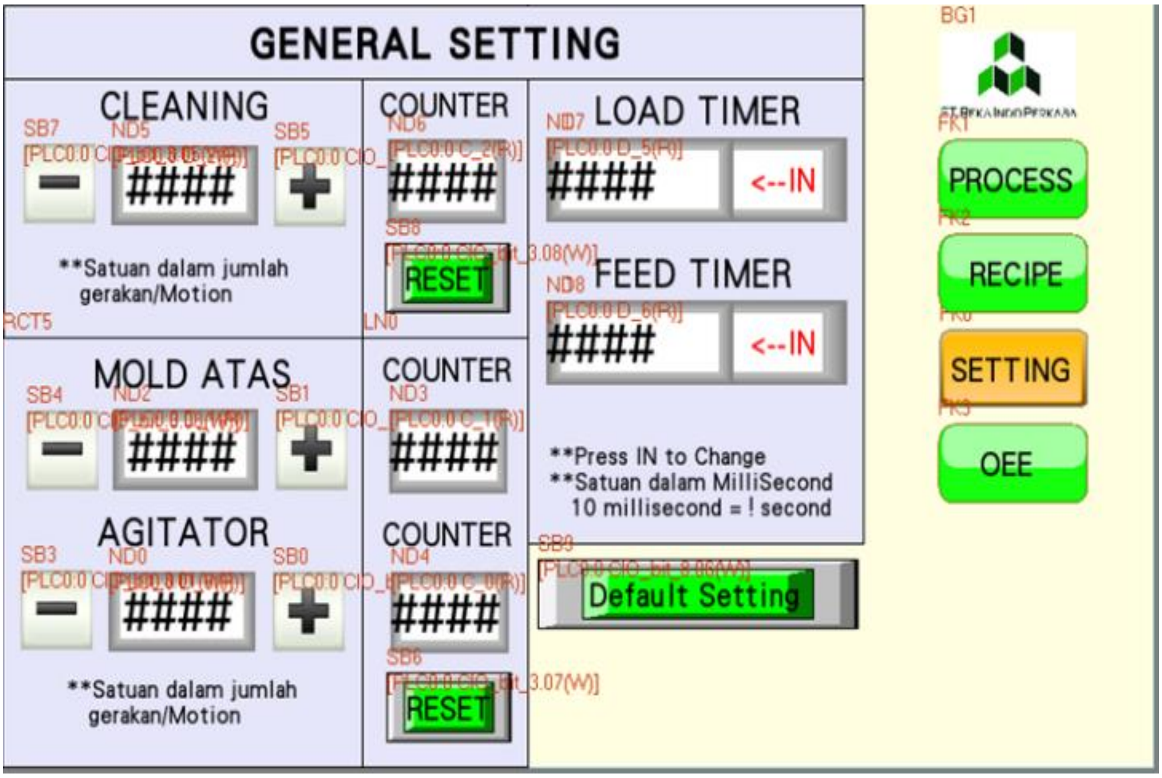

Figure 5 *Frame Setting*

The frame setting shown in Figure 6 is orange, which is used to change the speed of several movements and the response speed of the machine in order to provide flexibility for the operator during the production process. Descriptions for several settings (Figure 5) include:

1. CLEANING: the number of production cycles which then causes the machine to stop for mold cleaning. The optimum value is 5 and the maximum cleaning value is 10.
2. UP MOLD: The number of down movements of the upper mold. The optimum value is 2.
3. AGITATOR: The amount of forward motion of the agitator filler tub. Optimum Value 2.
4. LOAD TIMER: Amount of lag time after the product has been picked up. This variable is very influential on the skill of the operator, a skilled operator is able to run the machine with a Load Time value of less or equal to 3.5 seconds.

5. FEED TIMER: The amount of time the material is filled by the fill tank. 2.5 Seconds Optimum Value
6. DEFAULT SETTING: Return to factory default settings.

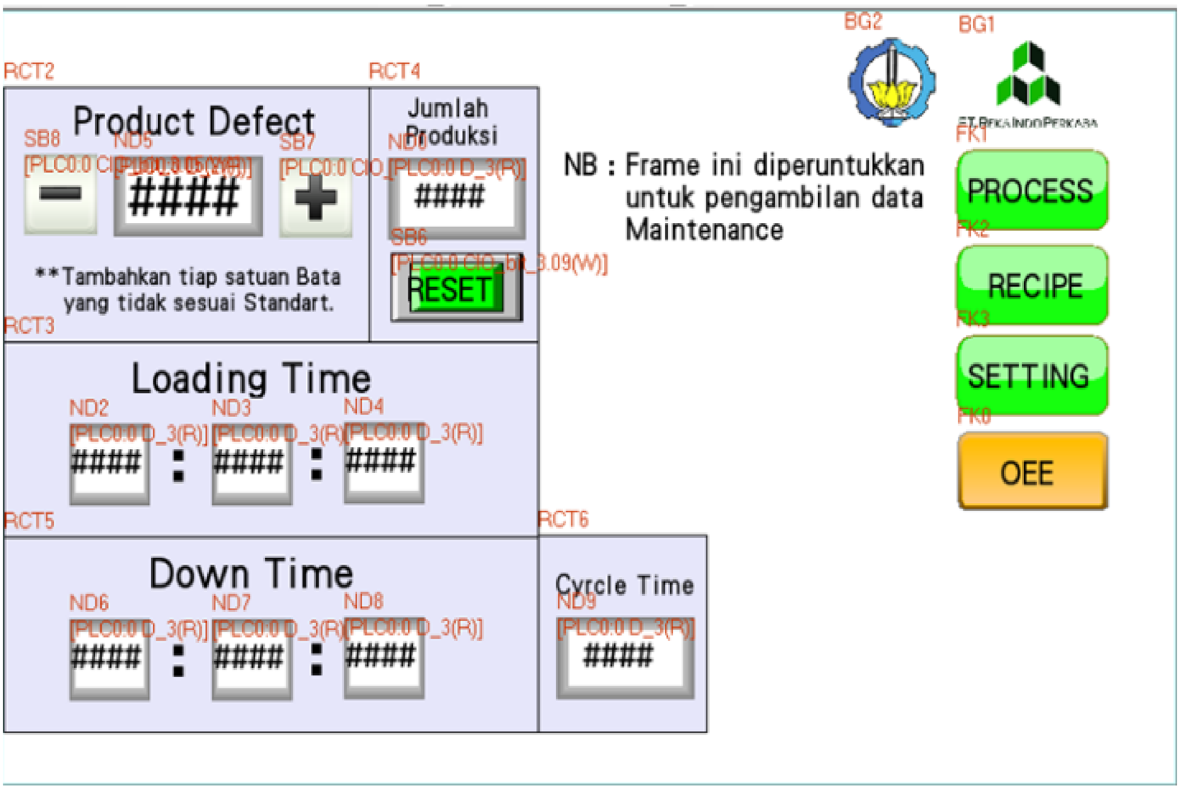

Figure 6 *Frame OEE*

In the frame (Figure 6) used as data collection to support this research, there is some important information, including:

1. Product Defect: The number of products that are not up to standard or damaged
2. Production Quantity: Displays the number of outputs while the machine is running, the reset button is used to clear the data and return it to 0
3. Loading Time: A timer in real time when the machine is running.
4. Down Time: Downtime will start counting when the buzzer is on or there is an emergency or the machine cannot work due to certain factors.
5. Cycle Time: is the time required for 1 time molding process.

After designing the HMI, the next step is to design the PLC program. The software used is CX-Programmer which is compatible with Omron CP1E PLC.

Data Analysis

After an overhaul of the system, the data obtained can be more specific, therefore the OEE calculation can be carried out more specifically.

This data is taken after making changes to the system and HMI. After an overhaul of the system, the data obtained can be more specific, therefore the OEE calculation can be carried out more specifically.

Table 4 *Data after system overhaul*

Date	Type	Ammount	Total	Output	Reject	Ideal Cycle Time (s)	Operation Time (s)	Loading Time (s)	Downtime	Downtime (minutes)	Target
Februari											
05/02/2022	Full Brick	6x320	1920	2120	24	19	07:28:13	448	01:45:16	105	2842
	½ Brick	1x200	200								
08/02/2022	Kanal Brick	7x280	1960	1960	21	18	07:41:35	461	02:21:02	141	3000
12/02/2022	Full Brick	8x320	2560	3960	35	16	09:09:01	509	None		4050
	Kanal Brick	5x280	1400								
14/02/2022	Full Brick	6x320	1920	3040	41	17	07:58:48	478	None		3176
	Kanal Brick	4x280	1120								
15/02/2022	Full Brick	7x320	2240	3080	29	17	07:37:04	457	None		3176
	Kanal Brick	3x280	840								
16/02/2022	Kanal Brick	7x280	1960	1960	31	18	07:26:17	446	02:01:36	121	3000
19/02/2022	Full Brick	3x320	960	2920	29	18	07:33:12	453	None		3000
	Kanal Brick	7x280	1960								
25/02/2022	Full Brick	8x320	2560	2560	19	18	07:42:41	462	00:51:01	51	3000
26/02/2022	Full Brick	3x320	960	2920	33	18	07:35:19	455	None		3000
	Kanal Brick	7x280	1960								
28/02/2022	Kanal Brick	10x280	2800	2800	27	18	07:46:57	464	None		3000

From table (4) it is known that the cycle time can be changed and accelerated, this has an impact on the amount of output produced, it is also known that the initial production target of 3000 bricks per day has been achieved, but there are several anomalies that cause the number of bricks to not meet the target, anomaly it happened due to downtime on the machine.

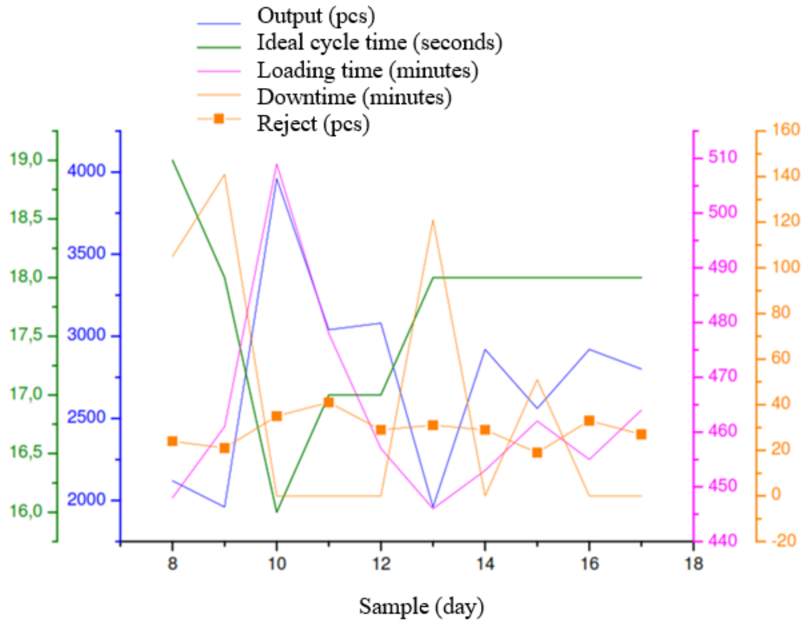

Figure 7 *Data Graph After Overhaul*

Figure 8 shows that the ideal cycle time is inversely proportional to the number of outputs, the smaller the ideal cycle time, the larger the number of outputs, other influential parameters include the loading time value is directly proportional to the number of outputs, the downtime value is inversely proportional to the number of outputs.

At this stage the calculation of 3 OEE parameters is carried out to determine the level of machine effectiveness.

Table 5 *OEE Analysis*

Dates February_2021	Performance Ratio	Availability Ratio	Rate Of Quality Product	OEE
05/02/2022	74,50%	76,50%	98,80%	56,31%
08/02/2022	65,30%	69,40%	98,90%	44,82%
12/02/2022	97,70%	100%	99,10%	96,82%
14/02/2022	95,70%	100%	98,60%	94,36%
15/02/2022	96,90%	100%	99%	95,93%
16/02/2022	65,30%	72,80%	98,40%	46,78%
19/02/2022	97,30%	100%	99%	96,33%
25/02/2022	85,30%	88,90%	99,20%	75,23%
26/02/2022	97,30%	100%	98,80%	96,13%
28/02/2022	93,30%	100%	99%	92,37%

At this stage, it is known that the OEE value in several periods has reached more than 90%, while the engine can be said to have a good efficiency value if it is more than 85%. However, in the data (Table 5), it is known that there are several anomalies, they occur due to downtime or the machine cannot operate due to certain conditions. If there is no anomaly or downtime the machine has been able to reach an effectiveness level of more than 90% and the total output is much better than the machine before the overhaul, for comparison see the following graph.

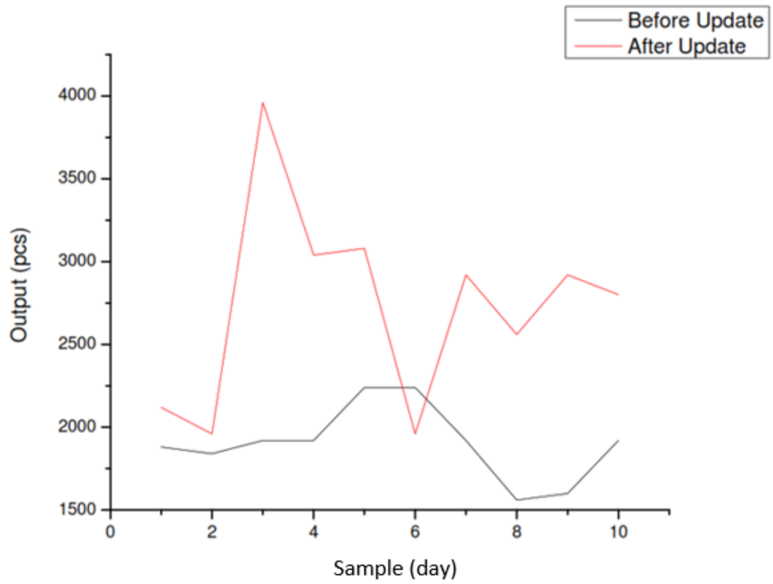

Figure 8 *Output Comparison Graph*

Figure 8 shows that the number of outputs before and after the update shows a significant difference, but there are anomalies in the 2nd and 6th day samples. the number of outputs showed a sharp decline, it was caused by the downtime at that time. The same thing also happens to the performance ratio in Figure 3.4, from this it can be concluded that the amount of output is directly proportional to the performance ratio.

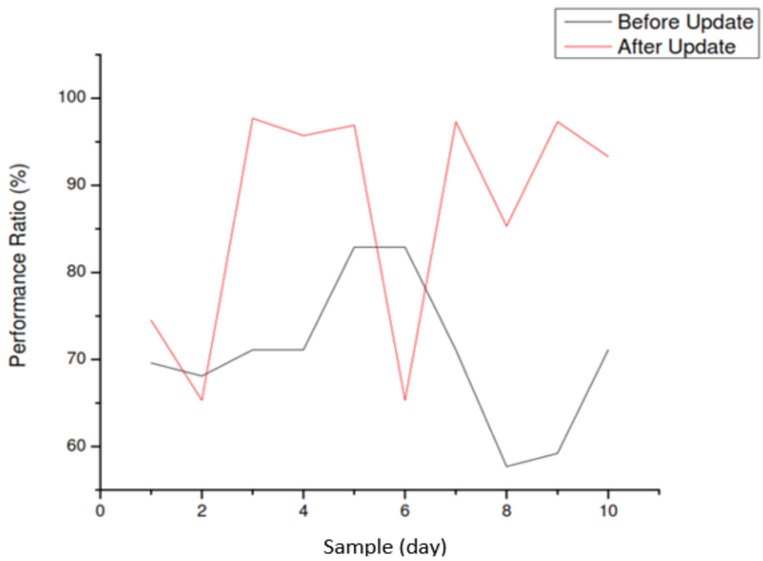

Figure 9 *Performance Ratio Comparison Chart*

Figure 10 shows that the performance ratio before and after the update is significantly different. However, there was an anomaly on the 2nd and 6th day samples. The performance ratio showed a sharp decline, it was caused by the occurrence of downtime.

Conclusion

Based on the discussion in the previous section, it can be concluded that:

1. To determine the level of effectiveness of the machine, one method that can be used is Overall Equipment Effectiveness (OEE), this method uses 3 parameters, namely Performance Ratio, Availability Ratio, and Rate of Quality product. After observing and collecting data in the 2021 period (before the system overhaul) data were obtained in the form of the average operation time per day (there is no system to calculate specific operation time), the type of brick and the amount of output produced in a certain period of time., and the machine's initial start-up cycle time data, from the data it was found that with a cycle time of 20 seconds and an operation time of 7.5 hours, the maximum output can only be achieved at 2700 bricks per day, therefore the initial production target is 3000 bricks per day. impossible to achieve. The initial system has no real calculations on Operation Time and Down Time, this causes the Availability Ratio cannot be formulated, the same thing also happens in the formulation of the Rate of Quality Product, for Product defect data has not been specifically recorded. After making changes to the system data to calculate the three OEE parameters have been obtained, and calculations can be carried out.

2. In the initial data processing (before changes were made to the system) the Performance ratio value did not touch the figure of 85%, around 65%. After being evaluated, there are 5 main parameters that have an impact on cycle time, namely the amount of cleaning, the number of collisions with the upper mold on the machine, the number of beats of the agitator during feed, the time span during which the feed takes place, and the load time (the time span required by the operator to pick up the bricks after out of the mold). The overhaul is done by adding 1 frame setting on the HMI which serves to change the five parameters and change the control system on the PLC. The impact of changes to the PLC cycle time control system can be adjusted according to the skill of the operator. With variable parameter changes and faster cycle times, the effectiveness of the machine increases, from data processing after an overhaul to the system, the OEE value can reach more than 90%, provided there are no anomalies or downtime.

3. With the existence of a more dynamic system (variables that can change according to the skill of the operator) then the efficiency of the engine can be maintained, and the engine performance is more stable.

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