Measurement and Effort to Improve OEE Value of SMC 2000 DST Machinery A PT. XYZ with PDCA Method

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Abstract. PT XYZ is a manufacturing company that produces packaged plastic bottles. Every month the company produces millions of packaged plastic bottles with various shapes and colors. The problem that still occurs today is the ineffectiveness of engine performance. This company has implemented Overall Equipment Effectiveness, but it is still limited to presenting data. Like the achievement of the average OEE value in 2017 and 2018 is 69.40% which is the OEE value of 10 Extrusion blow molding machines. Of the 10 machines, the SMC 2000 DST 3 engine achieved the lowest OEE value among the others, namely 57.95%. OEE calculations were carried out for January 2019 to November 2019 on the SMC 2000 DST 3 engine and the result was the OEE value was 59.70%. The cause of the OEE value of the SMC 2000 DST 3 machine is not ideally due to speed reduce losses. Then a causal analysis is carried out to determine the cause of speed reduce losses. Through brainstorming with related parties, the potential root cause of the problem can be obtained by using the Fishbone Diagram. Known 8 causes of 4 factors machine, material, human and method. Next, a critical to quality matrix is made to determine the ranking of the problems. It was found that the most dominant problem was that the mold cooler did not work optimally because the diameter of the channel was reduced and covered with crust. For this reason, efforts to improve and implement it using the PDCA method by considering the company's production schedule. By calculating the diameter of the channel that has been cleaned and has returned to its original size, the mold is no longer easy to heat so that the speed reduce losses can be reduced from 27.6% to 6.92% .

Keywords: overall equipment effectiveness · speed reduce losses · brainstorming · fishbone diagram · PDCA · critical to quality

1 Introduction

In the current era of globalization, all human activities can be done very quickly and without limits. This requires us to always follow and absorb all developments in all fields. This condition makes it very possible for parties who are unable or late to keep up with the times, they will be left behind and do not get their rightful place in their

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S. Sugiman et al. (Eds.): MIMSE-M-E 2022, AER 216, pp. 320–333, 2023.
https://doi.org/10.2991/978-94-6463-078-7_30

community. All information about the development of science and technology can be downloaded easily and quickly via the internet.

Along with the rapid development of the world, the industrial world is also a party that is greatly affected by these developments. So that the climate of competition is becoming increasingly fierce between companies with the same line of business or substitute business fields. The company's ability to absorb and apply advances in science and technology will be an important capital in winning industrial competition.

PT XYZ is a company whose line of business is producing packaged plastic bottles. Every month the Company produces millions of packaged plastic bottles with various shapes and colors. The problem that still occurs today is the ineffectiveness of engine performance. This company has implemented Overall Equipment Effectiveness, but it is still limited to presenting data.

The purpose of doing this research is to analyze the achievement of the value of availability, performance, and quality ratio as well as the OEE value of the blow molding machine as a production equipment and analyze and identify the root cause of the problem of not achieving the ideal OEE value according to world-class companies and identify potential causes the problem that dominates the causes of the existing causes, proposes improvements using the PDCA method to reduce the low level of OEE value compared to its ideal value as a world-class company.

The limitation of the problem in this paper is that the research period was only carried out for 11 months starting from January 2019 to November 2019, the achievement of the Overall Equipment Effectiveness value during 2017 and 2018 which was below the ideal OEE value, especially the SMC 2000 DST 3 engine which is an engine lowest performance among other machines. The calculation of the OEE value for the SMC 2000 DST 3 machine is carried out for the period January 2019 to November 2019. The calculation of the efficient value uses the Overall Equipment Effectiveness (OEE) method for the SMC 2000 DST 3 machine at PT XYZ, identifying the cause of the problem that is not ideally the Overall Equipment Effectiveness value (OEE) is the most dominant, the methods used to propose improvements to the causes of problems are Pareto diagrams, Cause and Effect Diagrams, Critical to Quality (CTQ), and PDCA.

2 Methods

2.1 Data Collection Methods

The initial stages of the research were carried out by making observations or direct observations as a whole and collecting data that supports the writing of this thesis research. Data collection is also done by means of direct interviews with several employees to identify problems faced by the company. In this study there are two types of data collection, the data obtained in the form of data arranged in written or documented form. Such as, company profile and data related to variables from Overall Equipment Effectiveness as well as direct data obtained through interviews.

2.2 Data Analysis Methods

Data processing is carried out using the Overall Equipment Effectiveness (OEE) method, the initial stages of data processing are calculating Availability values, the data needed for

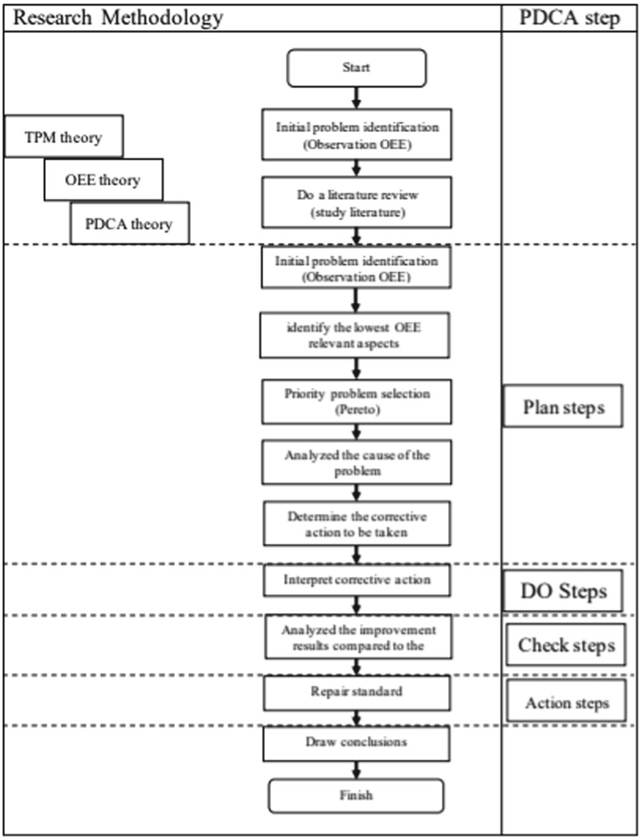


Fig. 1. Research Method.

calculating. Availability values are machine working time, planned downtime, machine downtime (failure and repair, set up adjustments). Then calculate Performance. The data used to calculate the performance ratio are the output quantity, actual cycle time, operating time (loading time, Failure and Repair, and Set up Adjustment). Furthermore, the quality ratio measurement, the data needed is the output quantity, startup reject, rework, and reject. The OEE value is obtained by multiplying the three variables so that the OEE value is obtained. After that, identify the factors that influence the cause of not ideal OEE values with a cause-and-effect diagram (fishbone). Through this fishbone diagram, an analysis of the 5M + 1E aspects will be carried out, namely man, material, machines, measurement, method, and environment. Fishbone diagrams are made by doing brainstorming involving units related to the production process. By using critical to quality (CTQ) analysis, the most dominant factors causing the problem are obtained. In general, the stages of research carried out are as shown in the form of a flow chart in the following Fig. 1.

Failure and Repair, and Set up Adjustments). Furthermore, the quality ratio measurement, the data needed is the output quantity, startup reject, rework, and reject. The OEE value is obtained by multiplying the three variables so that the OEE value is obtained. After that, identify the factors that influence the cause of not ideal OEE values with a cause-and-effect diagram (fishbone). Through this fishbone diagram, an analysis of the 5M + 1E aspects will be carried out, namely man, material, machines, measurement, method, and environment. Fishbone diagrams are made by doing brainstorming involving units related to the production process. By using critical to quality (CTQ) analysis, the factors that cause the most dominant problems are obtained.

2.3 PDCA Formula

The application of PDCA in this study follows a plan do check and action procedure, each of which will be described in detail. Improvements made to problems that occur using the PDCA method are carried out based on the results of research and data processing of Overall Equipment Effectiveness in 2017 and 2018 as well as the results of calculating OEE achievements in 2019.

Plan (Plan) The Plan stage in the PDCA method is the first step to be taken. At this stage, an analysis of the data on the progress of the production process is carried out in the period that has been running in the previous period. OEE data in 2017 and 2018 became the basic reference for determining the machine with the lowest OEE value.

Calculation of Availability Ratio Value Availability Ratio is the ratio between the time used for the machine to operate minus the length of time the machine is repaired and divided by the amount of time available. The data needed to calculate the Availability value are machine working time, planned downtime, downtime (failure and repair and set up and adjustment). Meanwhile, the formula used to find the Availability Ratio value (Nakajima, 1988) is below and the results is as seen in Fig. 2.

$$\text{Availability} = \frac{\textit{Loading Time} - \textit{Downtime}}{\textit{Loading Time}}$$

2.4 Performance Ratio Formula

Performance Ratio is a ratio that shows the ability of equipment to produce goods. The data used in this Performance Ratio measurement are Output, Actual Cycle Time, Operating Time (Loading Time, Failure and Repair, and Set up Adjustment). The formula used to find the Performance Ratio value is:

$$\text{Performance} = (\text{Out Put} \times \text{Optimal Cycle Time}) / (\text{Operating Time}) \times 100\%$$

2.5 Quality Ratio Formula

Quality Ratio is a ratio that describes the reliability of machines and equipment in producing products that comply with predetermined standards. The data needed in measuring the Quality Ratio are Output, Startup reject, Rework, and Reject. While the formula used to find the Quality Ratio value is below and the results is as seen in Fig. 3.

$$\textit{Quality Ratio} = \frac{\textit{Total Out put} - (\textit{rework} + \textit{reject start up} + \textit{defect proses})}{\textit{Total Out put}} \times 100\%$$

No	Periode	Machine working times (hrs)	Planned Down times (hrs)	Loading Times (hrs)	Failure & Repairs (hrs)	Set Up & Adjustment (hrs)	Minor Stoppage (hrs)	Operation times (hrs)	Availability Ratio (%)
1	Jan-19	624	8	616	62.75	30.50	1.50	521.25	84.62
2	Feb-19	552	8	544	45.50	15.00	3.00	480.50	88.33
3	Mar-19	600	8	592	53.00	20.50	2.50	516.00	87.16
4	Apr-19	576	8	568	50.50	25.50	3.50	488.50	86.00
5	May-19	624	8	616	48.75	15.00	4.00	548.25	89.00
6	Jun-19	432	0	432	30.50	40.50	0.00	361.00	83.56
7	Jul-19	648	8	640	25.00	27.00	2.50	585.50	91.48
8	Aug-19	624	8	616	34.50	32.00	2.00	547.50	88.88
9	Sep-19	600	8	592	20.50	24.50	4.50	542.50	91.64
10	Oct-19	648	8	640	30.50	21.00	3.00	585.50	91.48
11	Nov-19	600	8	592	42.50	25.50	2.50	521.50	88.09
Rata rata Availability 2019									88.21

Fig. 2. SMC Machina Availability Data (January 3 – November 2019).

No	*Periode*	*Total Out put (pcs)*	*Start up reject (pcs)*	*Defect proses (pcs)*	*Rework (pcs)*	*Out put Ok (pcs)*	*Quality Ratio (%)*
1	Jan-19	499,618	2,100	250	1,200	496,068	99.29
2	Feb-19	447,586	2,300	176	1,000	444,110	99.22
3	Mar-19	487,620	2,250	180	1,120	484,070	99.27
4	Apr-19	448,443	2,000	190	1150	445,103	99.26
5	May-19	495,892	1890	150	1210	492,642	99.34
6	Jun-19	360,639	2500	100	950	357,089	99.02
7	Jul-19	553,298	2170	165	1270	549,693	99.35
8	Aug-19	524,779	2100	166	1250	521,263	99.33
9	Sep-19	476,044	2230	148	1400	472,266	99.21
10	Oct-19	529,585	2000	168	1320	526,097	99.34
11	Nov-19	485,777	1980	145	1270	482,382	99.30
Rata rata *quality Rasio*							99.27

Fig. 3. SMC Machine Availability Data January 3 – November 2019

2.6 OEE Formula

Then the OEE value on the SMC 2000 DST 3 engine for the period January 2019 to November 2019 is 59.70%. The calculation method for OEE in the table above is below and the results is presented in Fig. 4.

$$\text{OEE} = (\text{Availability} \times \text{Performance} \times \text{Quality}) \times 100\%$$

Six Big Losses	Persentase (%)	Proporsi (%)	Persentase komulatif (%)
Speed Loss	27.09	68.95	68.95
Break down loss	6.89	17.54	86.49
Set Up Loss	4.42	11.25	97.73
Stoppage Loss	0.44	1.12	98.85
Start up Loss	0.28	0.71	99.57
Quality Loss	0.17	0.43	100.00
Total	39.29	100.00	

Fig. 4. Six Big Losses SMC 2000 DTC 3

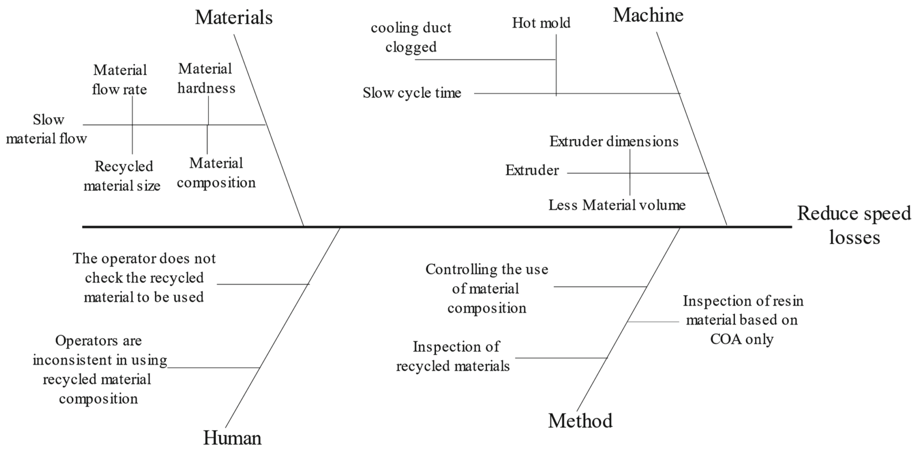


Fig. 5. Fishbone Reduce Losses SMC 2000 DTC 3

From the table above, speed reduce losses are the biggest losses and must be handled immediately. Then brainstorming is carried out to compile a fishbone diagram that is useful for identifying potential root causes of speed reduce losses (Fig. 5).

From the fishbone diagram in the picture above, there are 4 elements that can be categorized as contributing factors to the problem of speed reduce losses, namely machines, materials, methods and humans. Environmental factors are not the cause. The possible causes of each element can be detailed as shown in the description below based on each element as follows:

1. Machine

- Slow cycle times due to hot molds running at standard cycle times. The mol cooling duct is clogged with scale and dirt.

- The condition of the extruder is worn so that there is not much material being pushed forward.

2. Material

- Slow material flow rate causing slow cycle times.

3. Humans

- Operators do not check the recycled materials that will be used.
- Operators do not pay attention to the composition of virgin materials and recycled materials so that their use is unstable.

4. Method.

- The virgin material inspection procedure only sees the presence or absence of COA.
- There is no standard procedure for inspection of recycled materials.

3 Result and Discussion

3.1 Measurement

1. Machine

- It is necessary to clean the dirt that clogs the mold cooling channel (corrective). A mold preventive schedule is made periodically within the specified time.
- It is necessary to check the diameter of the Extruder within a certain period of time.

2. Material

- Inspection of virgin material must be carried out directly including hardness, melt flow index.

3. Humans.

- Make a check list of jobs by adding an approval column by the supervisor.
- Completed with a report on the preparation of production raw materials by adding approval of control by the supervisor.

4. Method.

- The virgin material inspection procedure only sees the presence or absence of COA.
- There is a need for standard procedures for inspection of recycled materials.

Factor	Potential caused speed reduce losses	Related parties									
		Head of production	Production supervisor	Head of quality department	Head of quality	Head of engineering department	Head of engineering	Head of maintenance department	Head of maintenance	Amount	Critical to quality
Machine	Hot mold	5	5	4	5	3	3	4	4	33	V
	Less volume materials output	4	3	5	3	4	4	3	3	29	
	Worn out extruder	4	4	3	3	3	3	3	3	26	
Materials	Slow material flow to the mold	3	3	4	3	3	3	3	3	27	
Human	Inspection of recycled materials is not carried out	3	3	3	3	2	2	2	2	20	
	virgin material inspection is not carried out	3	3	4	4	2	2	2	2	22	
Method	virgin material inspection method based on COA only	3	3	2	2	3	2	2	2	19	

Fig. 6. Estimated Energy Product 400 ml 2000

No	Item	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20
1	Available time (hours)	521	481	516	489	548.25	361
2	Speed (pcs/hours)	959	932	945	918	904.5	999
3	Estimated output (pcs)	499,618	447,586	487,620	448,443	495,892	360,639
4	Demand estimate (pcs)	430,000	430,000	430,000	430,000	430,000	430,000
5	Stock (pcs)	66,618	17,586	57,620			
6	Cumulative stock	66,618	84,204	141,824			

Fig. 7. Cleaning Cooling Tube Schedule

Of the many proposals, it is necessary to rank them in order to facilitate the order of implementation. With this aim, a questionnaire is needed to determine the order of priority. And the result is as follows (Figs. 6 and 7):

From the CTQ table, it can be seen that hot molds are in the top rank for immediate repair action.

Based on the results from the CTQ table, the work is designed for cleaning the mold cooling channel. As a first step, set a cleaning schedule that is synchronized with the production schedule.

From the table, information is obtained that until March 2020 there is a stock of 400 ml Energy bottles as many as 141,824 pcs. While product demand in April 2020 was 430,000 pcs. With a stock of 141,824 pcs, to meet April's demand of 430,000 pcs, in April 2020 we only need to produce 264.824 pcs. Means the machine and mold only need to work during the following time:

$$\begin{aligned} &\text{Production time in April 2020} \\ &= 264.824 / 918 \\ &= 288.48 \text{ hours.} \\ &= 12 \text{ Days.} \end{aligned}$$

According to table data, in April there were 489 h available and only 288,824 h needed for production. Then there are 489 h – 288,824 h = 200,176 h.

From the calculation above, for April 2020 the mold will be used for production for only 12 days, which is enough, from April 1, 2020 to April 12, 2020. The rest can start cleaning the cooling ducts according to the schedule below, as follows:

The schedule for the cleaning plan will be as follows (Table 1).

3.2 Do

Do is the process of implementing the planning carried out in the previous stage. At the plan stage, activity planning has been carried out and a schedule has also been prepared. The cleaning activities for the Energy 400 ml mold cooling channel are as follows:

- Remove the mold from the machine.
- Carry out disassembly of the mold by removing the neck, body and bottom. It was found that many cooling channels were clogged because there was a lot of crust that closed the cooling channels. Based on the image of the Energy 400 ml mold, the diameter of the cooling channel hole is 8 mm in diameter, but after being unloaded because it is covered with crust, it only has a diameter of 6 mm. so there is a 25% decrease in the diameter of the cooling channel.

Table 1. Cleaning Cooling Tube Schedule

No	Activity	Duration (Days)	Start	Finish	Status
1	Preparation	1	13-Apr-20	13-Apr-20	Plan
2	Removing the mold from the machine	1	14-Apr-20	15-Apr-20	Plan
3	Mold disassembly and cooling duct cleaning process.	5	15-Apr-20	20-Apr-20	Plan
4	Mold Mounting to the machine.	1	21-Apr-20	22-Apr-20	Plan
5	The mold is ready for production		23-Apr-20		

- After the mold has been unloaded, the cooling channel is cleaned by using a hand drill to scrape the dirt stuck to the cooling channel. After being matched, the cooling channel is cleaned with water. While making sure that there is no longer a layer of dirt that is still attached to the cooling channel area of the mold.
- After cleaning, the cooling channel is measured again and the diameter must return to its original size, namely 8 mm^2 in diameter (Table 2).

3.3 Checking (Evaluation)

Check is a stage in PDCA, namely evaluating the results of improvements and trials carried out at the DO stage. This check stage is a continuation of the Do stage. At this check stage, an evaluation of the test results will be carried out from repairing the cleaning of the mold cooling channel wall. From the analysis of the diameter of the cooling channel that the cooling channel hole is closed on average 25% of the actual diameter of the channel. That means we assume that so far the output of the mold is not optimal and only produces an output of 75% of the actual output of the mold.

After cleaning the cooling channel, it is assumed that the output will return to 100% of the mold output. So from this assumption can be calculated as follows:

The hourly output during this time was 75% of what it should have been 934 pcs per hour.

Then the assumption that the output after cleaning the mold cooling channel is 100%, then the calculation assumptions are as follows:

$$75\%\ \text{output mold} = 934\ \text{pcs.}$$
$$X = 934/75\% = 1245\ \text{pcs./hour.}$$

Assuming that after cleaning the mold cooling channel there is an increase in output per hour from the original 934 pcs per hour to 1245 pcs per hour, the configuration for achieving speed reduce losses for May 2020 is as follows (Table 3):

$$\text{Loading time May 20} = 616\ \text{hours}$$
$$\text{Available time May 20} = 548.25\ \text{hours.}$$
$$\text{Actual output May 20} = 682.571\ \text{pcs.}$$
$$\text{Standard output} = 1350\ \text{pcs/hour.}$$

$$\begin{aligned}&\text{Speed Reduce Losses}\\&= (\text{available Time} - (\text{Output/speed}))/(\text{Loading time}) \times 100\%\\&= (548.25 - (682.571/1350))/616 \times 100\%\\&= 42.65/616 \times 100\% = 6.92\%\end{aligned}$$

losses in May 2020 above achieved speed reduce losses of 6.92% meaning that speed reduce losses have decreased significantly.

As a result of the speed reduce losses, which experienced a very significant improvement, the performance ratio in May 2020 will also be better. Then the calculation will be as below:

Table 2. Cleaning Doing

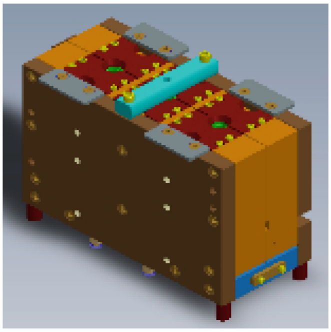
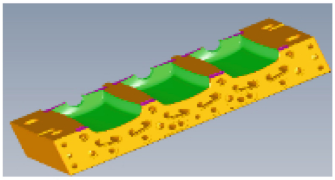
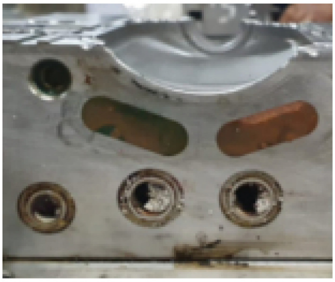
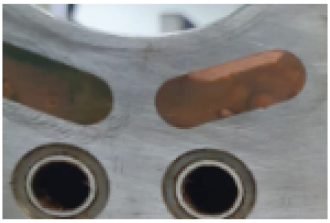
No	Activity	Figure
1	Plastic Bottle Maker Mold	
2	The condition of the mold when it is new, the diameter of the cooling channel is 8 mm	
3	Within 4 years the condition of the mold cooling channel is clogged with dirt, on average, almost 25% of the channel is clogged. When the channel size is only 8 mm in diameter after being clogged, the average diameter is only 6 mm.	
4	Condition The mold cooling channel after cleaning, the size returns to a diameter of 8 mm	

Table 3. Assumed achievement of Speed reduce Losses

Periode	Loading time (hours)	Available Time (hours)	Actual Output (Pcs)	Cycle time standard (Pcs / hours)	Losses time (hours)	Speed Losses (%)
Mei 20	616	548.25	682,571	1350	37.94	6.92

$$\text{Estimated Performance May 2020} = (\text{Out Put} \times \text{Optimal Cycle Time})/(\text{Operating Time}) \times 100\%$$

$$\text{Actual Estimated Output May 2020} = 682.571 \text{ pcs}$$

$$\text{Standard Cycle Time} = 1350 \text{ pcs per hour.}$$

$$= 16 \text{ seconds per 6 pcs} = 2.66 \text{ seconds/pcs}$$

$$= 0.0073 \text{ hours/pcs.} = 0.00072$$

$$\text{Operating time May 2020} = \text{Available time} = 548.25 \text{ hours.}$$

Then the estimated value of the SMC 2000 DST 3 engine performance in May 2020:

$$\begin{aligned} \text{Estimated Performance} &= (\text{Out Put} \times \text{Optimal Cycle Time})/(\text{Operating Time}) \times 100\% \\ &= (682.571 \times 0.00072)/548.25 \times 100\% \\ &= 0.899 \times 100\% \\ &= 89.64\% \end{aligned}$$

From the assumption of the calculation of the Performance ratio above, the results are as follows:

The calculation result of the SMC 2000 DST 3 engine performance ratio assumption for May 2020 is 89.64%.

The performance ratio in May 2019 was 66.03%, when compared with the assumption of achieving the performance ratio in May 2020, there was an increase of 21.46%.

The average Performance ratio from January 2019 to November 2019 was 68.18%, when compared with the assumption of achieving the performance ratio in May 2020, there was an increase of 23.61%.

3.4 Action (Standard)

Action is the final stage of the PDCA method, which is to standardize all documentation related to molds and cooling ducts. This standardization is intended so that later if it is needed or there is a manufacture of the same part or mold, then there is valid data as an initial guideline. So, there is no need for further observations or experiments. Only implementation and evaluation, if there are deviations, the corrective steps are very clear and documented. Making a regular mold maintenance schedule can be used as a standard system. Meanwhile, other improvement proposals need to be implemented immediately.

4 Conclusion

Based on the results of research and data processing on the Blow Molding machine at PT XYZ, several conclusions can be drawn, including:

- The results of observations of company data PT. XYZ's OEE achievement of blow molding machines for the 2017 and 2018 periods averaged 69.40%. As for the data for each machine, the lowest OEE achievement is the SMC 2000 DST 3 engine with 57.95% (Performance 69.35%, Availability 84.34%, and Quality 99.08%), while the machine with the highest OEE is the Automa 2 engine (D6BM- 002) with a value of 75.90%.
- The OEE value of the SMC 2000 DST 3 engine for the period January 2019 to November 2019 is 59.70% (performance ratio 68.18%, Availability ratio 88.21%, and Quality ratio 99.27%).
- From the two data periods used (Jan 2017 - Dec 2018 and Jan 2019 - Nov 2019) it shows that without a significant improvement, the OEE value will not reach the ideal value as a world-class company.
- From the calculation of the six big losses of the SMC 2000 DST 3 machine based on the production report for the period January 2019 to November 2019 the data obtained are speed reduce losses 27.09%, breakdown losses 6.89%, Set up losses 4.42% stoppage losses 0.81% start up losses 0.28% quality losses 0.17%.
- By using the Pareto diagram, it can be seen the proportion data of each of the six big losses variables. The proportion of speed losses 68.3%, the proportion of breakdown losses 17.4%, the proportion of Set up losses 11.1% the proportion of stoppage losses 2%, the proportion of start up losses 0.7%, and the proportion of quality losses 0.4%. Thus, speed reduce losses need to get top priority for improvement.
- By using Fishbone analysis and involving related parties, it can be seen that there are 8 factors that cause speed reduce losses that result in low performance values on the SMC 2000 DST 3 engine. And by using critical to quality, the highest ranking problem that must be handled is cooling print is not optimal.
- The proposed solution to the problem is to improve the cooling system of the mold by cleaning and removing the scale stuck to the cooling duct which caused the diameter of the duct to be reduced from 8 mm to 6 mm. By calculating the diameter of the channel back to its original size, the problem of hot molds can be reduced, so that speed reduce losses can be reduced from 27.6% to 6.92%.

Acknowledgement. I would like to thank those who have provided data and assisted in processing several analyzes related to this performance as well as the companies that have helped us.

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