Reducing Downtime of Extruder Machine Using Plan Do Check Action and Failure Mode and Effects Analysis Methods in Indonesia Leading Tire Manufacturing

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Abstract*—PT Tire Manufacturing Indonesia Tbk is the largest tire company in Southeast Asia. The company has a problem of high amount of downtime in the extruder machine. Extruder machine is a production machine that produces the tread of the tire. The amount of downtime caused by machine failure will reduce the quantity and quality of the product, so it will adversely affect competition between similar companies. The total of downtime per month is around 17.8 hours, then the potential production loss will be 3900 treads per month or equivalent to IDR.1,400,000,000. Therefore, this study aims to reduce the amount of downtime by implementing the PDCA cycle, seven tools and the FMEA method. The results showed that the downtime problem in the extruder machine 4 (ATE-4), especially in the skiver section can be minimized by using the PDCA, Seven Tools and FMEA approaches. The results of the improvements that have been made show that there is a decrease in downtime in the skiver section of the extruder machine from an average of 796 minutes per month to 30 minutes for the last 2 months.

***Keywords*—downtime, extruder machine, PDCA, FMEA, seven tools**

I. INTRODUCTION

PT TMI Tbk has several plants, each plant produces a different type of tire. Plant A is a plant that produces Bias tires type or tires intended for commercial vehicles. In this plant there are various types of production machines. In general, production process in plant A divided into three areas, there are material area, building area and curing area. In the material area, there are five types of machines, each machine has a different amount of downtime, from Fig. 1, it can be seen that the highest downtime is in the tread extruder number 4 (ATE-4) machine, the amount is 6415 minutes in six months. On average, the total of downtime per month is around 17.8 hours, then the potential production loss will be 3900 treads per month or equivalent to IDR.1,400,000,000.

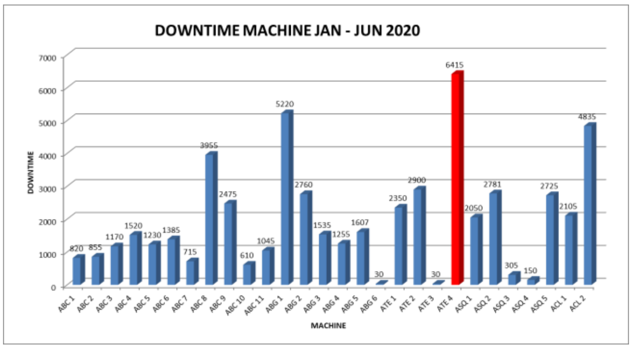

Fig. 1. Downtime data in the material area

The effect of this downtime is a decrease in machine speed and performance resulting in a low OEE value. Low OEE makes the results of production that are not as planned, many machining results are rejected and reworked, and requires long setup and adjustment times. Conversely, if the OEE is high, it will be able to increase productivity [1]. High machine downtime has an impact on the disruption of the production process, so that the achievement of production is not optimal [1]. Therefore, an analysis is needed to reduce the amount of downtime in the extruder machine.

This research will identify, analyze the root cause and reduce the amount of machine downtime in the extruder machine by using FMEA and Seven Tools in the frame of PDCA. This research used the PDCA frame, because with this method we can use it to get the best product quality [2]. With the help of the PDCA methodology, we are able to reduce rejection problems; we will improve product quality and productivity [2]. This research also used FMEA method because it can be used to find the cause of problems, in some cases of potential problems, along with workable solutions that can improve quality [3].

II. THEORITICAL PERSPECTIVE

A. *Downtime*

Minimizing machine downtime in the manufacturing industry can provide benefits such as higher machine efficiency. Reducing downtime can increase machine availability which in turn can increase production yields. Minimizing downtime can also reduce waiting times for orders and increase customer satisfaction with the products produced [4]. The production process will be hampered if there is machine downtime. Companies must reduce machine downtime so that the production process can run optimally. The production process which often has downtime has decreased its production capacity [5]. Production machines that suddenly cannot function or experience downtime cause losses for the company both in terms of time, profit opportunities, and costs incurred to improve the condition of a malfunctioning machine [6].

B. *Extruder Machine*

In general, an extruder machine consists of several main components, namely an electric motor, screw, hopper, barrel, die and heater. The extruder machine is driven by using an electric motor that can move the screw. The heater will heat the plastic material or compound that is inserted through the hopper and then the screw movement will push the plastic material that has melted through the nozzle and into the mold or die [7]

C. *Plan, Do, Check, Action (PDCA)*

PDCA is a model for making continuous improvement by planning, doing, checking, and taking action. The PDCA cycle is generally used to test and implement changes to improve the performance of a product, process or a system in the future [8].

D. *Failure Mode and Effect Analysis*

FMEA is a technique used to identify, prioritize and reduce problems from a system, design, or process before they occur. In addition, FMEA is a methodology designed to identify potential failure modes in a product or process before they occur, consider the risks associated with these failure modes, identify and implement corrective actions to address the most important problems [9]. FMEA identifies information on each type of failure, cause of failure, impact of failure and recommended action. Furthermore, to determine the priority level which is considered to have a high risk of each failure, the Risk Priority Number (RPN) method is used [10]. The RPN value comes from the multiplication of the severity of each failure impact, the probability of occurrence of each cause of failure and the level of detection of each cause of failure [10]. The formula for calculating RPN is [10].

$$RPN = S \times O \times D \quad (1)$$

Where:

S = Severity, O = Occurrence, and D = Detection

The criteria for determining number for severity, occurrence and detection can be seen in Table 1, Table 2 and Table 3.

TABLE I
DETERMINATION OF SEVERITY VALUE [11]

EFFECTS	RANKING	DESCRIPTION
Dangerous without warning	10	A system failure that has a very dangerous effect
Dangerous and there is a warning	9	A system failure that produces harmful effects
Very High	8	The system does not operate
High	7	The system operates but cannot run fully
Moderate	6	The system is operating and safe but has decreased performance so that it affects output
Low	5	Experience a gradual decline in performance
Very Low	4	Little effect on system performance
Small	3	Little effect on system performance
Very Small	2	Negligible effect on system performance
None	1	There is no effect

TABLE II
DETERMINATION OF OCCURRENCE VALUE [10]

RATING	PROBABILITY OF OCCURANCE
10	More than 50 per 7200 hours of use
9	36-50 per 7200 hours of use
8	31-35 per 7200 hours of use
7	26-30 per 7200 hours of use
6	21-25 per 7200 hours of use
5	16-20 per 7200 hours of use
4	11-15 per 7200 hours of use
3	5-10 per 7200 hours of use
2	Less than 5 per 7200 hours of use
1	Never at all

TABLE III
DETERMINATION OF DETECTION VALUE [11]

RATING	DETECTION DESIGN CONTROL
10	The check will always be unable to detect potential causes or failure mechanisms and modes of failure.
9	The check has a "very remote" possibility of being able to detect potential causes or failure mechanisms and failure modes.
8	The check has the possibility of "remote" being able to detect potential causes or failure mechanisms and modes of failure.
7	Checks have a very low probability of being able to detect potential causes of failure and failure modes.
6	Checks have a low likelihood of being able to detect potential causes or failure mechanisms and modes of failure.
5	The checks have a "moderate" probability of detecting potential causes or mechanisms of failure and failure modes.
4	Checks have a “moderately high” probability of detecting potential causes or mechanisms of failure and failure modes.
3	Checks have a high probability of detecting potential causes or failure mechanisms and modes of failure.
2	Checks have a very high probability of detecting potential causes or failure mechanisms and modes of failure.
1	The check will always detect potential causes or failure mechanisms and failure modes.

E. *Seven Tools*

Seven tools are tools used to map problems to make them easier to understand and find the root cause of a problem [12].

- Check Sheet
  A check sheet is a data collection sheet that is used to facilitate and simplify data recording. Check sheets can be used to determine the distribution of the production process, determine the number of defective products, the location of defects, and the cause of defects [12].

- Stratification
  Stratification is a table that classifies problems (in this case machine downtime) into several groups. This study classifies machine downtime into their respective parts [12].

- Histogram
  A histogram is a kind of bar chart that is used to show variations in data. In the context of quality

management, a histogram is a graphical device that shows the distribution and pattern of data from a process [12].

- Scatter Diagram
  Scatter diagrams are used to express the relationship between one factor and certain characteristics. If the two variables are correlated, the coordinate point is in the form of a line or curve [12].

- Control Chart
  Control chart is a map that is used to change the process over time. It will be able to detect whether the process is running well or not. The map is used to evaluate whether a process is under statistical quality control or not [12].

- Pareto Chart
  The Pareto chart is a chart containing both a bar chart and a line chart. Bar charts show data classifications and values, while line charts represent cumulative data totals. Data classification is sorted from left to right according to the order of highest to lowest ranking. The Pareto chart identifies 20% of the causes of problems vital to achieving 80% of improvement overall [12].

- Fishbone Diagram
  A cause-and-effect diagram is a tool used to identify various potential causes of an effect or problem and analyze the problem through brainstorming. The problem will be broken down into related categories; which includes humans, materials, machines, procedures, policies, and so on. Each category has a cause that needs to be broken down through a brainstorming session [12].

III. RESEARCH METHODOLOGY

Referring to Fig. 3, this research is classified into descriptive research, the methods used are PDCA and FMEA. The data needed are data machine damage on the material machine area. The selection of the most critical machines is illustrated by the Pareto diagram. PDCA and FMEA methods are used to determine critical components contained in machines in the material area of PT Tire Manufacturing Indonesia. The PDCA method consists of four steps, they are Plan, Do, Check and Action.

A. *Scoope of the Research*

The scope of this research is

- To analyze the downtime data of tire manufacturing machine on Bias Plant
- To develop the improvement to reduce the amount of downtime machine
- To compare the before and after data to analyses the effectiveness

This research was conducted at PT Tire Manufacturing Indonesia's especially at extruder machine of Bias tire plant, which is located in Banten province, Indonesia. There are 4 extruder machines in Bias tire plant. This research contains efforts to reduce downtime in the extruder machine.

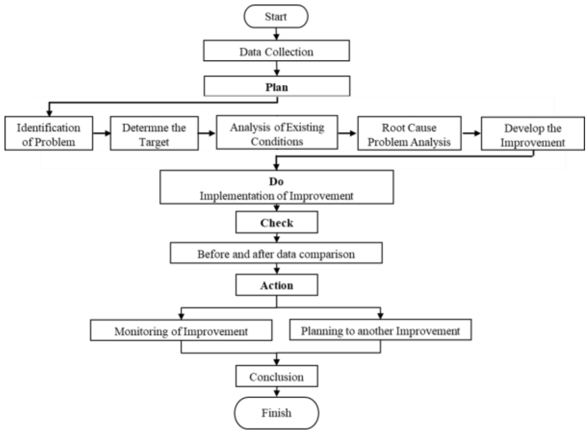

Fig. 2. Research flow

B. *Equipment*

Extruder machine is one of the machines in PT Tire Manufacturing Indonesia. This machine has a tread product output or a part of the tire that is in direct contact with the road as shown in Fig. 3. The working principle of the extruder machine is to change the compound into tread through the injection process.

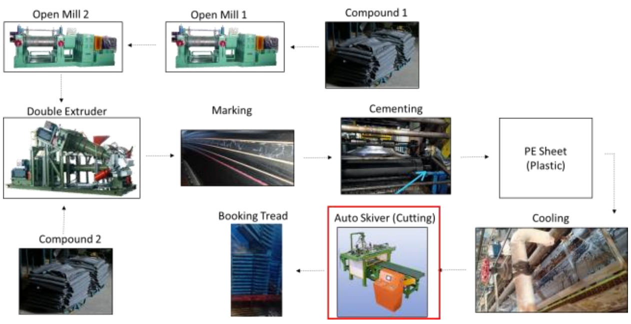

Fig. 1. Flow of tread production process

There are two types of compounds used to produce treads, we can call it compound 1 and compound 2. Compound 1 must go through a two milling process in the open mill, namely open mill 1 and open mill 2, then enter the top extruder (upper extruder), while compound 2 goes directly to the bottom of the extruder (lower extruder). The output of the extruder is tread, this tread will go to the marking section using a conveyor. In this section the tread is given a colorful outline and the identity of the tread. This line serves to make it easier to find out the type of tread. After passing the marking process, the tread will go to the cementing process. Cementing process is the process of coating the bottom of the tread with cement. The function of cement is so that during the assembly process the tread can stick firmly to other material. The next process is Plastic Plating, this coating functions to protect the cement from being contaminated with foreign objects, such as dust and etc. After the tread is coated with plastic, the tread will go to the cooling process. This process serves to reduce the tread temperature. After the tread goes through the cooling process, the next process is cutting the tread on the Auto Skiver section. The length of the tread is cut according to the specifications of each type of the tread. After the tread is cut, the next process is booking. Booking is the process of placing tread pieces on the pan truck by the operator.

IV. RESULT AND DISCUSSION

A. *Plan*

- Determine the theme

From Fig. 1 it can be seen that the Extruder 4 (ATE-4) machine is a machine that has the highest downtime, which is 6415 minutes. This downtime causes the extruder machine's productivity to drop. After knowing that the extruder machine 4 is the highest contributor to downtime, the next step is to stratify or group the types of damage that occur.

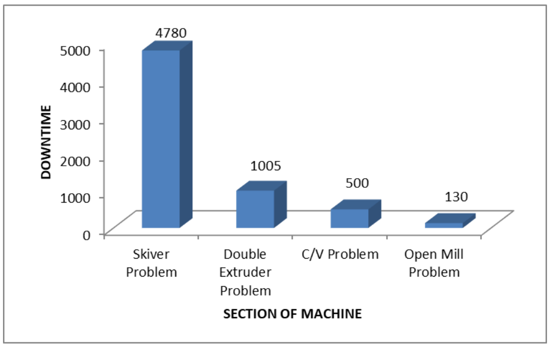

Fig. 4. Breakdown downtime per section

From Fig. 4, it can be seen clearly that the skiver section is the section that has the highest downtime value, which is equal to 4780 minutes. Based on the data presentation that has been done, the research will focus on making improvements to the skiver section.

- Analysis of existing condition

After looking at the data exposure at the stage of determining the theme, Fig. 5 is showing the most damage occurs in the skiver section. The following is an overview of how the skiver works and analyzes the existing conditions why the skiver section is often damaged.

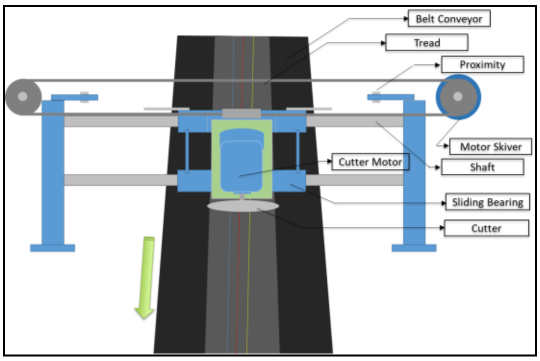

Fig. 2. Sketch of the skiver section

The skiver section is part of the Extruder Machine line which functions to cut treads according to predetermined lengths and angles. In this section there are several main sections, such as Belt Conveyor, Proximity, Shaft, Induction Motor, Sliding Bearing, Cutter, Flexible Hydraulic and Cylinder Hydraulic. The following will explain how the skiver section works. When the tread length on the conveyor belt is in accordance with the predetermined size, the hydraulic cylinder will drop, after which the skiver motor will move to the left. Skiver motor will stop moving to the left after hitting the proximity sensor. Then simultaneously the hydraulic cylinder rises to the top and the tread cut on the conveyor belt moves forward. Then the skiver motor returns to the right and the tread continues to move forward until the tread length is met. The tread cutting process uses running water to avoid slipping between the tread and the knife when cutting.

- Problem analysis (fishbone diagram)

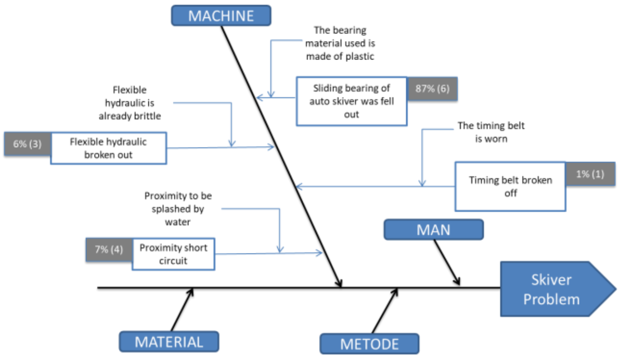

Fig. 3. Fishbone diagram

From the fishbone diagram in Fig. 6 It can be seen that the factors that cause the skiver problem come from the machine factor. In the machine factor there are 4 problems that have different downtime percentages, starting from bearing damage which has a downtime percentage of 87% with a frequency of damage 6 times in a period of 6 months, then proximity damage which has a downtime percentage of 7% with a failure frequency of 4 times, followed by the downtime of the flexible hydraulic section which has a percentage of 6% and a frequency of failure of 3 times and the last is the downtime of the timing belt which has a percentage of 1% with a frequency of failure of 1 time in 6 months.

- Problem analysis (FMEA)

The FMEA method shows the Risk Priority Number (RPN) value as a reference in determining the selection of maintenance strategies, namely, predictive maintenance, preventive maintenance or corrective maintenance. The Risk Priority Number (RPN) value is a risk rating for each failure mode obtained by multiplying three elements, namely the value of severity, occurrence, and detection. Table 4 is the RPN value of the skiver section.

TABLE IV
RISK PRIORITY NUMBER OF SKIVER SECTION

Item	Function	Failur Mode	Failur Mode Effect (s)	Severity	Failure Cause	Occurrence	Current Control Prevention	Current Control Detection	Detection	RPN	Recommendation	Action Taken	Resulted S	Resulted O	Resulted D	Resulted RPN
1	Skiver Section	Linear Motion (Bearing)	Machine stop production	8	The bearing material used is made of plastic	10	Montly Checksheet	Check the condition of the linear motion baller	5	400	Change the bearing material to a stronger one	Replace the linear motion (bearing) to bushing	8	1	5	40
2		Proximity Sensor	Machine stop production	8	Proximity to be splashed by water	4	Montly Checksheet	Check the function of proximity	10	320	Change the sensor type to avoid splashing water	Replace the proximity sensor to photo cell sensor	8	1	10	80
3		Flexible Hydraulic	Machine stop production	8	Flexible hydraulic already brittle	3	Montly Checksheet	Check the condition of the surface flexible hydraulic	4	96	-	-	-	-	-	-
4		Timing Belt	Machine stop production	8	The timing belt is worn	2	Montly Checksheet	Check the condition of the surface timing belt	4	64	-	-	-	-	-	-

The maintenance strategy can be determined based on the RPN value. Preventive maintenance strategies (200 <RPN <300) and corrective maintenance (RPN <200), while for RPN values more than 300 are categorized as predictive [10]. In this research, we will improve the parts that have an RPN value more than 300 or change their types so that the RPN value decreases. So, based on the RPN value and the level of downtime, the parts that will be improved are the sliding bearing and the proximity sensor.

- Develop the improvement

In planning improvements we use the 5W + H rule that has been mentioned in the theoretical basis. To make it easier to write and read the results of the analysis, and then make it in tabular form such as Table 5.

TABLE V
IMPROVEMENT PLANNING 5W + 1H

Main Problem	Factor	Cause Problem	What	Why	How	Where	When	Who	Target
Damage of Auto Skiver	Machine	Bearing Problem	Sliding bearing of auto skiver was fell out	The bearing material used is made of plastic	Replaced the sliding bearing to bushing	ATE-4	23-Oct-20	Engineering Dept.	Auto Skiver is not stuck anymore
	Machine	Proximity Problem	Proximity short circuit	Proximity to be splashed by water	Replaced type of sensor from proximity to photocell	ATE-4	23-Oct-20	Engineering Dept.	Sensor is not short circuit

In Fig. 7 you can see the old parts and the new parts that will be used.

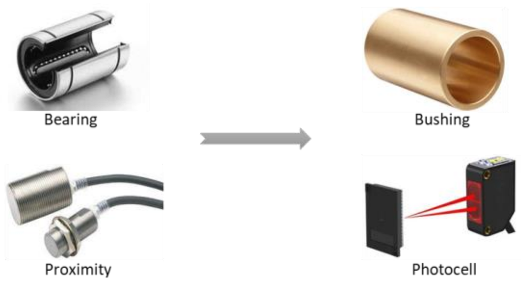

Fig. 4. Part preparation

B. Do (Implementation of Improvement

From Fig. 5 and Fig. 8, it can be seen the difference between the skiver before and after the improvement. Before modification the sensor used was proximity, while after modification it was replaced with a photocell sensor, then the bearings had been replaced with bushings, but in the picture there is no visible difference because the position of the bushing is closed or obstructed by other parts.

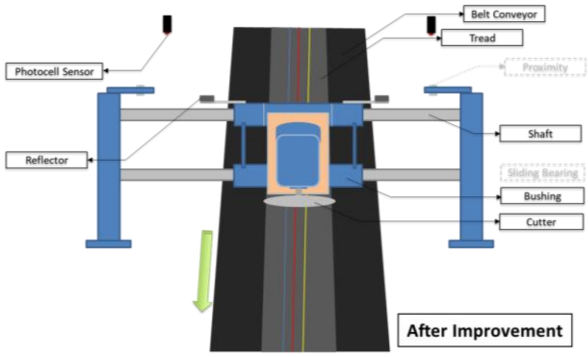

Fig. 5. Sketch of skiver section after improvement

C. Check (Before and After Data Comparison)

Evaluation of the results is done by comparing the downtime data of the extruder machine in the skiver section before and after modification. In Figure 4, it can be seen that the total downtime of the skiver part is 4780 minutes in 6 months, or the average is 796 minutes per month. After modification or since October 23, 2020, downtime on the skiver has dropped to 30 minutes for the last 2 months. After analyzing the downtime, it comes from a leak in the Flexible Hydraulic part, as shown in Fig. 9.

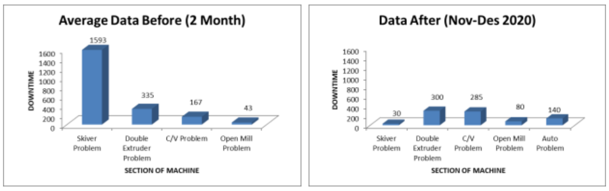

Fig. 6. Before and after data comparison

D. Action

- Monitoring of improvement

TABLE VI
MONITORING OF IMPROVEMENT

No	Standardization	Nov-20				Dec-20			
	Week	1	2	3	4	1	2	3	4
1	Angle cut according to spec	OK	OK	OK	OK	OK	OK	OK	OK
2	Auto skiver can run auto	OK	OK	OK	OK	OK	OK	OK	OK

Table 6 is a table of monitoring results carried out during the last 2 months, from November 2020 to December 2020. From the monitoring results, the improvements we have made have better effectiveness than before.

- Planning to another improvement

After we know the effectiveness of the improvements made, the next step is to impact other machines that have the same specifications, namely extruder machine number 1 (ATE-1) and extruder number 2 (ATE-2). In addition to impacting other machines, the next improvement is to improve machines that have a high downtime value, the machine is a bead grommet 1 (ABG-1) machine.

- Economic analysis

Apart from reducing the amount of downtime, there are other advantages of the improvements that have been made, namely preventing loss of production opportunity due to damage to the skiver part of the extruder machine. Opportunity loss that can be prevented from repairs that have been made per month is IDR 1.069.233.687.

V. CONCLUSION

A. *Conclusion*

- With the PDCA cycle approach, FMEA analysis and seven tools can reduce the amount of downtime so that it can increase productivity. The results of the improvements that have been made show that there is a decrease in downtime in the skiver section of the extruder machine from an average of 796 minutes per month to 30 minutes for the last 2 months (November - December 2020).
- The improvements made to the skiver section were able to reduce the amount of downtime on the extruder machine. Downtime on the extruder machine has decreased from 6415 minutes for 6 months or an average of 2138 minutes per 2 months to 835 minutes during the last 2 months (November-December 2020). The improvement made was by replacing spare parts that were often damaged with new types of spare parts based on better analysis. The spare parts are sliding bearings which are replaced with bushings, then the proximity sensors are replaced with photocell sensors.
- From the results that have been obtained, the increased uptime can eliminate the loss production opportunity of IDR. 1.069.233.687 / month and can reduce downtime machine.

B. *Recommendation*

- Further research can analyze the problem of downtime due to machine failure in the bead grommet 1 (ABG-1) machine for 5220 minutes for 6 months.
- Recommendation for the company Implementation the improvement to other machines that have the same specifications, namely extruder machine number 1 (ATE-1) and extruder number 2 (ATE-2).

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