International Journal of Research in Engineering, Science and Management
Volume-1, Issue-12, December-2018
www.ijresm.com | ISSN (Online): 2581-5792

Increased Productivity of Injection Molding with Analysis of Overall Equipment Effectiveness (OEE)

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***Abstract*: The productivity of a product is important for every company. There are 5 injection molds with the highest available production hours in April - July. OEE approach are used to measure productivity of the injection mold. Mold SLDX has lowest OEE values, with an average value of 76.6% . Based on measurement OEE, performance rate has lowest rate, with 81.8% rather than other approaches. Performance rate of injection molding affected by cavity efficiency and cycle time performance. Cavity efficiency become root cause that decrease performance rate of mold SLDX, with average cavity efficiency is 84.13% from April- July. Based on 5 whys, wrong sequence on the mold become root cause of problem that cause low cavity efficiency.. Improvement is done by modify sequence of the mold and add detent puller as safety system of the mold to prevent wrong sequence of the mold. There are increasing values of cavity efficiency after modification of mold design from 84.13% to 99.23% from August – September. Increasing cavity efficiency also increase performance rate of mold SLDX from 81,8% to 98.2% from August- September. Increasing performance rate also increase OEE value of mold SLDX from 76.6% to 94.33% from August- September.**

***Keywords*: Injection, Mold, OEE, Cavity, 5 whys**

1. Introduction

Increased productivity in an industrial company is an important role that must be carried out continuously to be able to be competitive with similar industrial companies. In overcoming competitiveness among similar companies (for example, plastic packaging industry companies) in Indonesia, especially those in the Cikarang area, companies must have a strategy to dominate the market by giving satisfaction to customers in quality and fulfillment of customer demand. The strategy carried out by the company is by prioritizing the quality of three important indicators in the process of making plastic packaging which include the performance of machines, materials and molds [1].

Overall Equipment Effectiveness (OEE) is a method that can improve productivity. This can be measured by the production activities carried out should be appropriate to the work standards. OEE has a systematic calculation process to identify all productivity losses so that it can streamline resources and the level of production performance. OEE is a comprehensive measurement of how well it performs a given design capacity. It is a common TPM metric and key component in lean manufacturing.

One plastic packaging industry company has a very dense production process activity in April to July 2018. There are 5 injection molds that are ranked highest for the mold category which is the mold with availability production hours, including Mold ALC 40, Mold ALC 80, Mold SLDX, Mold ASGR, and Mold PLGD as shown in Fig. 1.

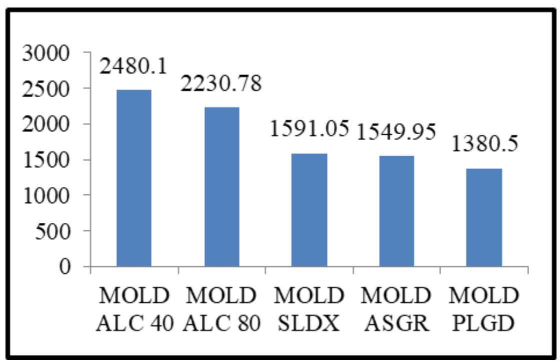

Fig. 1. Production Hours of 5 injection molds period April – July 2018

After OEE calculation is applied to the injection mold, and showed that mold SLDX get the OEE values from April- July 2018 as low as 75.60% as shown in Table 1.

Table 1
OEE of 5 Mold period April – July 2018

Mold	Apr - July 2018			
	AR (%)	PR (%)	QR (%)	OEE (%)
MOLD ALC 40	90.9%	93.4%	99.3%	84.30%
MOLD ALC 80	92.0%	97.4%	99.3%	88.96%
MOLD SLDX	93.7%	82.2%	99.3%	76.50%
MOLD ASGR	97.1%	97.5%	99.5%	94.19%
MOLD PLGD	95.3%	98.6%	98.0%	92.14%

Based on OEE calculations specifically from mold SLDX, the results show that the Performance Rate of mold SLDX is as low, with an average of 81.8%, and the lowest in June with a figure of 72% as shown in Table 2.

OEE Result of MOLD SLDX is specifically calculated from April – July 2018 and shown in Fig. 3. As shown in Fig. 2, OEE Result is below the standard of OEE World Class in 85%, so

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the improvement must be done to increase OEE and gain world class standard.

Table 2
OEE of Mold SLDX period April – July 2018

MOLD SLDX				
Month	AR (%)	PR (%)	QR (%)	OEE (%)
April	98.5%	82.2%	99.5%	80.57%
May	93.6%	84.9%	99.7%	79.20%
June	91.8%	72.0%	98.3%	64.93%
July	93.3%	88.1%	99.5%	81.78%
Average	94.3%	81.8%	99.2%	76.6%

2. Literature review

A. Injection Moulding

Injection molding is an important manufacturing process in the production of bulk plastic products in complex shapes and sizes with high precision. [2] Injection Molding is the process of conducting the formation of articles using a liquid plastic material, for compacted and then released by opening the two-part mold [3]. The injection molding process can be done in several stages, including [4]:

1) Selection and adjustment of the product to be produced to the specifications of plastic such as tensile strength, compressive strength, rigidity, etc.
2) Preparation process injection, with predefined parameters.
3) Injection the meld resin to the cavity and then allowing it to solidify.
4) Take the final product from the mold

B. Overall Equipment Effectiveness (OEE)

OEE developed by Seiichi Nakajima in 1960 to evaluate how effectively a manufacturing operation is used [5]. OEE procedures focused on the concept of zero waste [6]. By calculating OEE, it can be seen that 3 (three) important components that influence the effectiveness of the machine are availabilty, performance rate, and quality rate [7].

$$OEE = Availability\ x\ Performance\ x\ Quality \quad (1)$$

The calculation of OEE develop continuous improvement by creating added value for the company [8]. In such efforts, the OEE approach should be pursued to achieve the value of OEE to be closer to the target of world standard value [9]. The world standard of OEE is the availability rate is 90%, the performance rate is 95%, and the quality rate is 99% with OEE worth 85% [10].

Availability Time is the availability of a machine / equipment that produces a comparison between operating times (operating time) to the preparation time (loading time) of a machine / equipment [11]. Performance rate is a benchmark of the efficiency of a machine's performance running the production process. Performance rate, measuring the output deviation from ideal time [12]. Quality Rate is the ratio of the number of good products to the number of products processed [13].

C. Root Cause Analysis (RCA)

Root Cause Analysis (RCA) is an analytical technique that is gradually and focus more on finding the root cause of the problem, and not just look at the symptoms of a problem [14]. The purpose of RCA is to determine how to save problems by designing prevention that recognizes and removes the root causes [15]. The steps of RCA are identifying and clarifying undesired outcomes, devoting data, placing events and conditions on event and causal table factors (incident tables and causal factors), use a table of causes or other methods to identify all potential causes, identify the failure mode to the bottom failure mode, and continue the "why" question to identify the most critical root causes [16].

3. Methodology

Data processing is done in order to resolve the problem under study is to:

A. OEE analysis from Mold SLDX

A1. Calculation of Availability Rate (AR) from Mold SLDX

Availability rate calculation based on the data from the operating time (is the time when mold produces products) and the time of loading. This calculation determines the extent of the machines' willingness to operate or the utilization of the equipment. The AR calculation is performed by the following equation:

$$Availability\ Rate = \frac{Operationg\ Time}{Availability\ Time}\ x\ 100\% \quad (2)$$

A2. Calculation of Performance Rate (PR) from Mold SLDX

Performance rate calculation based on availability time, total cavities in mold, target production quantities (TPQ), and ideal cycle time. The PR calculation is performed by the following equation:

$$TPQ = \frac{Available\ Time\ x\ Total\ Cavities}{Cycle\ Time} \quad (3)$$

$$Performance\ Rate = \frac{Output}{TPQ}\ x\ 100\ \% \quad (4)$$

A3. Calculation of Quality Rate (QR) from Mold SLDX

Quality rate calculation based on output and defect product. The QR calculation is performed by the following equation:

$$Quality\ Rate = \frac{Output - Defect}{Output}\ x\ 100\% \quad (5)$$

A4. OEE calculation from Mold SLDX

OEE in Action: OEE taken a manufacturing unit and then breaks down its performance into 3 different components namely: Availability Rate, Performance Rate, and Quality Rate. The OEE calculation is performed by the following equation:

$$OEE = Availability\ x\ Performance\ x\ Quality \quad (6)$$

B. Study framework

The framework of this study is illustrated in Fig. 2, which is in two parts.

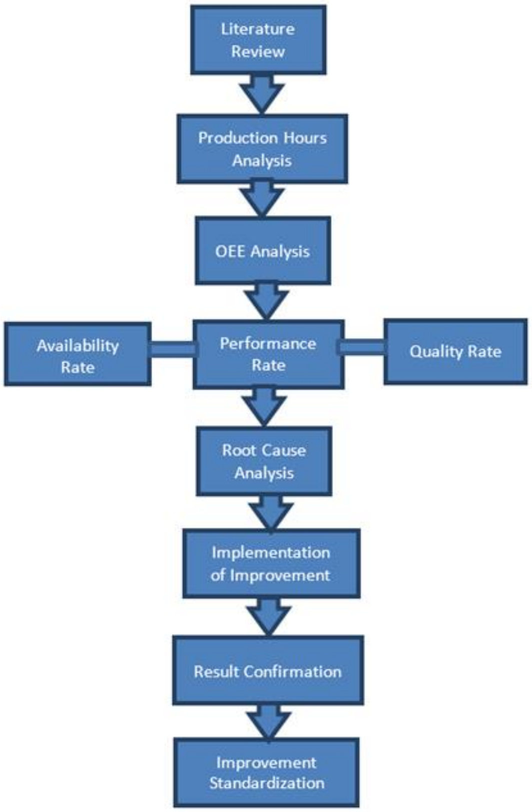

Fig. 2. Study Framework

4. Result

A. *OEE analysis from Mold SLDX*

Table 3
Availability Rate (AR) of Mold SLDX period April – July 2018

Availability Rate				
Month	Available Time (s)	Down Time (s)	Operating Time (s)	AR (%)
April	727200	10800	716400	98.5%
May	1954800	126000	1828800	93.6%
June	1440000	118800	1321200	91.8%
July	1605600	108000	1497600	93.3%
Average				94.3%

A1. Percentage of Availability Rate (AR) from Mold SLDX

The results of the AR Mold SLDX period April - July 2018 shown in Table 3. As shown below, the availability rate still high enough, with the average between April-July 2018 is 94.3 %, above 90% which is Availability Rate World Class standards.

A2. Percentage of Performance Rate (AR) from Mold SLDX

The results of the PR Mold SLDX period April - July 2018 shown in Table 4. As shown below, the performance rate is low enough, with the average between April-July 2018 is 81.8 %, below 95% which is Performance Rate World Class standards.

Table 4
Performance Rate (PR) of Mold SLDX period April – July 2018

Performance Rate					
Month	Output (pcs)	Cycle Time (s)	Total Cav. (pcs)	Target Produc. Qty. (pc)	PR (%)
April	265638	18	8	323200	82.2%
May	737978	18	8	868800	84.9%
June	460872	18	8	640000	72.0%
July	628575	18	8	713600	88.1%
Average					81.8%

Table 5
Table title comes here

Month	Output (pcs)	Defect (pcs)	Finish Good (pcs)	QR (%)
April	265638	1304	264334	99.5%
May	737978	2506	735472	99.7%
June	460872	7978	452894	98.3%
July	628575	2937	625638	99.5%
Average				99.2%

A3. Percentage of Quality Rate (AR) from Mold SLDX

The results of the QR Mold SLDX period April – July 2018 shown in Table 5. As shown below, the quality rate is high enough, with the average between April-July 2018 is 99.2 %, above 99% which is Quality Rate World Class standards.

Table 6
OEE of Mold SLDX period April – July 2018

Month	OEE (%)
April	80.57%
May	79.20%
June	64.93%
July	81.78%
Average	76.6%

B. *Percentage OEE from Mold SLDX*

The results of the QEE Mold SLDX period April - July 2018 shown in Table 6. As shown below, based on calculation Availability Rate x Performance Rate x Quality Rate, OEE from April – July 2018 has average 76.6% and it still below 85% which is OEE World Class Standard.

Based on Availabilty Rate Analysis, Performance Rate Analysis, Quality Rate Analysis, and OEE Analysis, concluded that Performance Rate give significant result to decrease OEE. Compared to Availability Rate & Quality Rate, Performance Rate is the only parameter that below standard Therefore, conclusion is the main problem start from Performance Rate.

Table 7
Cavity Efficiency of Mold SLDX period April – July 2018

Month	Cavity Eff. (%)	KPI of Cavity Eff.	Actual Cycle Time (s)	Stand. Cycle Time (s)	Eff. of Cycle Time
April	87.50%	100%	18	18	100%
May	83.06%	100%	18	18	100%
June	77.80%	100%	18	18	100%
July	88.16%	100%	18	18	100%
Average	84.13%	100%	18	18	100%

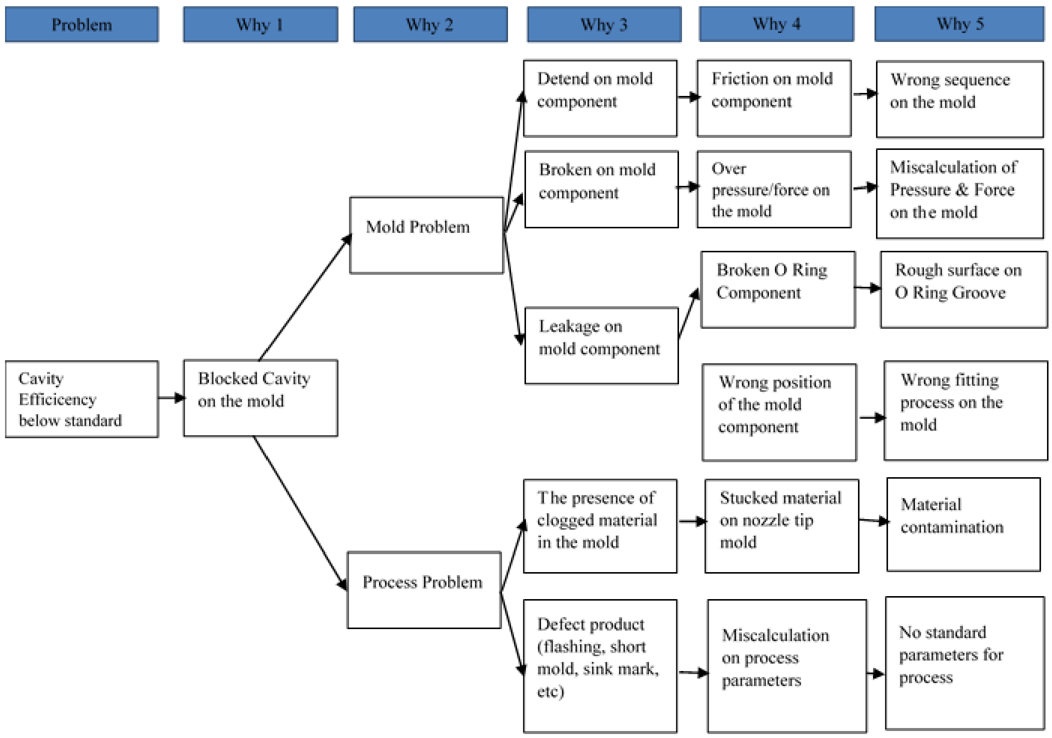

Fig. 3. Root Cause Analysis (RCA) of Mold SLDX period April–July 2018

Table 8
Countermeasure Analysis of Mold SLDX period April – July 2018

No.	Suspected Cause	Action Item	Responsible	Finding
1	Wrong sequence on the mold	Correction of mold sequence	Mold Maintenance	Mold sequence is not completely safe
		Safety system for mold sequence	Mold Maintenance	Safety system for mold sequence is not available
2	Miscalculation of Pressure & Force on the mold	Correction of pressure & force calculation on the mold	Process Engineer	Pressure & force calculation on the mold is correct
3	Rough surface on O Ring Groove	Polishing on O Ring Groove	Mold Maintenance	O Ring Groove is not rough and still has radius for the groove
4	Wrong fitting process on the mold	Correction on fitting and greasing procedure of the mold	Mold Maintenance	Mold is on correct fitting position
5	Material contamination	Develop filtering system to prevent material contamination	Material Preparation	Material contamination is not found
6	No standard parameters for process	Develop standard parameter for process	Process Engineer	Standard parameter for process already made

Based on an analysis of Performance Rate, in Injection Molding, Performance Rate is influenced by two factors, namely the cycle time and cavity efficiency. Cavity Efficiency becomes concern, because it is below the standard KPI of Cavity Efficiency, meanwhile Cycle Time still stable and same with the standard.

C. Calculation of Cavity Efficiency

The results of the Efficiency Mold Cavity SLDX period April-July 2018 shown in Table 7.

Target of Cavity Efficiency is 100%, while the result from April – July 2018 is below standard. Based on Cavity Efficiency analysis, concluded that Cavity Efficiency become critical factor that decrease Performance Rate of Mold SLDX.

D. Root Cause Analysis (RCA)

The results of analysis of Root Cause Analysis (RCA) in Mold SLDX period April-July 2018 shown in Fig. 3. Root Cause Analysis used is 5 Why Analysis. Cavity Efficiency below standard caused by blocked cavity on the mold. Blocked cavity on the mold caused by mold problem and process problem.

E. Countermeasure analysis

Results Countermeasure Analysis on the Mold SLDX period April-July 2018 shown in Table 8. Countermeasure analyzed by possible root cause shown in Fig. 3.

F. Implementation

As previously reviewed, dented on mold component caused by friction between mold components. Friction happened because there are wrong sequences on mold mechanism as shown Figure 4. Wrong sequences happened on mold mechanism are:

1. Mold close
2. Slider plate close & Core Plate forward into cavity plate

3. Injection process
4. Slider plate open, core plate backward
5. Slider plate stucked on cavity plate
6. Core plate move backward while slider plate still stucked on cavity plate.
7. Friction happened between slider plate and core plate
8. Mold dented and cavity must be blocked to prevent defect

Fig. 4. Detend on mold component SLDX

Improvement must be done to guarantee the mechanism of mold safety. As previously explained, the wrong sequence happened when slider plate stucked on cavity plate. When slider plate stucked on cavty plate, the slider plate cannot be opened, but the core move backward. Improvement must be done to prevent the slider plate stucked on cavity plate. The correct one is the slider plate must follow the movement of core plate. When the slider plate follow the movement of core plate, slider plate can be opened and the friction will not happen, so improvement must be done to make the slider plate follow movement of core plate. Slider plate can follow movement of core plate if there are some mechanism that pull the slider plate into core plate, so that improvement made by modify design of mold. With additional component, named Detent Puller, the mechanism to pull slider plate into core plate can be happened.

Fig. 5 shown design of mold after improvement when closed position. Fig. 6 with shown position of mold when opened.

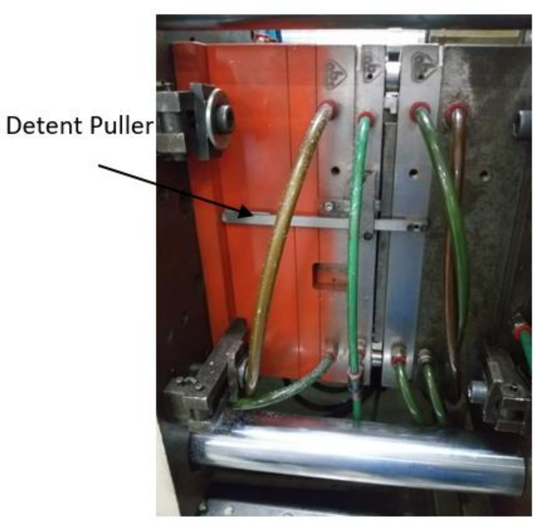

Fig. 5. Mold Close

Fig. 6. Mold Open

After detent puller added into mold, the sequence change and safety. The sequence are:

1. Mold close
2. Slider plate close & Core Plate forward into cavity plate
3. Injection process
4. Slider plate open, core plate backward
5. Slider plate pulled by detent puller to follow core plate movement
6. Core plate move backward and slider plate open
7. There are no contact and no friction between core plate and slider plate

G. Goal setting

Goal setting of improvement is 100% of cavity efficiency as shown in Table 9.

Table 9
Goal setting of cavity efficiency improvement

Current Condition		Goal	
Cavity Efficiency (%)		Cavity Efficiency (%)	
April	87.50%	August	100.00%
May	83.06%	September	100.00%
June	77.80%	Average	100.00%
July	88.16%		
Average	84.13%		

Table 10
Goal setting of OEE improvement

Current Condition		Goal	
OEE (%)		OEE (%)	
April	80.57%	August	85.00%
May	79.20%	September	85.00%
June	64.93%	Average	85.00%
July	81.78%		
Average	76.62%		

Increasing cavity efficiency of mold, will increase Performance Rate and also OEE of the mold. Increasing cavity efficiency, with target 100% Cavity efficiency, also OEE will increase. OEE Goal setting of the mold is 85%, which is World Class OEE Standard, as shown in Table 10.

H. Final result

Implementation of improvement done when detent puller already assembled on the mold. Cavity efficiency measurement after improvement start from August – September 2018. As shown in Table 11, cavity efficiency already increased from average 84.13% from April- July 2018 to 99.23% from August-September 2018. As shown, the result still below the target, which is 100%.

Availability Rate, Performance Rate and Quality Rate are also measured from August – September 2018 with result shown in Table 12, Table 13, and Table 14. There are some improvement in Availability Rate, which before improvement is 94.3% average from April- July 2018 to 96.4% average from August- September 2018 with the result in Table 15.

The most significant improvement is in Performance Rate, which before improvement is 81.8% average from April- July 2018 to 98.2% average from August- September 2018 with the result in Table 13.

Quality Rate are also increase, which before improvement is 99.2 % average from April- July 2018 to 99.7% average from August- September 2018 with the result in Table 14.

There are some significant improvement in OEE, caused by significant improvement in Performance Rate, which before improvement is 76.62% average from April- July 2018 to 93.93% average from August- September 2018 with the result in Table 15.

5. Conclusions and recommendations

In the study resulted in an increase in the average percentage of cavities where previously the average percentage of cavities in April - July 2018 was 84.13% while after improvement the average percentage of cavities in August - September 2018 was 99.23% as shown in the Figure 15 and OEE percentage increase from 76.6% in April-July 2018 to 94.33% in August-September 2018.

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Table 11
Cavity efficiency of Mold SLDX after improvement

Month	Cavity Efficiency (%)	Actual Cycle Time (s)	Standard Cycle Time (s)	Efficiency of Cycle Time
August	98.82%	18	18	100%
September	99.64%	18	18	100%
Average	99.23%	18	18	100%

Table 12
Availability Rate (AR) of Mold SLDX after improvement

Availability Rate				
Month	Available Time (s)	Downtime (s)	Operating Time (s)	AR (%)
August	1879200	45000	1834200	97.6%
September	1846800	90000	1756800	95.1%
Average	1863000	67500	1795500	96.4%

Table 13
Performance Rate (PR) of Mold SLDX after improvement

Performance Rate					
Month	Output (pcs)	Cycle Time (s)	Total Cavities (pcs)	Target Production Quantities (pcs)	PR (%)
August	812475	18	8	835200	97.3%
September	813199	18	8	820800	99.1%
Average	812837	18	8	828000	98.2%

Table 14
Quality Rate (QR) of Mold SLDX after improvement

Quality Rate				
Month	Output (pcs)	Defect (pcs)	Finish Good (pcs)	QR (%)
August	812475	1947	810528	99.8%
September	813199	2735	810464	99.7%
Average	812837	2341	810496	99.7%

Table 15
OEE of Mold SLDX after improvement

OEE	
Month	OEE (%)
August	94.72%
September	93.93%
Average	94.33%

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