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PDCA - Eight Steps Implementation to Increasing Productivity in the Production of Compound Tread Off Road TBR

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ABSTRACT

This study aims to implement the PDCA-eight steps to improve the productivity of the Tread Off Road TBR compound at Tire Manufacturer. Implementation begins with determining the theme of improvement with Pareto diagram tools to select production machines for improvement. The second step, set the target of improvement with histogram data. The third step, use a checksheet to find all possible causes during the observation and divide it into 4 categories: Man, Machine, Material & Method. The fourth step is to analyze the root of the problem using the fishbone diagram. The fifth and sixth steps, Plan & implement Corrective Actions using the 5W + 1H method. The seventh stage, evaluation of the results using the Pareto diagram for productivity and SPC for evaluation of compound quality. The Pareto diagram shows an increase in productivity of 31.15% and quality is maintained with an average CPK of 2.33. The last stage is to standardize and determine the next plan. The results of the implementation in this study indicate that this implementation can increase production productivity.

Keywords: PDCA, Productivity, Quality, Pareto, Compound, Improvement, SPC.

INTRODUCTION

Indonesia is one of the countries that are members of the Group of Twenty, which is a forum that aims to gather the economic strength of developed and developing countries so that world economic growth is stable (G20 Foundation, 2017). In 2018, Indonesia was ranked fourth among the G20 countries with an economic growth of 5.17%. The manufacturing industry sector is one of the contributors to national economic growth. According to the Badan Pusat Statistik Indonesia website, the manufacturing industry in that year was able to contribute 20% to the National Gross Domestic Product (GDP). This is inseparable from small, medium and large companies, both state-owned and private companies that can compete in the era of globalization so that they will participate in advancing the nation.

Productivity is one aspect that makes companies have the opportunity to compete. With the development of technology and information, companies are required to continue to increase productivity and make efficient use of available resources.

Tire manufacturer is a company engaged in the automotive sub-sector and its components. Tire manufacturer produces various types of tires for vehicles, such as cars, motorbikes, buses, internal and industrial tires. Tires consist of 85% compound and other supporting materials. Each tire has its own specifications according to its function and requires a different compound.

Throughout 2019, the Mixing Center Plant as a compound producer at Tire Manufacturer met compound request to the PCR Plant by 96%, fulfillment of compound requests to the MC Tire plant at 95%, fulfillment of BIAS Plant compound requests reaching 95%, and fulfill compound requests to Flap Plant reaches 98%. However, the fulfillment of the request for compound TBR Plant did not meet the company's target, which was only 92% of the company's target of 95%. Based on PPC department data, the lowest TBR compound productivity is Compound Tread, with a productivity of 1,220 tons / hour.

To be able to meet the demand for TBR Plant, it is necessary to improve productivity. Kaizen is one of the management strategies to improve productivity. One of the main steps of kaizen is continuous improvement, which is continuous improvement to continuously optimize the resources used, both in raw materials, machines, human resources, processes and the environment. In its implementation, continuous improvement has various methods or procedures, one of which is The Deming Cycle or PDCA (Plan Do Check Action).

Carrying out continuous improvement with the PDCA cycle, there are various methods. One of the basic methods of implementing the PDCA cycle is to use the Eight Steps and Seven Tools. The use of that can help build a framework of thought and run systematically so that continuous improvements can be made.

LITERATURE REVIEW

Productivity

Productivity is the relationship between input and output in a production system (Heizer, 2014). Productivity becomes an index that measures the output of goods or services compared to inputs consisting of labor, raw materials, energy and other resources used to produce output (Stevenson and Chuong, 2014). The general concept of productivity is a comparison between output and input per time.

$$\textbf{Productivity} = \frac{\textit{Output}}{\textit{Input}} \quad (1)$$

Productivity consists of two dimensions, the first is the dimension related to achievement, quality, quantity and time. And the second dimension is efficiency in the effort to realize the use or implementation of the work.

Productivity and production are different things, but in a productivity effort there are components in the form of production, quality performance and quantity. Productivity is a combination of effectiveness and efficiency. So that in measuring productivity it can be formulated:

$$\textbf{Productivity} = \frac{\textit{Output Result}}{\textit{Input Used}}$$

$$= \frac{\textit{Achievement of objectives}}{\textit{Resource Utilization}} \frac{\textit{Effectiveness}}{\textit{Efficiency}} \quad (2)$$

PDCA (Plan, Do, Check, Action)

Continuous improvement or "Kaizen" is a process of continuous improvement with the aim of increasing output, both in terms of quality and productivity (Santos Barbosa et al, 2019). With a predetermined time and consistent process, Kaizen will achieve goals with big results.

The PDCA (Plan Do Check Action) cycle is the first step in implementing Kaizen so that continuous improvement can be carried out (Darmawan, 2018) . The PDCA cycle is one of the tools to achieve quality control and productivity, both in improving and increasing standards, the most important concepts in Kaizen. PDCA consists of four words, namely "Plan, Do, Check, Act" (Arturo et al, 2018). The PDCA cycle is a cycle in the problem-solving process by performing four repetitive steps that are often used in quality control

The stages of the PDCA cycle can be divided into eight (Chauhan et al, 2014). The “Plan” consists of 5 stages, consisting of (1) Determining a Theme for Improvement based on Problem Identification. (2) Setting Improvement Targets. (3) Seeking All Possible Causes. (4) Analyzing the Root Cause of the Problem. (5) Planning Corrective Actions.

The" Do" stage is (6) Implement Improvement. The "Check" stage is (7) Evaluation of Results. And the last stage is "Action" which consists of steps (8) Standardization and Further Plans.

The eight-step PDCA cycle implementation uses seven tools to simplify implementation at each step. The seven tools referred to are (1) scatter diagrams, (2) Checksheets, (3) Histograms, (4) Pareto, (5) Causal diagrams, (6) Control Charts, (7) flow charts.

Step 1 Problem Identification and Theme Determination

Identification begins with analyzing each element using the SIPOC diagram: Supplier-Input-Process-Output-Customers. Problems will be raised as a theme, themes are matters relating to quality and productivity issues that exist in the organization or company. Determining the theme is both related to and in line with management policies or targets and is sustainable with supporting data. To choose the priority of the fault, the tool that will be used is the Pareto diagram. Heizer and Render (2014) say that the Pareto Diagram (Pareto Analysis) is a method of error, the problem of defects to help focus attention on problem solving efforts.

Step 2 Setting Targets

The goals of the PDCA activities should be set with targets. Targets consist of SMART criteria, Targets must be **S**pecific, **M**easurable, **A**chievable, have clear **R**easons and within a specified **T**imeframe.

Step 3 Look for All Possible Causes

The search for causes begins with data collection, data analysis, observation and documentation of possible causes of problems in existing conditions. The results of data collection and processing and observations can be grouped into controllable factors known as 4M: Man, Method, Material, Machine. The tool used in this step is a checksheet during field observations.

Step 4 Analyze the Root Cause of the Problem

Problems can be identified because they cause symptoms, but these symptoms are not the cause. Symptoms arise for a reason. Using the "why" method which is repeated to the root of the problem, so that the solution to the problem that will be taken can be right on target and have a big effect on the results of the improvement. The tool used in finding the root of the problem is a fish bone diagram. Each fishbone in the diagram represents a possible source of error. This diagram is useful for showing the main factors that affect quality and have an effect on the problem to be improved. (Heizer dan Render, 2014)

Step 5 Planning Corrective Action

Determination of steps in the improvement planning based on the results of the root cause analysis that has been obtained. Elimination of root causes is focused on the scope of responsibility of the department in the organization (controllable causes) and it is better to be able to anticipate uncontrollable but predictable causes. Complete corrective action planning can use the 5W2H1T table. The 5W2H1T table consists of What, Why, When, Who, Where, How, How Much & Target.

Step 6 Implement Improvement

Implementing improvements requires a commitment from the organization or company to be able to eliminate the root of the problem identified in the previous step. Recording the implementation of improvements are also conducted with respect to the technical and systematic improvement, the results achieved, and the person in charge of implementation of improvements. So that identification of the causes of deviations if they do not reach the target will be easily detected and corrected.

Step 7 Evaluating the Improvement Results

After pelaksanaann improvement over a certain period, conducted the review and improvement of evaluation of the results of the implementation of the targets set. The tool used for quality evaluation is a control chart or SPC, while for achieving productivity targets using a pareto diagram. According to Stevenson and Chuong (2014), a control chart is a tool used to monitor and evaluate an activity / process running well in accordance with the expected quality graphically.

Step 8 Standardize Improvement and Determine Next Improvement Plan

Standardization aims to maintain and control the results of improvements. Standardization also aims so that mistakes do not repeat themselves or cause the same problem. The determination of the next theme can be related to the previous theme which has not been effective and efficient, or it can start with new quality problems according to the needs of the organization or company.

RESEARCH METHODS

The type of research that will be used is quantitative research and the research design used in this research is descriptive. This research variable consists of several dimensions for the causative factors in conducting this research and in terms of indicators to determine the items to be improved.

Table 1 Operational Definition

Research variable	**Dimensions**	**Indicator**	**Data source**
Productivity Compound Tread Off Road TBR	Product productivity	Number of products with time used in the production process (Tonnes / Hour)	Production Report for PPC (Production Planning Control) Department & Technical Departments
	Product Finish	Total production of Compound Tread Off Road TBR (kg)	PPC (Production Planning Control) Department Production Report
	Cause Factors: Man, Material, Machine, Method	Human Error, Material Condition, Machine Improvement, Parameter Setting, Training, Process Improvement	Reports and interviews of QC (Quality Control) department, Technical Department & Engineering Department
Quality Compound Tread Off Road TBR	Product quality	Physical Properties Compound (Company Standard	Technical Department & Quality Assurance Department

Source : Tire Manufacturer

In Table 1, it describes the variables consisting of several dimensions for the causative factors in conducting this research and in terms of indicators to find out which items will be improved. In this study, the subject population who will implement the PDCA-Eight Steps is the employees who make policy and implement improvements in the production process. And the population of the object of this research is all compound products produced by the Plant Mixing Center at Tire Manufacturer.

Samples from the subjects of this study are the entire population who carry out, so it is called saturated samples. As for the sample object in this study, the product will be applied by PDCA-Eight steps using purposive sampling with the criteria (1) Compound Tread Off TBR produced on the most machine production lines with production data during the period January 2019 to August 2020. (2) Compound Tread Off TBR which is produced under the supervision of the technical department and the Quality Control department.

The data collection method used in this research is using primary and secondary data. Primary data obtained from the main source, namely by conducting field studies to companies or observative directly. The data needed to help the analysis process by interviewing operators in each existing process by looking at man, machine, material & method factors. Primary data was also obtained through discussions, namely exchanging thoughts, ideas and opinions from discussion participants with the Technical Dept. QC Dept, Production Dept., Engineering Dept. relating to data and information required in the problem solving process. Secondary data used in this study are divided into 2. (1) Document

Study: Document study is carried out by collecting data sourced from documents from the Production, Quality Control, Technical, Engineering, and Laboratory departments regarding quality standards of production output and production machine processes. (2) Study / Literature Study: A literature study is conducted to obtain data collected by experts or other parties by studying books, articles and other data sources.

RESULT AND DISCUSSION

Before starting to improve productivity, it is necessary to identify using the SIPOC (Supplier, Input, Process, Output & Customer) diagram in order to identify each element in the PDCA implementation project - Eight Steps before running.

Table 2 Diagram of SIPOC Production Process for Compound Off Road Tread TBR

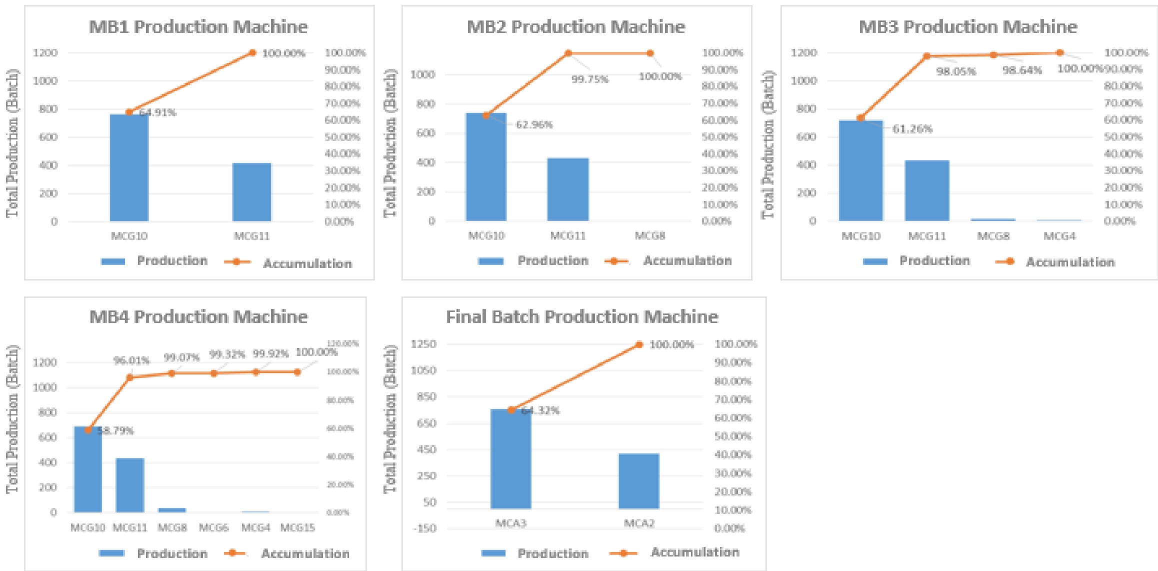
Supplier	Input	Process	Output	Customer
Warehouse Department	Chemical Raw Materials	Mixing	Compound Off Road Tread TBR	TBR Plant
	Natural Rubber			
	Filler			
Utility Department	Electricity			
	Steam			
Production Department	Mixing Machines			
	Operator			

Source: Results of secondary data processing from Tire Manufacturer (2020)

The SIPOC diagram in table 2 illustrates the production process and displays the elements involved in the production process. The following is the SIPOC table for the TBR Compound Off Road Tread Production Process.

Plan (Planning)

(1) Determine the Theme of Improvement based on Problem Identification : Compound Tread Off Road TBR throughout 2018 was produced as many as 1177 batches. Where in the production process using several machines, including MCG 4, MCG 6, MCG 8, MCG 10, MCG 11, & MCG 15. While in the Final Batch process, using MCA 2 and MCA 3 machines. To be more specific in improving productivity, then use the Pareto diagram to see the priority of the machine to be improved.



Source: Results of secondary data processing from Tire Manufacturer (2020)

Figure 1. Pareto Diagram of Compound Production Machine

Based on the results of the analysis using the Pareto diagram in Figure 1, the compound Tread Off Road TBR at Masterbatch 1 to Masterbatch 4 stages is mostly produced in MCG10 machines, and at the Final Batch stage it is produced the most in MCA 3. So the theme of improvement in the implementation of PDCA - Eight The step is "Increasing the Productivity of Compound Tread Off Road TBR on production machines Masterbatch 1 - Masterbatch 4 in MCG 10 and Final Batch in MCA 3".

(2) Setting Improvement Targets : Improvement target refers to compounds that have the same number of production processes but have the highest productivity. The target for improving the productivity of the Tread Off Road TBR compound refers to the Rim Chafter compound of 1.596 tons / hour or an increase of 30.85%. The target is then submitted to the mixing technical manager as the improvement team's advisor for approval.

(3) Seeking All Possible Causes. The causes that may decrease productivity are divided into 4, which are known as 4M, namely Machine, Method, Material, & Man. Team Improvement analyzes by means of direct observation in the field and observing the data obtained from the machine to know the impact of each factor that makes the productivity of the Tread Off Road TBR compound lower than the other compounds. From the results of direct observation in the field and data obtained from the machine, the following results were obtained.

Machine (Machine). Analysis of existing conditions is carried out by visiting the production process field to see the actual condition of the machine and compared with the specifications. The review is carried out using a Check Sheet so that the specifications can be recorded in detail and nothing is missed.

Table 3 Results of field observations on the production process

Parameter	Masterbatch 1			Masterbatch 2		
	Specification	**Actual**	**Status**	**Specification**	**Actual**	**Status**
Rotor Speed	40 - 50 RPM	40 - 50 RPM	OK	30-35 RPM	30-35 RPM	OK
Ram Pressure	45 ± 7 N / cm²	43 N / cm²	OK	45 ± 7 N / cm²	43 N / cm²	OK
Mixing Time	40 " - 125 °C - 165 °C	40 " - 125 °C - 165 °C	OK	40 " - 160 °C	40 " - 160 °C	OK
Dump Temp.	165 + 10 °C	166 won	OK	160 + 10 °C	167 °C	OK
Cooling Chamber	40-60 °C	51 °C	OK	40-60	53 °C	OK
Parameter	**Masterbatch 3**			**Masterbatch 4**		
	Specification	**Actual**	**Status**	**Specification**	**Actual**	**Status**
Rotor Speed	25 - 35 RPM	25 - 35 RPM	OK	25-30 RPM	25-30 RPM	OK
Ram Pressure	45 ± 7 N / cm²	43 N / cm²	OK	45 ± 7 N / cm²	43 N / cm²	OK
Mixing Time	30 " - 125 °C - 145 °C	30 " - 125 °C - 145 °C	OK	40 " - 145 °C	40 " - 145 °C	OK
Dump Temp.	145 + 10 °C	147 °C	OK	145 + 10 °C	146 °C	OK
Cooling Chamber	40-60 °C	52 °C	OK	40-60 °C	53 °C	OK
Parameter	**Final Batch**					
	Specification	**Actual**	**Status**			
Rotor Speed	20 RPM	20 RPM	OK			
Ram Pressure	45 ± 7 N / cm²	47 N / cm²	OK			
Mixing Time	60 " - 60 " - 110 °C	60 " - 60 " - 110 °C	OK			
Dump Temp.	110 + 10 °C	113 °C	OK			
Cooling Chamber	40-60 °C	56 °C	OK			

Source: Primary data processing results (2020)

Table 3 is the check sheet results from field observations. In the speed parameter checksheet, the specifications require that the machine is at RPM 40-50 on masterbatch 1, RPM 30-35 on masterbatch 2, RPM 25-35 on masterbatch 3, RPM 25-30 on masterbatch 4 and RPM 20 on the finalbatch. From the observations it was found that the machine can meet all specifications and was given OK status.

Then in the Ram Pressure parameter, from masterbatch 1 to 4 and the final batch specifications require that Ram Pressure be able to press 45 N / cm² with a lower limit pressure tolerance of 38 N / cm² and an upper limit pressure tolerance of 52 N / cm². On masterbatch 1 to masterbatch 4, Ram Pressure at the time of observation showed the number 43 N / cm², indicating that the machine's Ram Pressure still met specifications, so it was marked OK on the status.

In the mixing time machine parameter, the comparison between the mixing time process specification and the actual process that occurs on the machine during production shows no difference, both in masterbatch 1 to masterbatch 4 and in the final batch. So that the status label is written OK.

In the Dump Temperature parameter, the specifications for masterbatch 1 are 165 + 10 ℃ and when the actual observation shows the temperature is 166 ^{o}C, then the observation checksheet status is given an OK mark. In masterbatch 2, the specification shows 160 + 10 ℃ and when the observation is at 167 ℃, because the temperature value is still within tolerance, it is declared OK. In masterbatch 3 and 4, the production process specification requires that the dump temperature be 145 + 10 ℃. And at the time of field observation, the masterbatch 3 shows the dump temperature is 147 ℃ and the mastebatch 4 shows the temperature is 146 ℃. The temperature is still within specification tolerance, so it is marked OK on the status checksheet. In the final batch, the dump temperature specification is at 110 + 10 ℃, and at the time of field observation it shows a temperature of 113 ^{o}C and is still within specification tolerance, so the status on the checksheet is filled with OK.

In the cooling chamber machine parameters, masterbatch 1 to masterbatch 4 and the final batch have the same specifications, which are vulnerable to temperatures of 40-60 ^{o}C. From the observations, it was found that at masterbatch 1, the temperature of the coolong chamber was 51^{o}C, and the masterbatch 2, 3, 4 and the final batch were at 53^{o}C, 52^{o}C, 53^{o}C, 56^{o}C, respectively. From the results of these observations, all cooling chamber parameters were declared OK.

From the results of the above observations, all parameters meet the predetermined specifications. So that there is no cause from the machine category that causes productivity to decrease.

***Man* (Human)**

In the production process for MCG 10 and MCA 3 machines, the APS system - Automatic Process System is used. Where the production process from entering the material and mixing process occurs automatically, so there is no interference from the production operator. The production operator is only tasked with preparing the material before entering the machine, making configurations in selecting the compound process method that has been provided, and operating the machine by simply pressing the start button. The production process will run according to a predetermined program until the end. If there are obstacles in material preparation, it is not included in the production cycle time. Due to the cycletime of production, a type of compound is calculated starting from when the operator presses the start button (when all the materials are ready) until the compound is finished processing.

Material

Each type of compound has its own role in the part of the tire. So that in production, each compound also consists of various types of materials that vary depending on its function. This can also affect the production process, where the compound material for Tread Off Road TBR consists of 100% natural rubber, carbon and other supporting chemicals. Where in the compound production process with a composition of 100% natural rubber, it takes a longer process than synthetic rubber.

***Method* (Method)**

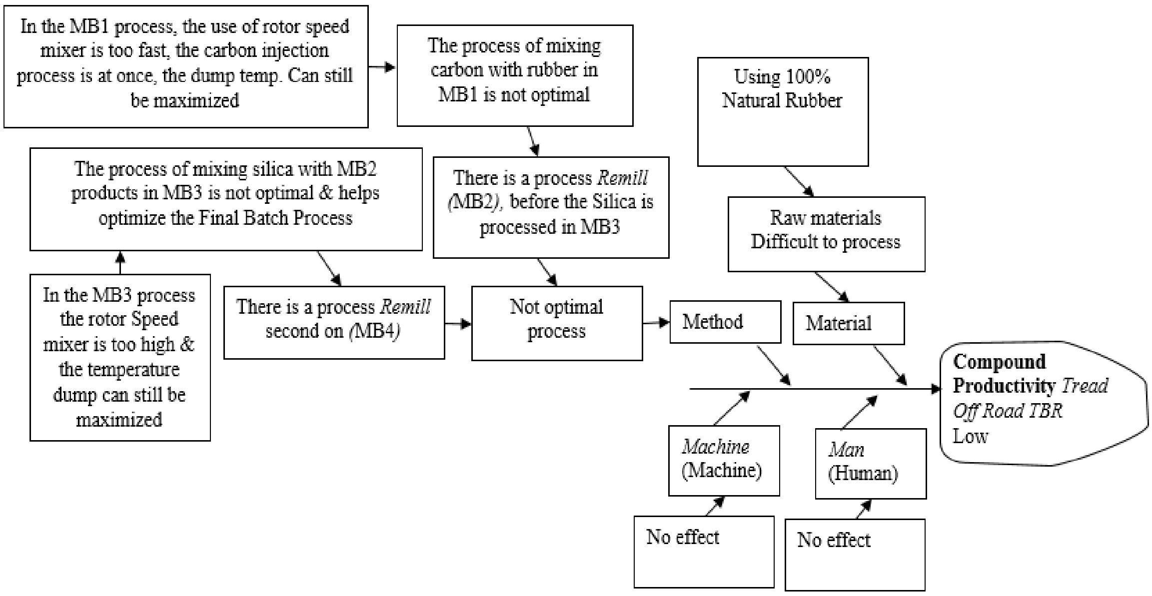
In the Tread Off Road TBR compound production process, there is a repetitive process, namely Masterbatch 2 and Masterbatch 4. Where in that process, there is a process that is only carried out by the mixing process without adding any material. It is intended that the process of mixing natural rubber with filler is maximized, both carbon and silica. But ideally, this should be done after the composition of the filer and rubber material has been mixed. In Masterbatch 2, it can be said that it is not optimal because in Masterbatch 3 the production process still adds fillers - silica and chemicals to the compound. In masterbatch 4, the mixing process was also carried out without adding any material. This is because the silica mixing in the Masterbatch 3 stage is not optimal. Besides that, The remill process in Masterbatch 4 also helps the Final Batch process for better mixing of chemicals. Both processes make the productivity of the Tread Off Road TBR compound low, because it requires a process that takes longer. Table 4 describes the production process and the order of the materials used.

Table 4. Stages of the compound production process for Tread Off Road TBR and Material used

Process Stages	Material
Masterbatch 1	Natural Rubber
	Carbon Black
	Chemical Package MB1
Masterbatch 2	Product Masterbatch 1
Masterbatch 3	Product Masterbatch 2
	Silica
	Chemical Package MB3
Masterbatch 4	Product Masterbatch 3
Final Batch	Product Masterbatch 4
	Chemical Package Final Batch

Source: Results of secondary data processing (2020)

(4) Analyzing the Root Cause of the Problem: Search for the root cause of the problem can be done using a cause - effect diagram (Fishbone Chart Diagram) by using the question "why" until the root of the problem is found.



Source: Results of primary data processing (2020)

Figure 2. Fishbone diagram of low TBR Compound Tread Off Road productivity

The fishbone diagram is formed based on an analysis of existing conditions and is shaped to resemble a fish bone to find out the root cause from the problem. From the fishbone diagram in Figure 3, it is found that the root cause of the low TBR Tread Off Road compound productivity has 3 root problems. First, in the MB1 process the use of engine speed is too fast, the carbon injection process is at once, the dump temp is still low and can still be maximized. Second, in the MB3 process, the engine speed is too high & the dump temperature can still be maximized and the third is the use of natural rubber with a 100% composition.

(5) Planning Corrective Actions: Solutions are sought for the main problems found at the stage of analyzing the root cause of the problem using the 5W + 1H tool which is described as follows:

Table 5 Corrective Action Planning

No.	What		Why	How	Where, When, Who
	Root of the problem	**Improvement Plan**	**Cause**	**Improvement Activities**	**PIC, Place, Time**
1	In MB1, the use of engine RPM is too fast, carbon injection process at once, dump temp. Can still be maximized	Optimizing the Masterbatch 1 process and eliminating the remill process stage (Masterbatch 2)	The mixing that was not optimal resulted in an additional process in Masterbatch 2	Modify the Masterbatch 1 process & validate the final product	Technical Staff Dept. MCG 10, MCA 3, 21 June 2019
2	On MB3, Engine RPM Too high & temperature dump can still be maximized	Optimizing the Masterbatch 3 & Final Batch process and eliminating the remill process stage (Masterbatch 4)	The mixing that is not optimal has resulted in an additional process in Masterbatch 4	Modify the Masterbatch 3 process & validate the final product	Technical Staff Dept. MCG 10, MCA 3, 21 June 2019

Source: Primary data processing results (2020)

Table 5 describes the improvement plan using the details of 5W1H. The root of the problem in the material factor,which is the use of 100% natural rubber, no corrective action is taken. This is because the replacement of natural rubber material will have a significant impact on the tire quality products.

Do (Implementation)

(6) Implement the improvements: The improvement will be carried out according to the plan. The first modification is to change the production process at the Masterbatch 1 stage with changes in Carbon Injection divided into 2, changing the speed from 50-40 RPM to 45 RPM, Swipe Ram Up Down Movement to 3x and eliminating the Maserbatch 2 process.Then doing a production test with process modification until the Final Batch stage. Then the final batch product will be tested for the quality of the Physical Properties Compound. The second modification is combining the first modification process and combining by making changes to the Masterbatch 3 and Final Batch processes with changes in the Speed MB 3 rotor from 35-25 RPM to 45-20 RPM, Changing the Final MB Speed from 20 RPM to 20-18 RPM, Changes Dump Temperature MB3 from 145°C to 155°C, changing Final Dump Temperature MB from 110°C to 115°C, changing Swipe Ram Up Down Final MB to three times and eliminating the masterbatch process 4. Then the Compound Tread Off Road TBR was produced again with that process. Then the products from the Final Batch will be tested for the quality of the Physical Properties Compound. Comparasion the modification are described in detail in tabel 6.

Tabel 6. comparison between the Regular process, Modification 1 and Modification 2

Parameter	Masterbatch 1 Process Spesification			Masterbatch 2 Process Spesification		
	Regular	**Modification 1**	**Modification 2**	**Regular**	**Modification 1**	**Modification 2**
Rotor Speed	40 - 50 RPM	45 RPM	45 RPM	30 - 35 RPM	Skip the process of Masterbatch 2	Skip the process of Masterbatch 2
Ram Pressure	45±7 N/cm²	45±7 N/cm²	45±7 N/cm²	45±7 N/cm²		
Mixing Time	40" - 125°C - 165 °C	40" - 35" - 35" – 165°C	40" - 35" - 35" – 165°C	40" - 160 °C		
Dump Temp.	165 ± 10 °C	165 ± 10 °C	165 ± 10 °C	160 ± 10 °C		
Carbon Inject	All at once	divided into two stages	divided into two stages	No Carbon		
Ram Press Swipe	2x	3x	3x	1x		

Parameter	Masterbatch 3 Process Spesification			Masterbatch 4 Process Spesification		
	Regular	**Modification 1**	**Modification 2**	**Regular**	**Modification 1**	**Modification 2**
Rotor Speed	25 - 35 RPM	25 - 35 RPM	45 - 20 RPM	25-30 RPM	25-30 RPM	Skip the process of Masterbatch 4
Ram Pressure	45±7 N/cm²	45±7 N/cm²	45±7 N/cm²	45±7 N/cm²	45±7 N/cm²	
Mixing Time	30" - 125°C - 145 °C	30" - 125°C - 145 °C	40" – 40" / 140°C - 155 °C	40" - 145 °C	40" - 145 °C	
Dump Temp.	145 ± 10 °C	145 ± 10 °C	165 ± 10 °C	145 ± 10 °C	145 ± 10 °C	
Ram Press Swipe	2x	2x	3x	1x	1x	

Table 6 continued

Parameter	Final Batch Process Spesification		
	Regular	Modification 1	Modification 2
Rotor Speed	20 RPM	20 RPM	20-18 RPM
Ram Pressure	45±7 N/cm²	45±7 N/cm²	45±7 N/cm²
Mixing Time	60" - 60" - 110 °C	60" - 60" - 110 °C	40" - 40" - 30" - 115 °C
Dump Temp.	110 ± 10 °C	110 ± 10 °C	115 ± 10 °C
Ram Press Swipe	2x	2x	3x

Source: Primary data processing results (2020)

The systematics and implementation of productivity improvements are described in detail in table 7.

Table 7 Technical Implementation of Compound Tread Off Road TBR Productivity Improvement

Root Cause	Improvement	Technical Improvement	Systematics of Improvement	PIC, Place, Time
The process of mixing Carbon with rubber in Masterbatch 1 has not been optimal	Optimizing the Masterbatch 1 process and eliminating the remill process stage (Masterbatch 2)	Modify the process on Masterbatch 1 and proceed to Masterbatch 3, 4 & Final Batch.	Perform a production scale test Observing the process & sampling Conduct quality test for compound products Perform advanced validation for modified processes.	Technical Staff Dept. MCG10 & MCA3 June 2019
The mixing process of Silica with MB2 product in Masterbatch 3 is not optimal	Optimizing the Masterbatch 3 & Final Batch process and eliminating the remill process stage (Masterbatch 4)	Modify the process on Masterbatch 3 & Final Batch	Test To test the production scale Observing the process & sampling Conduct quality test for compound products Perform advanced validation for modified processes.	Technical Staff Dept.MCG10 & MCA3 July 2019

Source: Primary data processing results (2020)

The improvement is carried out by means of the improvement team from the technical department to test the production process directly. To be able to know the comparison of productivity & quality of the resulting compound, the improvement team conducted a production process test using the regular production process, modification 1 and modification 2 at a time, so as to minimize the variables that affect product results. Each production process consists of 6 batches of Final Mixing which are then reviewed for productivity and quality.

From the results of the production test between the regular process, modification 1 and modification 2, the productivity data for each process are obtained as follows:

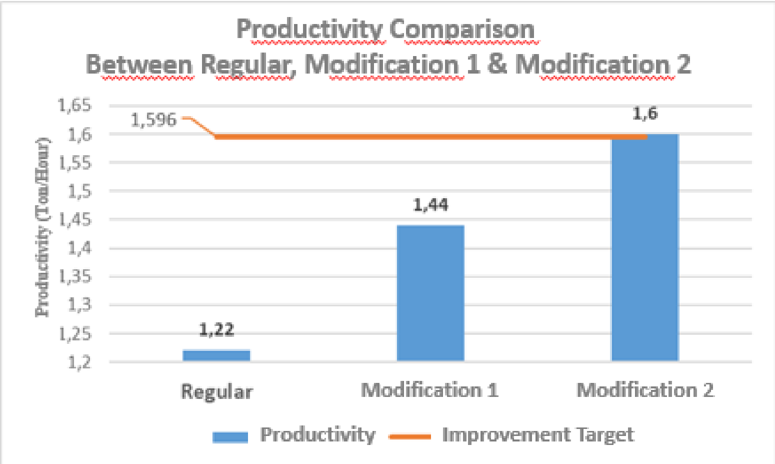
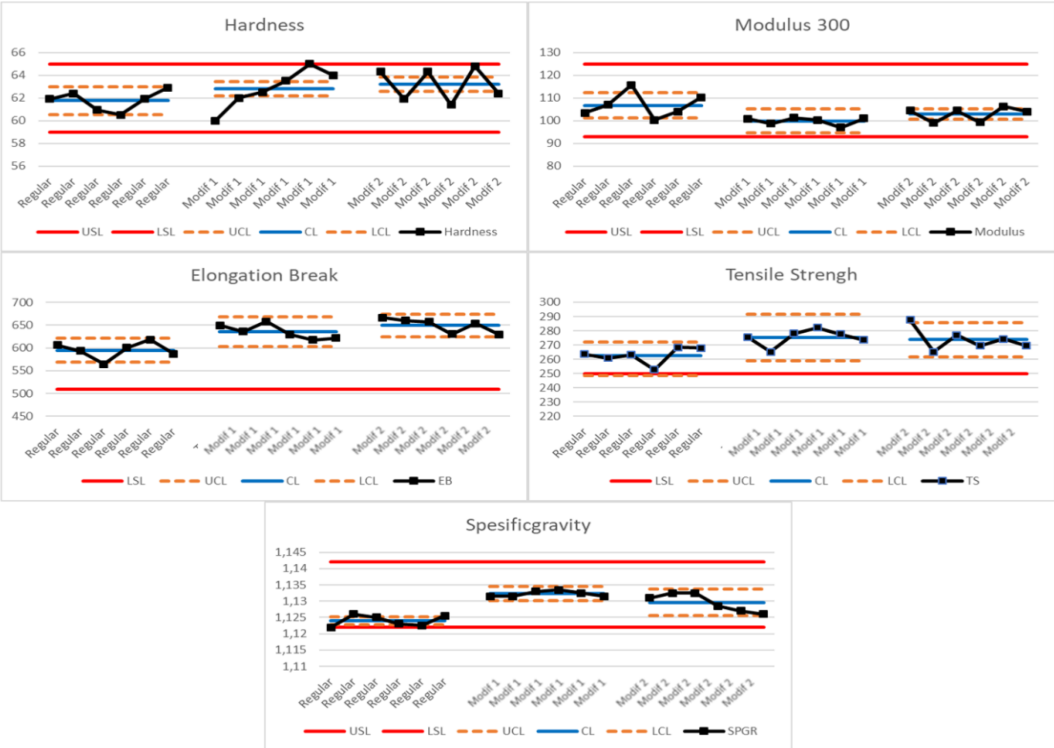


Figure 4. Pareto diagram of productivity improvement result, *Source: Results of secondary data processing (2020)*

Figure 4 illustrates the comparison of the results of the production test using the regular process, the productivity is 1.22 tonnes / hour, while the production using modification process 1 increases the productivity to 1.44 tonnes / hour, and for production using modification process 2 the productivity reaches 1.6 tonnes / hour. The target of productivity improvement is 1.596 tons / hour, so that the modification process 2 meets the predetermined target. Compound product must meet the standards of the Physical Properties Compound which consists of Hardness, Modulus 300, Elongation Break and Specific gravity. SPC is used to evaluate the quality of the three processes as shown in Figure 5.

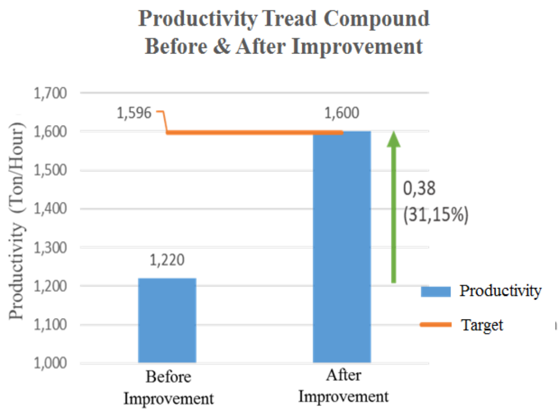


Source: Results of secondary data processing (2020)
Figure 5. Comparison of the quality of the compound

From the SPC graph in Figure 5 shows that all processes produce products that meet standards. From the calculation of Cpk on SPC, it was found that the compund produced by modification process 2 had a higher average value (2.4) compared to the regular process (1.6) and modification process 1 (2.1). Based on quality and productivity considerations, modification process 2 was chosen to be the solution to the problem of low compound tread productivity. The modification process 2 is then applied to the production process to undergo production scale trials.

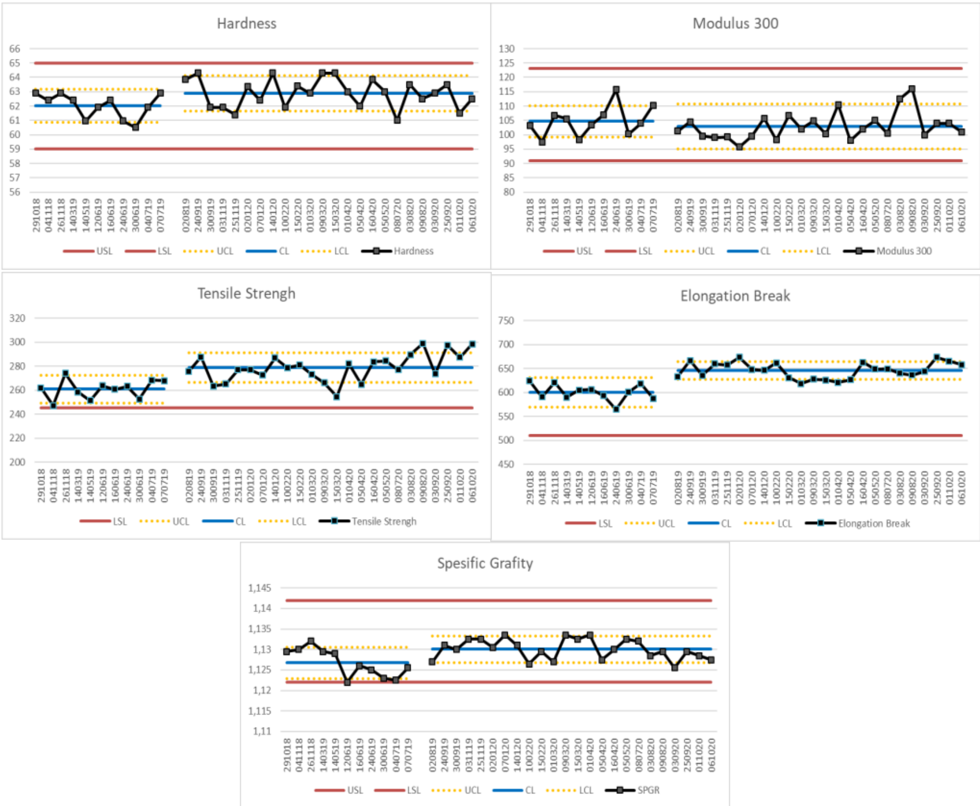
Check (Implementation Evaluation)

(7) Evaluating the results of the improvements: Evaluation of the results of repairs is done by comparing the conditions before and after improvement, by reviewing the productivity of compound making and the quality of the compound. The following is a graph of the comparison histogram productivity before and after the improvement.



Source: Results of secondary data processing (2020)
Figure 6. Productivity comparison after modification process 2 is implemented

From Figure 6, the graph illustrates that the productivity of the Tread Off Road TBR compound reaches 1,600 tons / hour. This indicates that productivity has increased by 0.1600 tons / hour or an increase of 31.15% which was originally only 1.220 tons / hour. The increase in productivity has exceeded the target of improvement, which is 1.596 tons / hour. In terms of quality, comparison evaluation between before and after using control charts.



Source: Results of secondary data processing (2020)

Figure 7. Quality Compound before and after improvement use modification 2 implemented

Table 7 Description of Quality Comparison Statistics Before (Bef) and After (Aft) Repair

STATISTICAL DESCRIPTION	Hardness		Modulus		EB		TS		SPGR	
	Bef	Aft	Bef	Aft	Bef	Aft	Bef	Aft	Bef	Aft
Number of samples (n)	2	2	2	2	2	2	2	2	2	2
Number of sub groups (N)	11	24	11	24	11	24	11	24	11	24
3. Lower Std. Limit	59	59	91	91	510	510	245	245	1,122	1,122
4. Upper Std. Limit	65	65	123	123	0	0	0	0	1,142	1,142
5. $\bar{X}$ Average ($\bar{\bar{X}}$)	62.01	62.89	104.73	102.92	600.01	646.26	260.81	279.03	1.13	1.13
6. Maximum	63.4	64.3	116.0	116.0	639.9	680.0	281.0	303.0	1,1	1,1
7. Minimum	60.5	60.0	94.5	93.5	562.8	608.0	246.0	252.5	1,1	1,1
8.Range Average ($\bar{R}$)	0.62	0.65	2.91	4.17	16.35	9.98	6.28	6.55	0.00	0.00
9. Std. Dev. ($\bar{R}$ / d2)	0.55	0.58	2.58	3.69	14.50	8.85	5,57	5.81	0.00	0.00
Std. Dev. (σ n - 1)	0.93	1.09	5,52	5.46	19.96	18.04	8.93	11.99	0.00	0.00
Capability Index (Cp)	1.82	1.72	2.07	1.44	0.00	0.00	0.00	0.00	1.88	2.20
CPU	1.82	1.21	2.36	1.81	0.00	0.00	0.00	0.00	2.87	2.63
Cpl	1.83	2.24	1.77	1.08	2.07	5.13	0.95	1.95	0.89	1.77
Process Capability (Cpk)	**1.82**	**1.21**	**1.77**	**1.08**	**2.07**	**5.13**	**0.95**	**1.95**	**0.89**	**1.77**
Average Cpk Before (Bef)	**(1.82 + 1.77 +2.07 + 0.95 + 0.89): 5 = 1.50**									
Average Cpk After (Aft)	**(1.21 + 1.77 + 5.13 + 1.95 + 1.77): 5 = 2.23**									
UCL = $\bar{\bar{X}}$ + A2$\bar{R}$	63.17	64.12	110.20	110.75	630.76	665.02	272.62	291.35	1.13	1.13
CL = $\bar{\bar{X}}$	62.01	62.89	104.73	102.92	600.01	646.26	260.81	279.03	1.13	1.13
LCL = $\bar{\bar{X}}$ - A2$\bar{R}$	60.85	61.66	99.26	95.08	569.27	627.50	249.00	266.71	1.12	1.13
Outspec (NG)	0	0	0	0	0	0	0	0	0	0
% NG	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

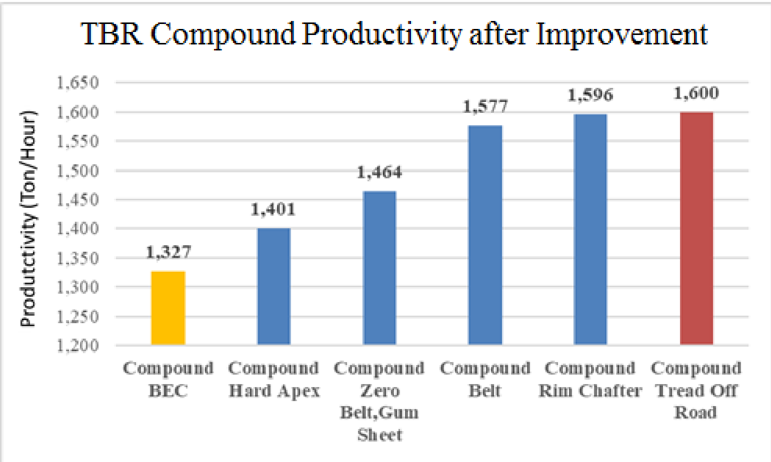
Source: Results of secondary data processing (2020)

The SPC graph in Figure 7 shows the quality of the TBR Tread Off Road compound after improvement is not much different from before the improvement. This indicates that the implementation of productivity improvements does not change the quality of the Tread Off Road TBR compound product. The control limit line is still within the company standard, which indicates that even though the results are unstable, they are still in the company standard. This can also be seen from table 7 where the mean value of Cpk from the five test items of the product produced after improvement is greater (2.23 points) than before the improvement (1.5 point). From these results, it can be said that the process of improvement results in products that are more in accordance with the standards given by the company.

With the optimization of the process in the compound production of Tread Off Road TBR from 5 production stages to 3 production stages, there is a change in production costs. Due to the reduced stages, the production costs are also reduced. Based on calculations from the PPIC (Production Planning & Inventory Control) department, the improvements that have been made can save production overhead costs by 41.06%.

Act (Follow up)

(8) Standardize Solutions & Further improvement plans: Standardization is carried out by changing the specification of the Tread Off Road TBR compound production process using 5 stages in each machine, with the production process of Tread Off Road TBR compound modification using 3 stages. The implementation of improvements is stated in the technical department document with a change in the 5-stage production process specification with revision number 07 / 01R01 to a 3-stage production process specification with revision number 07 / 02R02.



Source: Results of secondary data processing (2020)

Figure 8. The six compounds with the lowest productivity

After standardization, the next step is to plan for further improvements. The next improvement, referring to the background related to productivity in figure 6, is to increase the productivity of the BEC compound which has a productivity of 1.327 tons / hour.

CONCLUSIONS AND SUGGESTIONS

CONCLUSION

Based on the implementation that has been done, it can be concluded:

1. The factor that causes low productivity in the Compound Off Road Tread TBR Plant product at the Mixing Plant is that there is a production process that has not been optimal at Masterbatch 1 and Masterbatch 3 in mixing natural rubber with filler compound, which causes additional remill stages in Masterbatch 2 and Masterbatch 4.
2. Implementation of improvements to increase the productivity of the Off Road Tread TBR Plant compound at the Mixing Center Plant using the PDCA-Eight Steps method running systematically using 7 tools and successfully increasing productivity by

31.15% and saving production overhead by 41.67%.

3. The quality of TBR's Off Road Tread compound after increasing Plant productivity at the Mixing Center Plant using the PDCA-Eight Steps method is getting better. This is evidenced by the Cpk average which increased from 1.50 to 2.33.

SUGGESTIONS

Based on the analysis and conclusions of this study, the suggestions are given:

1. Implementation of PDCA-Eight steps in the production process of the compound Tread Off Road TBR can be implemented and results in better productivity, quality and production costs. Development suggestions for tire factories in terms of implementing the PDCA-Eight steps are the massive scale application of each department and employee. So that problem solving and improvement can be systematic, sustainable and well documented.
2. Further research can develop the PDCA-eight steps using other quality control tools, such as DMAIC (Design-Measure-Analyze-Improve-Control) and FMEA (Failure mode and effects analysis).
3. Further research can examine the effect of implementation on the performance of employees who have applied the PDCA-Eight steps method.

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