Improving Work in Process Quality (Bias Cutting Process) by Using Poka-Yoke and Define Measure Analysis Improve and Control (DMAIC) Method in Leading Motorcycle Tire Manufacturing

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Abstract*—The leading tire manufacturing has a cost of poor quality on scrap work in process and Rework. Cost of Poor Quality on scrap work in process has a 90% contribution to the total rejected of products. Nylon scrap is one part of in-process scrap work, which dominates the overall scrap work in process. In nylon scrap, there is a type of scrap, namely avoid condition which contributes 74% of total nylon scrap. This research was conducted which aims to improve quality by minimizing nylon scrap. The method used to reduce nylon scrap is the DMAIC approach and Poka yoke design. The Improvement of the Scrap Work in Process by Using action plan 5W + 1H and designing method of DMAIC & Poka yoke design can be shown the data of scrap decreased 26% for Scrap Out spec quality and 68% for return from next process. The analysis of economy impacted outlook of payback period are 0.06 month and 1.05 month. The result in a reduction scrap nylon resulting in a value from 5880 PPM to 3454 PPM by maximum target 4270 PPM.

***Keywords:* poka-yoke, DMAIC, 5W+1H, payback period, nylon scrap.**

I. Introduction

Product quality can be related to an indicator of manufacturing performance level. The quality can be purposed to the most economical level [1]. Motorcycle manufacturing is one of industry in Indonesian country that be exported product of Tire motorcycle. Exported tire motorcycle in Indonesian company is increased than imported tire motorcycle. Based on data, from 2015 to 2019 exported Tire motorcycle is increased from 34167 US Dollar Thousand to 79090 Dollar Thousand and for import decreased from 10733 US Dollar Thousand to 7558 Dollar Thousand [2]. The competitive business of manufacturing is oriented to profit, effort to take more profit there are some kind of the way to achieve it. There are several wastes that can be reduced to get more profit, one of the waste can be reduced is scrap. Scrap means product that produced by abnormal condition of the product [1]. The manufacturer of motorcycle tire, there are several departments in the manufacturing process, from the material department to the finish good department. Bias cutting process is one of department that produced canvas by used to tire case in motorcycle tire. Extruding process is department that produced tread which is used to touch the road surface in motorcycle tire. Bead grommet process is department that produced bead by used forming round and strong tire motorcycle. Three departments have difference kind of the scrap such as extruding department bring about rejected of compound scrap, bias cutting department bring about rejected of nylon scrap and bead grommet department bring about rejected of wire scrap. Each material process departments have target to control cost of poor quality [3].

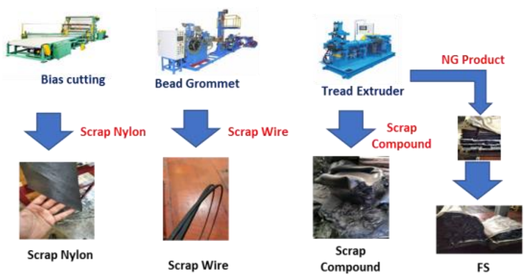

Fig. 1. Scheme work in process scrap and rework

There are two kinds of Cost of Poor Quality on scrap tire. They are Scrap Work in Process (WIP) and Rework. The Dominant Cost of Poor Quality such Scrap WIP around 90% and Rework 10% (Reference: Internal Annual COPQ Tire Motorcycle). WIP scrap data breakdown that has the largest contribution by nylon scrap has 52.3 % [3]. Nylon scrap has an over target of actual scrap which is around 39% from data 2018 to 2020. Actual PPM (Part per Million) of scrap nylon 5880 PPM and target from management 4270 PPM, therefore the actual scrap data (PPM) by target Management over around 39%.

Based on the problems that have been described, an analysis is carried out on how to improve quality in nylon scrap. Increasing quality in nylon product will affect the decrease in the amount of scrap. The analysis conducted in this study used the DMAIC approach, fishbone diagrams and several seven QC tools. 6 Sigma is a management system that is used to strive for improvement process efficiency or defect reduction [4]. DMAIC is five phases that can be increased manufacturing efficiency especially motorcycle tire manufacturing [5]. DMAIC method has content of analysis to Identified sources the causes of defective products can also be using the Ishikawa diagram [1]. The root cause (why analysis) is a part of several factors (incidence, conditions, factor organizational) which contribute, or the possible cause and followed by unexpected consequences [5]. Problem of scrap also can define and identify by using RCA [5]. The prevention of occurrence defect and eliminate problem of variation process (human failure) can be solved by Poka-Yoke concept [6].

II. LIERATURE REVIEW & RESEARCH METHODOLOGY

A. DMAIC

A methodology adopted to approach this case study is DMAIC (Define, Measure, Analyze, Improve and Control)[7]. Through the DMAIC method, it is possible to think about and solve a problem sequentially, it is also possible to smoothly complete the phase and start the next phase [8].

- Define

Define phase is determining the problem, assigning customer requirements [9]. The process of characterization and identification uses a Bar chart. This tool allows focus on the factors that cause variation process and Definition of project metrics. Make a segmentation of the focus categories to be analyzed [8].

- Measure

Choose critical to quality and was done by looking for the focus of the problem to be analyzed [5]. Also, this stage calculation DPMO and sigma level are needed [1]. The calculation of Defect per million Opportunities and sigma level can be defined.

$$DPMO = \frac{\text{Number Of Defect}}{\text{Number Of Products Or Products Inspected}} \times 1{,}000{,}000 \qquad (1)$$

$$Sigma\ Level = \frac{\text{NORMSINV}((1000000 - \text{DPMO})}{1000000} + 1.5 \qquad (2)$$

- Analysis

Analysis: Under this DMAIC Analysis phase, an investigation problems and defects (Scrap) is carried out to analyze the root causes and an action plan for that [5]. This phase also using several tools such as, Paired t – test, fishbone diagram, RCA, tree diagram and 5W +1H [1, 5, 8, 10, 11].

- Improve

The improve phase focuses on understanding full on the main cause that is identified in analyze phase, in phase improve, among others, namely Design of experiments. This phase describes the activities carried out based on the root of the problem obtained [5].

- Control

Stage set Standardization, control and maintain processes which has been repaired in the long run to prevent potential problems that will occur or when there is a change in process, labor and turnover management. And also, this stage is calculated Capability process (PPM) measurement after improve [12].

B. POKA-YOKE

Poka yoke is one of the main components in Shingo's zero Quality Control system where this system aims to remove defects or realize defects from an early age[13]. The purpose of poka yoke is to create preventive activities, therefore that the process does not experience errors or even when an error occurs, it can be corrected as soon as possible [14]. In addition, the Poka Yoke work system is to prevent defects at the source before defects appear in the after-process, therefore this is the most effective way to reduce inspection time. Basically, there are 3 basic functions of Poka yoke, namely: 1. Control the process as not to cause product defects. 2. Shutdown Stop the production process when realizing that it has made a defect. 3. Warning Give a warning when a potential defect product occurs.

C. Flow of Research

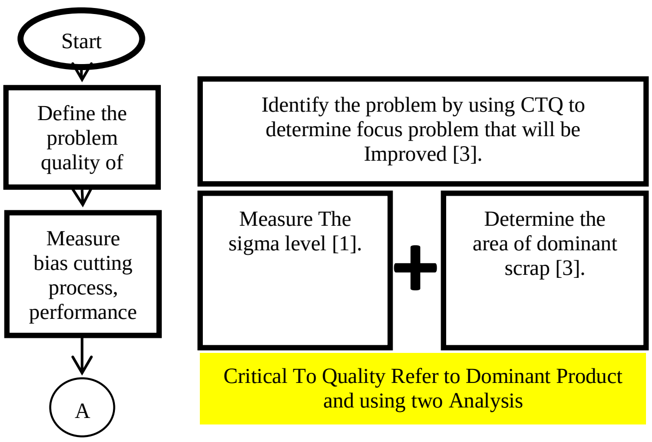

Fig. 2. Flow of research

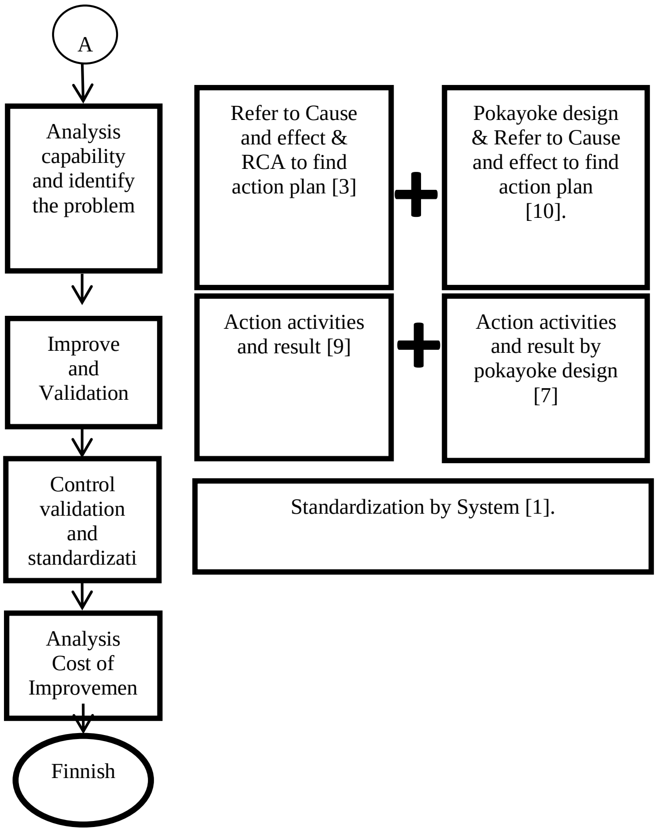

Fig. 2. Flow of research (*Cont.*)

DMAIC is a closed-loop process that eliminates unproductive process steps, often focuses on new measurements and applies technology for quality improvement [1]. Pokayoke design is used in detecting defects, stopping the production system and providing feedback as soon as possible [13, 15]. Therefore, to get the factors that cause problems and make improvements to prevent defects from happening again [15]. Provides an easy introduction to 7 QC, RCA and Fishbone analysis tools to increase or decrease non value added and defects that occur in manufacturing systems by applying them based on this area of lean manufacturing and their implementation [5]. The DMAIC structured approach serves as the basis for problem, an approach that combines with quality tools such as Pareto diagrams [8], control charts, cause and effect diagrams [15], flow charts [15], and several six sigma tools and can increase significant product quality improvement, support costs and drive the start of another project using a similar approach [8].

III. Result

The result of this research is using DMAIC framework.

A. *Define*

The define process has stages to define problems, objectives, and processes. In define, it is explained that there are two categories of nylon scrap that cause scrap over of target management. the two categories are Avoid and un-Aviod scrap.

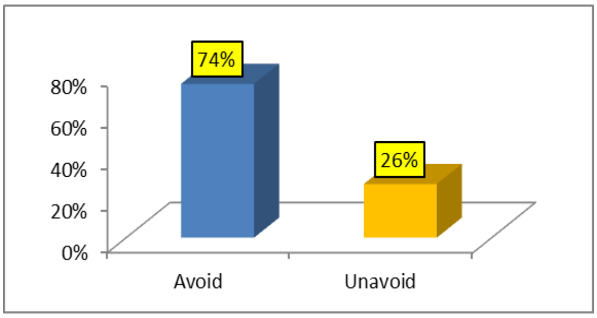

Fig. 3. Avoid VS Un-avoid scrap

Based on the data the avoid scrap is the dominant problem by 74% from totally scrap. The avoid scrap is divided by out spec Quality or process Failure and returned from next process.

B. *Measure*

Based on data taken from 2018 to 2020, the average -scrap per year reaches 1523 Kg Meanwhile, the resulting production average from 259004 Kg.

$$DPMO = \frac{Average\ Scrap}{Average\ Production} \times 1000000 \quad (3)$$

$$DPMO = \frac{1523}{259004} \times 1000000 \quad (4)$$

$$DPMO = 5880$$

Based on the calculation average defect part per million is 5880 PPM but the target is 4270 PPM. Otherwise, the actual scrap is over the target. The sigma level of this case is 4.02 by using the formula. Also, this phase developed P- Chart and the result of scrap within in control limit by the value of max and min such as 0.009 and 0.002. After calculation performance base line, determined of the critical quality to be analyzed by using Pareto diagram are out specification and return from next process by value of percentage such as 40% and 34% from totally kind of scrap.

C. *Analysis*

Based on the results of the measurement, this stage it explains that there are two categories of scrap included in the type of avoid scrap, namely out specification and returned from next process and both of scraps in this study will be analyzed.

- Out Specification & Process Failure

Out specification and Failure process is scrap that occurs in the bias cutting process. Out specification and process failures are scrap caused by non-conformity of sample limits and process failures in product manufacturing. Then from the achievement of the scrap, an analysis was carried out by determining the most dominant machine that caused the scrap to occur. The most dominant machine that will be focused is Machine 03, There is a Pareto diagram of the causes of scrap out specifications and failure processes.

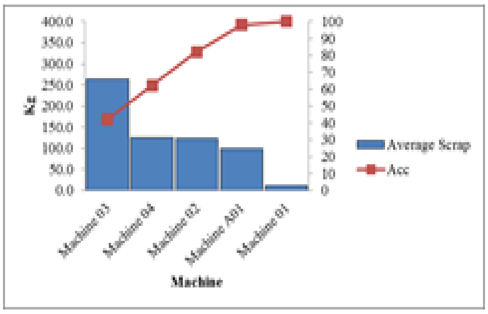

Fig. 4. Average scrap nylon out spec quality per machine

Machine 03 which is the most dominant machine from the causes of scrap out specifications and failure process. The next analysis is cause and effect of the out specification and process failure using root cause analysis.

TABLE I
ROOT CAUSE ANALYSIS MACHINE 03

Analysis Why	Nylon Scrap Machine 03		
Why 1	Failed Cutting	Failed Cutting	Process Changing of Treatment & Selection Material NG
Why 2	As Brake Slip	Rail Base Cutter is Not Center	Pasting Method is not Uniform
Why 3	As Brake Broken	Motor Base cutter escapes the rail	Pasting Method there is no regulation
Why 4	Home Brake there is Broken suddenly	motion of cutter exceed its rail cutter	There is no Standard of pasting Method to minimize scrap

The analysis of why-why point 4 is the root cause that underlies the improvement. But also, this stage is using 5W +1H to make action plan and testing by paired t test for make sure the improvement will be affected before and after. Then after the paired t-test the improvement that will affect to reduction scrap can be impacted to another machine.

TABLE II
ANALYSIS PAIRED T - TEST

Possible (X)	Statistic Test	Sig.	Prob.	Con.
Adding Spring or Not Using Spring	Two Proportion Test	0.000402	0.05	H0 is rejected,
Replacement of the home brake periodically before the failure occurs or Not	Two Proportion Test	0.434241	0.05	H0 is accepted
Method Of Selection and changing treatment and Selection or Not	Two Proportion Test	3.3E-14	0.05	H0 is rejected

Scrap after the home brake improvement is carried out because the sig value is > 0.05. Where, the improvement of add spring and selection / size change material method the value of sig < 0.05 and then it can be said that H0 is rejected (there is a decrease in scrap after improvement). From these results, the chosen improvement is adding spring and selection/size change material method. The normally test and paired test analysis using a confidence interval of 0.95 or with an alpha level of 0.05 otherwise if sig. value > 0.05 then there is no effect of scrap reduction before and after. But if sig value < 0.05 then improvement has effect of scrap reduction. Otherwise, Replacement of the home brake periodically before the failure occurs is not recommended to be implemented improvement.

- Returned from Next Process

Return from next process is scrap produced by returning the assembling process because the product does not comply with standards or specifications (Quality NG) while for scrap returns because BO (Balance Out) is due to material unbalance during the assembling process. Scrap returns from section building, namely NG quality and balance out and NG quality dominates scrap compared to balance out around 99% dominates then the BO.

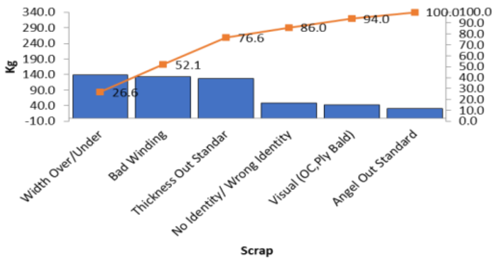

Fig. 5. Pareto diagram of scrap from next process

TABLE III
DESCRIPTION ELEMENT PROCESS AREA BASED ON NG PRODUCT

NO	FLOW PROCESS	ELEMEN PROCESS	ACTIVIY PROCESS	NG PRODUCT
1	Hoister Process	Hoist Machine Safety Check	Check Helm	No Ng Product of Return from Next Process
			Sling Tail Hoist	
		Process Hoister	Take A Treatment Material by Hoist	No Ng Product of Return from Next Process
			Put The Treatment Into Le Off	
2		Checking Machine Function	Condition Conveyor	No Ng Product of Return from Next Process
			Condition Sling Piston	
			Condition Cuter Unit	
	Joint Process	Jointer Process	Setting Angel	Angel Ng
			Cutter Process	No Ng Product of Return from Next Process
			Joint Process	Joint Ng
3	Winding Process	Material Checking	Angel Checking	Angel Ng
			Visual Checking	Ply Bald, OC,
			Width Checking	Width Over / Under
			Thickness Checking	Thickness Ng
		Booking Process	Prepare Liner	Bad Winding
			Take A Ply or Material into Liner	Bad Winding
			Give Identity Product	No Identity
		Checking	Width Checking	Width Over / Under

TABLE IV
WHY – WHY ANALYSIS RETURN FROM NEXT PROCESS SCRAP

Analysis Why	Width Overr / Under		Bad Winding	Thickness Out Standard
Why 1	Wrong Position To Checking	Man Power doesn't do the periodic Check	Wrong Position Of working and procedure	Operator doesn't checking Thickness
Why 2	Error Human & the opeator doesn't know	Difficult to Check in Beak Time	Operator Doesn't lock the Shaft	Area Checking too Far From Works station
Why 3	There is no Proofing to remembering operator	Man Power Only 2 Person on One Machine	Lock must Using L Key	Checking tools must be standing
Why 4		Operator Forget to checking	Operator Difficult to Lock The Shaft	Checking tools is not common used in work station area

Based on this type of scrap, the most dominant type of scrap with a total contribution value of 70% was selected for analysis. The type of return next process scrap there are width over/under, bad winding and thickness out standard. After determined the focus scrap will be analyzed then check the element process by using tree diagram and described on the table that made the scrap.

The analysis of why-why point 4 is the root cause that underlies the improvement. But also, this stage is using 5W +1H to make action plan to be improvement.

D. Improve

- Out Specification & Process Failure Improvement
  - Adding Spring

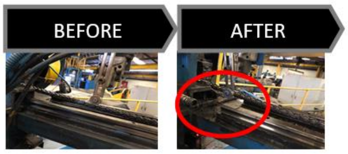

Fig. 6. Adding spring improvement

  - Make effective method to handling reduce scrap

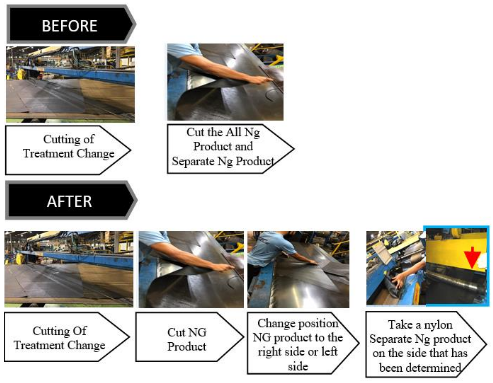

Fig. 7. Method of reducing scrap selection and material changing

- Return from Next Process Improvement

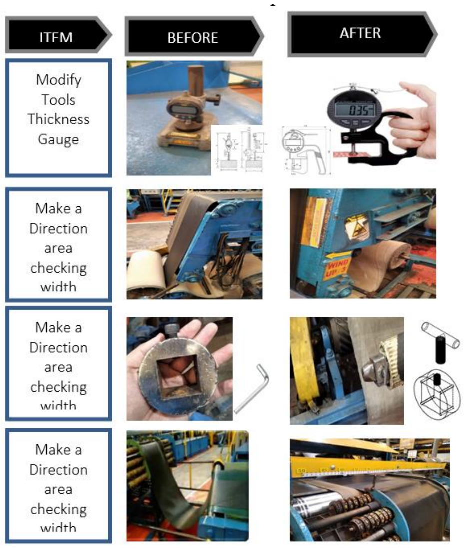

Fig. 9. Improvement of Scrap Return from next Process

E. Control

Scrap Out specification & Process Failure Decreased 26% by implementing Root cause and statistic paired t-test and scrap of returned from next Process decreased 68% by using Poka yoke Design, Tree Diagram and Ishikawa diagram. The social responsibility to achieving management target by analysis result is the achievement actual scrap data from 5880 PPM to be 3454 PPM by the target from management maximum 4270 PPM. To keep control stable; looking standards, check sheets and standard operational procedures were created to become part of the system.

F. Cost Analysis of Improvement

Pay Back Period of Investment improvement scrap out spec. & process failure 0.06 month & scrap returned from next process 1.05 month.

IV. Conclusion

The root causes of the categories for Nylon can be identified by the types of the categories of nylon scrap from the analysis that may occur in the bias cutting process by using Pareto diagram are Out specification & process failure (40%) and returned from next process (34%). Improvement to reducing scrap out specification, there are two items such as adding spring and Method of Selection or changing material by remove one item is caused of hypothesis is accepted by value of significance 0.434241 and value of σ using 0.05. Improvement to reducing scrap return from next process, there are four items such as Modify Tools Thickness Gauge, direction area checking width position, modify handling lock shaft and mold width for visual checking. Scrap Out specification & Process Failure Decreased 26% by implementing Root cause and statistic paired t-test. Scrap of Returned from next Process decreased 68% by using Poka yoke Design. Pay Back Period of Investment scrap out spec. & process failure improvement such as 0.06 & scrap returned from next process 1.05 month. The achievement of management target by analysis result is the actual scrap data from 5880 PPM to be 3454 PPM by the maximum target 4270 PPM. Improve by using new machine and comparing the reduction of scrap for looking at the best solution also calculated by using Feasibility study will be interesting for future work.

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