



## Case Study in Increasing Overall Equipment Effectiveness on Progressive Press Machine Using Plan-do-check-act Cycle

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### ABSTRACT

Press automotive components manufacturer in Indonesia with the Overall Equipment Effectiveness (OEE) achievement was 60.7%, it was below than world company level as mention in Japanese Institute of Plant Maintenance (JIPM)- Total Productive Maintenance (TPM) standard, the biggest OEE components problem was availability value that achieved 63.3%, then the biggest availability problem was dies preparation time. Using TPM method and Plan-Do-Check-Act (PDCA) cycle with Pareto chart and Fishbone diagram, we succeeded to improve dies setting time within one months. We could increase the availability value from 63.3% became 67.8% and finally OEE value increased from 60.7% became 65.3%.

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## 1. INTRODUCTION

Automotive industry was grown year by year, tough competition by introducing new car model and new car brand entered to Indonesian market. Car sales amount in Indonesia from 2016 until 2018 has extensively increased [1]. The demand of cars in Indonesia has increased well, thus car manufacturers compete to win the competitive car market [2]. Increasing in the exchange rate of United State of America dollar against the Indonesian rupiah had an influence on the increasing of imported components, and also increasing of the regional minimum wages in Indonesia had impacted on the increasing of labor cost [3]. Increasing the costs of Indonesian automotive manufacture forced automotive industries must improve the cost of operation through increasing productivity, reducing quality defect, eliminating waste, etcetera.

There were many researches in automotive industry using Total Productive Maintenance (TPM) method, researching in automotive components manufacturing especially in Computer Numerical Control (CNC) machining line by improving on availability rate from 91.8 to 95.7% and it impacted to the Overall Equipment Effectiveness (OEE) value increased from 63.8% to

88.1% after implementing the Autonomous Maintenance [4]. Then there was research in the maintenance sector of company which supplies automotive air-conditioning tubes, the improvement could increase the availability from 75 to 85%, and there was a significant increase in OEE from 74 to 82% [5].

This research was done in Indonesian automotive press components manufacturer. In this press production process need many press dies to produce many press parts. Other researchers who observed the components manufacturers that used mold/dies as follows, improvement in stamping production line using Single Minute Exchange of Dies (SMED) method, by reducing non added value activities, it could increase the clamps production capacity of press machine from 60,000 to 105,000 pcs/day [6]. Improvement in injection molding machines using SMED method, the improvement result for setup time reduced from 43.24 to 21.00 minutes, by reducing set up time for non added value activities [7]. Improvement proposal to increase the availability value on the insulation line in a cable manufacturing unit [8].

Step by step improvement to solve process problems had been done by various method, there was research improved performance of equipment by enhancement of

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speed factor [9], other research in thermal power plant improved a coal handling unit using a probabilistic approach [10]. Define-Measure-Analyse-Improve-Control (DMAIC) cycle and Failure Mode and Effect Analysis (FMEA) method were used to increase the Availability value from 91 to 96% in automotive company [11]. DMAIC and Supply Chain Operations Reference (SCOR) method was used to improve supply chain performance in the textile dye case became 93% [12]. The research did improvement in automotive company using Quality Function Deployment (QFD) method, it improved the rate of quality from 96.4% became 97.9% that impacted to increase OEE value from 92 to 93% [13]. QFD approach was used to increase the quality of chocolate products [14]. Following researches did the improvement using Plan-Do-Check-Act (PDCA) cycle. PDCA cycle was done to improve quality problem in an electronic components company, it decreased the quality defect till 79% [15]. PDCA cycle was also used for reducing the Cans Loss Index (CLI) in a beverage company, the improvement reduced CLI from 0.97% to 0.78% [16].

The purpose of this study is to analyze the application of TPM in automotive components manufacturer, especially on progressive press 600T machine. This machine still has big room to improve the productivity problem in order to reduce the process cost. This research completed the TPM improvement application result based on case study on progressive press 600T machine using PDCA problem solving cycle.

## 2. LITERATURE REVIEW

**2.1. Total Productive Maintenance** Ahuja and Khamba [17] reported that Total Productive Maintenance (TPM) is a unique Japanese philosophy, it has been developed based on the Productive Maintenance concepts and methodologies. TPM was introduced by Nippon Denso Co. Ltd. of Japan, a supplier of Toyota Motor Company Co. Ltd, Japan in 1971. Nakajima [18] introduced the Total Productive Maintenance refers to the key words: Total, Productive, and Maintenance, as follows:

- Total means involvement of all employees and management then covers the total life cycle of the production process.
- Productive means increasing productivity through zero accidents, zero defects and zero damage, then minimize the problems in the production process.
- Maintenance means maintaining good production system.

**2.2. Overall Equipment Effectiveness** The Overall Equipment Effectiveness (OEE) is a value that being used to evaluate and measure the extension of the

successful TPM implementation, this measurement is very important in order to find out which areas need to be improved in machine productivity and product quality.

OEE is formulated as Equation (1).

$$OEE = AV \times PE \times RQ \times 1,000,000\% \quad (1)$$

where Availability (AV) is formulated as Equation (2):

$$AV = \frac{\text{Loading Time} - \text{Breakdown Time}}{\text{Loading Time}} \times 100\% \quad (2)$$

Performance Efficiency (PE) is formulated as Equation (3):

$$PE = \frac{\text{Process Amount} \times \text{Ideal Cycle Time}}{\text{Loading Time} - \text{Breakdown Time}} \times 100\% \quad (3)$$

Rate of Quality (RQ) is formulated as Equation (4):

$$RQ = \frac{\text{Process Amount} \times \text{Defect Amount}}{\text{Process Amount}} \times 100\% \quad (4)$$

World Class Manufacturing OEE's Standard and it's three OEE factors are shown in Table 1 below:

**2.3. PDCA Cycle** The PDCA cycle is step by step improvement, it has four steps that started by "Plan" step then it is continued by "Do", "Check" and finalized by "Act" step. This method is based on process improvement according to Deming cycle.

In "Plan" step, it started to define the problems from research area, then we choose the priority problems that need to be improved from all listed problems, researchers usually utilize Fishbone diagram to find out the root causes. Furthermore we develop possible solutions plan based on root causes. A useful tool which helps to show the problem can be used Graph, Pareto Diagram, Histogram and Control Chart. Quality management methods to solve a problem on the production line using several quality tools can bring more significant benefits and be more productive [19].

In "Do" step, we improve all selected solutions plan. In order to avoid big problem in current process, it will be better if we have pilot solutions in order to confirm the validity and accuracy of analytical step before, thus we have time to make any corrections before applying the solutions on a large scale in actual process.

In "Control" step, we control the improvement result and process. In this stage need confirmation of any changes at the "Do" step before. It also needs to control of the process in order to minimize deviation from the each objective and ensure that all corrections are

**TABLE 1.** World class manufacturing OEE's standard

Availability (AV)	90%
Performance Efficiency (PE)	95%
Rate of Quality (RQ)	99%
Overall Equipment Effectiveness (OEE)	85%

implemented before happening bad impact on the result and the process. A useful tool which helps to control the data can be used Control Chart in order to identify the process whether controllable or not.

In “Act” step, after successfully achieving problem solving activities, we need to standardize all activities in order to avoid same root causes occurred and impacted to the same problem happen. PDCA cycle as continues improvement cycle, therefore we must continue to do the others improvement by choosing new theme of problems.

### 3. RESEARCH METHODOLOGY

This research used secondary data that collected from press production report, it consists the press machine loading time, machine breakdown time, machine stand-by, production amount and number of defect products. The objective of this research is to find out a solution to the availability problems on the 600T progressive press machine. Researchers used Total Productive Maintenance method with utilization of Pareto diagram and Fishbone diagram. All problem solving activities use Plan-Do-Check-Act (PDCA) cycle.

The framework of this research is illustrated in Figure 1. Starting from gap between Overall Equipment Effectiveness (OEE) achievement and OEE company target on the 600T progressive press machine, then analyze the components of OEE problems using Pareto diagram as a tool to analyze the root causes. We did focus group discussion session and observed 600T progressive press machine directly in order to define and choose the problems that will be improved, after that we analyzed the root causes, then we proposed variant solution plans. We involved related parties such as Production, Maintenance, Inspection and Engineering section in order to increase the analysis accuracy and to propose variant solution plans.

### 4. RESULTS AND DISCUSSION

This research did improvement by utilizing Plan-Do-

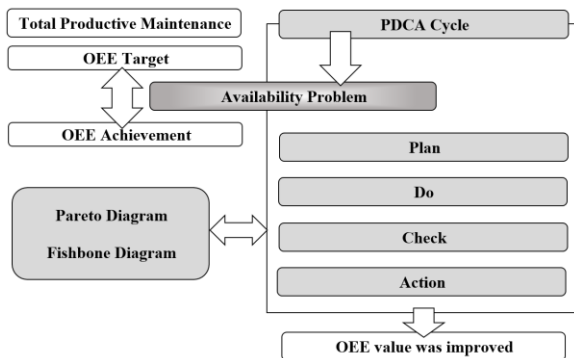


Figure 1. Research framework

Check-Act (PDCA) cycle based on previous research in wide area. The difference of this research and others are the improvement was held in automotive 600T progressive press machine using PDCA cycle with quality control tools. This 600T progressive press machine produced press components for car seat track adjuster and window regulator as shown in Figure 2.

#### 4. 1. “Plan” Step

The first step is “Plan”, we started to observe the problems that found on the 600T progressive press machine. The comparison of OEE achievement and company target from October until December 2019 can be seen in Figure 3. The OEE company target was 75% while the OEE average achievement in three months was 60.7%, thus the OEE achievement was below than the world class company target as valued 85%. There was a gap that need to be improved the problem 14.3% to achieve company target and 24.3% to achieve world class company target.

We defined the OEE achievement problem based on three components such as Availability (AV), Performance Efficiency (PE) and Rate of Quality (RQ). The achievement of OEE components compared to world class company target as shown in Figure 4.



Figure 2. Press product image

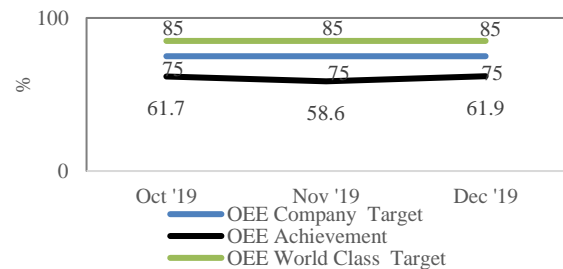


Figure 3. OEE achievement and company target

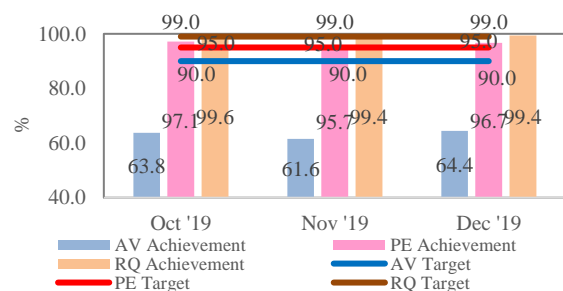


Figure 4. OEE components achievement and world class target

From Figure 4, we could see that the PE and RQ value achieved the world class target, just AV value did not achieve world class target. There was 26.7% gap between AV value achievement and world class target, thus we defined the 600T progressive press machine problem was availability achievement that need to be improved. We observed and measured the availability contribution problems in three months. We gathered related information for the availability problem in current process using Pareto chart, we found the biggest contribution time problem to the availability was Dies preparation than followed by Machine breakdown, Coil preparation, Quality Control check and Minor stoppages. All Availability problems contribution as shown in Figure 5.

Dies preparation flow process on 600T progressive press machine can be seen in Figure 6.

In this research we agreed to improve “End coil process problem” in dies preparation of 600T progressive press machine. We continued to measure the time of end coil preparation job as shown in Table 2.

From Table 2, we found that there were waste times in the End coil preparation job, such as Pulling end coil, Turning on switch and Checking pilot pin.

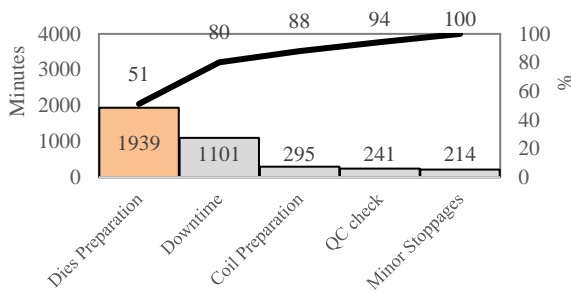


Figure 5. Availability problems contribution

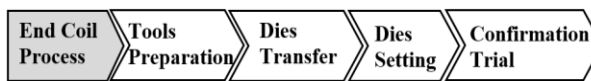


Figure 6. Dies preparation flow process

TABLE 2. End coil preparation detail job time

No.	Job	Actual Time (s)	Waste Time
1	Pulling end coil	71	Yes
2	Turning on switch	11	Yes
3	Moving dies before lower limit	28	No
4	Checking pilot pin	52	Yes
5	Moving dies until upper limit	28	No
<b>TOTAL</b>		<b>190</b>	

We analyzed the end coil process time was over than target. We involved all related parties in order to find out the causes of problem, we used Fishbone Diagram as shown in Figure 7. From Figure 7, we could inform that the effect of this problem was over time in the end coil process, it was written at head of fish. We started to find the root cause from problem finding in Table 2 as following activities: Pulling end coil, Turning on switch and Checking pilot pin. Using why-why question for pulling end coil over time was caused by weak clamping of end coil roller, it was caused by there was a gap between end coil roller and supporter. The overtime problem of turning on switch was caused by unstable of end coil position, it was caused by no stopper for end coil position. The overtime problem of checking pilot pin was caused by un clear seen of pilot pin hole, it was caused by not enough lighting in pin hole area. Thus the root causes of end coil preparation overtime were gap between end coil roller and supporter, no stopper for end coil position and not enough lighting in pin hole area.

For root cause of a gap between end coil roller and supporter, we proposed solutions plan: additional filler plate in coil adjuster and additional pressure spring in coil adjuster. For root cause of no stopper for end coil position, we proposed following solutions plan: additional stopper for end coil position and making end coil special sliding construction. For root cause of not enough lighting in pin hole area, we proposed following solutions plan: additional lamp for pin hole area and moving the current lamp position to pin hole area.

After discussion among researcher, we decided to choose the solutions plan as follow: for root cause of gap between end coil roller and supporter, we decided solutions plan was additional pressure spring in coil adjuster. For root cause of no end coil position stopper, we decided solution plan was additional stopper for end coil position. For root cause of not enough lighting in pin hole area, we decided solution plan was moving the current lamp position to the pin hole area.

**4. 2. “Do” Step** In the “Do” step, we improved all selected solutions plan within one month. In order to avoid big problem in current process, thus the improvements were done after working hours. First

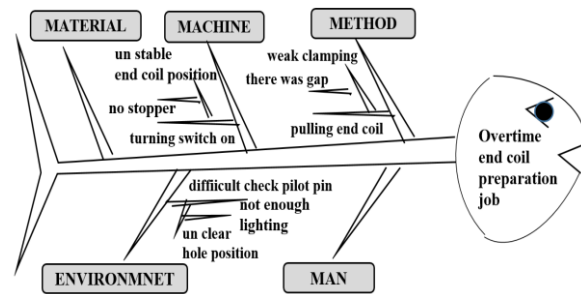


Figure 7. Fishbone Diagram

improvement was additional pressure spring on coil adjuster, first spring length was 30 mm, the coil movement was unsmooth, then it changed to 20 mm spring length, the coil movement was still unsmooth, then it change to 14 mm spring length, the coil movement was smooth in this condition. Second improvement was additional stopper for end coil position, after implementing this second solution, the end coil position have been fixed. Third improvement was moving the current lamp position to the pin hole area. Improvement activities as shown in Table 3.

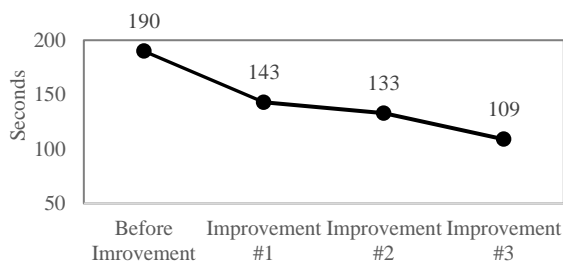
**4. 3. "Check" Step**

In the "Check" step, we controlled the improvement result and process. First improvement was additional pressure spring on coil adjuster, in this improvement we could reduce time to pull the end coil from 71 seconds became 24 seconds. Second improvement was additional stopper for end coil position, in this improvement we could reduce time to fix the end coil position from 11 seconds became 1 second. Third improvement was moving the current lamp position to the pin hole area. After implementing this third solution, we could reduce time to check pilot pin from 52 to 28 seconds. Finally we could reduce end coil preparation time from 190 seconds became 109 seconds. Trend of time reduction for each improvement can be shown in Figure 8.

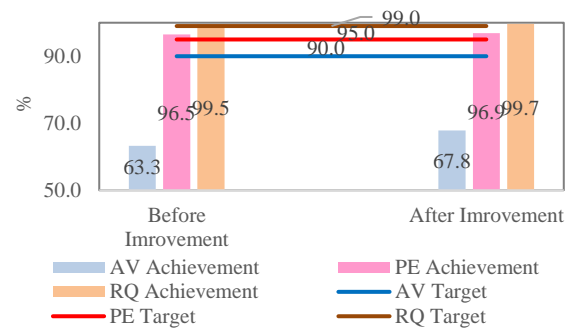
Based on reducing time of end coil preparation, we could calculate the Overall Equipment Effectiveness (OEE) components, it impacted to the increasing of Availability (AV) value. the result of three OEE components before and after improvement compare to the World class target can be shown in Figure 9.

**TABLE 3.** Improvement activities

No.	Improvement Activities	Spent Time (h)	Manpower (Person)	Cost (US \$)
1	Additional pressure spring	32	2	550
2	Additional stopper	16	2	170
3	Moving lamp position	8	2	120



**Figure 8.** Trend of time reduction



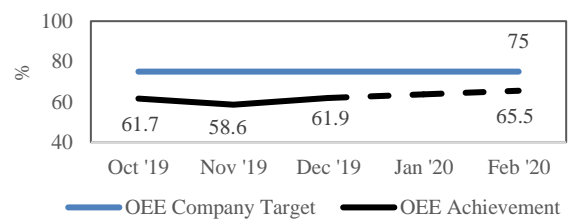
**Figure 9.** OEE components achievement comparison

Finally, this improvement could impact to OEE achievement from 61.9% in December 2019 became 65.5% in February 2020 as shown in Figure 10.

**4. 4. "Act" Step**

In the "Act" step, we standardized all activities in order to avoid same root causes occurred and impacted to the same problem happen. There were three root causes that needed to be controlled as follows: there was a gap between end coil roller then we standardized the function of pressure spring on coil adjuster, there was not stopper for end coil position then we standardized the function of additional stopper for end coil position and special sliding construction, lighting in pin hole area was not enough then we standardized the lamp position for pin hole area. Next action that will be improved is the problem in dies preparation especially in tools preparation job.

In order to avoid machine breakdown because of these improvements, we trained all related operators to do Autonomous Maintenance (AM) with following Autonomous Maintenance check sheet as shown in Figure 11.



**Figure 10.** OEE achievement after improvement

No.	ITEM	STANDARD	KEY POINT	IMAGE	INCHARGE	
					1st Shift	2nd Shift
1	Pressure spring on coil adjuster	Spring 14 mm	- Enough pressure - Adjustable bolt to add spring force			
2	Stopper for "end coil" position	On position	- It can stop "end coil" movement			
3	Lamp position for "pin hole" area	Lighting 300 Lux	- Enough lighting for pin hole area			

**Figure 11.** Autonomous Maintenance Check Sheet

## 5. CONCLUSION

Based on the previous average OEE value on the 600T progressive press machine was 60.7%, this achievement was lower than the World Class Manufacturing OEE's standard 85%. It was below than company's OEE target 70%. Thus there was gap 9.3% for improvement in order to achieve company target. From the data analysis, we found the biggest gap of OEE factors to the company target was AV as valued 63.3%, then we focused to increase the AV value. Based on Fishbone diagram, we found the root causes as follows: There was gap between end coil roller and supporter, There was not a stopper for end coil position, Lighting in pin hole area was not enough. Then improvement activities were done based on above root causes as follows: Improving coil table with pressure spring and stopper, and Moving lamp position to pin area. After implementing above improvements, we could increase AV value from 63.3 to 67.8% then impacted to OEE achievement from 60.7 to 65.3%.

We hope to others researcher can continue to do the research in TPM area in order to increase the OEE value based on improvement in utilization of Industrial Revolution 4.0.

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**Persian Abstract**

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**چکیده**

مطبوعات سازنده قطعات خودرو در اندونزی با موفقیت کلی تجهیزات (OEE) 60.7٪، آن را کمتر از سطح شرکت جهانی است، همانطور که در موسسه نگهداری کارخانه ژاپن (JIPM) ذکر شده است - استاندارد نگهداری تولیدی کل (TPM)، بزرگترین اجزای OEE مشکل مقدار در دسترس بودن بود که 63.3٪ بدست آورد، سپس بزرگترین مشکل در دسترس بودن زمان آماده سازی بود. با استفاده از روش TPM و چرخه (PDCA) Plan-Do-Check-Act با نمودار پارتو و نمودار Fishbone، ما موفق به بهبود زمان تنظیم قالب در طی یک ماه شدیم. ما می توانیم مقدار در دسترس بودن را از 63.3٪ به 67.8٪ و در نهایت مقدار OEE از 60.7٪ به 65.3٪ افزایش دهیم.

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