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Six Sigma DMAIC for Quality Improvement of Cone Roll Defects on Winding Section: A Case Study on Spinning Industry

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ABSTRACT

Cone roll defects are a critical problem in winding machines at PT Excellence Qualities Yarn. The study aims to decrease cone roll defects by combining Six Sigma DMAIC (Define, Measure, Analyze, Improve, and Control) combined FMEA (Failure Mode and Effect Analyze). The defect rate of the cone roll was up to 33%, causing a massive loss to the company. The Pareto diagram showed the first two defects; 74.4% are tailless, and swelled from eight types of defects were identified. After performing improvements by project Six Sigma, defection was reduced following the project aim is under 15%. The Sigma's level increased from 3.51 to 3.61 within one month of the implementation. This research can recommend improvement seeing the Six Sigma DMAIC method to decrease the textile industry defect rate, especially in the spinning industry.

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INTRODUCTION

The textile Industry cannot be separated from life. Every product we wear is a textile product. The development of the times and the Global economy has also caused changes in every sector, especially the textile industry. The textile industry is one of the manufacturing sectors that contributes a lot to the country's foreign exchange, which recorded the highest growth exceeding economic growth in the third quarter of 2019 in Indonesia the textile industry. Therefore, the textile industry is essential to the country's economy [1]. Therefore, manufacturers are required and responsible for ensuring that consumers receive materials of sufficient quality for the price paid. Manufacturers must also maintain consistent quality standards while meeting specified specifications with processes and quality controls that must be effective [2]. Because one of the bases of reputation in textile company competition is quality, reliability and process capability, quality costs, and delivery (at the right time and quantity employing quality control [3] [4] [5]. Quality is a dynamic state characterized by goods, individuals, or workforce, processes and activities, and environmental shifts that fulfill or exceed consumers' wants [6].

PT Excellence Qualities Yarn (PT EQY) is a textile industry company engaged in yarn spinning. The spinning industry is an upstream textile industry that processes fiber into yarn [7] [8]. Spinning is a process utilized to make fibers or filaments from natural or synthetic polymers, or to make yarn from natural or synthetic fibers and filaments by twisting or other techniques of tying the fibers or filaments together, resulting in a relatively smooth and continuous length of yarn [9]. Various types of yarn produced by PT Excellence Qualities Yarn will be marketed in various parts of Indonesia to export to various countries, with marketing objectives such as Asia, America, Africa, and Europe. Over 90% of PT Excellence Qualities Yarn's output capacity is exported, and the remaining 10% is local. Therefore, PT Excellence Qualities Yarn is expected to provide high-quality yarn products to meet market demand. However, the yarn-spinning process to produce high-quality products cannot be distinguished from a variety of difficulties produced by a variety of variables.

One of the problems occurs in the winding process on the winding machine. The winding section with a winding machine is necessary after the spinning process because small spinneret packages are primarily unsuitable for subsequent processes such as weaving and knitting [2]. PT Excellence Qualities Yarn has already used the winding machine "Saurer Schlafhorst" with the auto corner 6 type, which already uses a uster quantum 3 sensors with an accuracy in reading quality that is getting better than the previous generation of machines. However, in the production process, not everything can run smoothly. There must be production results that do not meet standards. The industry has given more focus to the winding section as yarn quality plays a significant role in developing new products and producing better-quality products [10]. PT EQY is a textile firm in Indonesia that specializes in yarn industry that, in current conditions, is experiencing quality-related problems. Problems in the production process include cone defects such as bulge winding, tailless, swelled, whisker, saddle, dirty, end missing and stepped-on winding section. Production evidence demonstrates that various product defects reach the cumulative the proportion of defects is higher than the corporate average, which is 9-33% every week. Therefore, process control to maximize product quality must be carried out to reduce defects in all production processes, especially in the final process when the yarn has become a cone roll form on the Winding Machine. It is helpful to affect competitiveness and is considered essential to win the business competition.

Six Sigma is a lean tool and strategy as a statistical Quality tool with DMAIC (Define- Measure- Analysis- Identify- Control) to accomplish it [11] that is commonly used to performance strategy improvement by many significant businesses process management to improve productivity and quality performance and reduce defects in any process [12,13]. Six Sigma is a significant innovation in quality management and process improvement that has established an impressive reputation in different kinds of businesses since the beginning of the 1990s and has been employed in management businesses, products, or services over the previous two decades [14].

This study is a study case to propose a step-by-step procedure for using DMAIC stages to reduce cone defects in the winding section. Several tools and techniques in lean manufacturing, like the Pareto diagram, ishikawa diagram (fishbone), and FMEA (Failure Mode and Effect Analysis), are used in the analysis and improvement stage. The aims are to reduce the defects opportunity causing the poor product quality and production target, so that can reduce the high rejection rate of product. The novelty of this study is to make quality improvements by Six Sigma DMAIC combined with other lean manufacturing tools to reduce the defect rate of the final process of the spinning industry in textile companies.

LITERATURE REVIEW

Six Sigma is at the forefront of many firms' priority lists when cutting costs and increasing efficiency. It has appeared as a focus zone of study to provide more significant advantages to the industry [13]. Motorola is one of the well-known industries that has effectively embraced Six Sigma. [15], which saves up to USD 2.2 billion [13]. Because Six Sigma generates significant improvements to the bottom line through planning and observing day-to-day business operations. The Six Sigma DMAIC process can save money and enhance quality on the shop floor [12]. Literature analysis suggests the six- sigma DMAIC technique is the best practice for boosting the quality of processes in manufacturing sectors [15]. In the manufacturing industry, the Six Sigma DMAIC technique is used in a variety of processes to improve quality, i.e., strips manufactured [13], service industries (equipment repair) [16], automotive (auto manufacturer) [17], railcar industry [18], biopharmaceutical [19]Recent research has discussed the benefits of six Sigma DMAIC in the textile industry to carry out a quality control evaluation on carded and combed yarn production in one of Indonesian textile industry [20]. A study by [21] used DMAIC for an energy audit in a textile company's Spinning department, which may result in energy cost savings.

Furthermore, the Six Sigma implementation approach has been demonstrated in several case studies, even though there are few publications on the Six Sigma DMAIC technique in the Indonesian textile industry. The author considers that a case study using the ix Sigma DMAIC technique would benefit a wildly spinning Indonesian textile industry by gaining more knowledge and lessons learned. In order to lower the number of faults in yarn production, the empirical study by case study presented in this study applies the Six-Sigma DMAIC technique in Indonesian textile company in the winding section. Therefore, to increase quality, it is critical to count and remove the number of defects.

RESEARCH METHODOLOGY

A case study on the practice of the Six Sigma DMAIC identified problem statement and Data pertaining to the project issue has been gathered from observation with the discussions with the industry quality team and literature reviews. This study gives a case study on implementing the Six Sigma DMAIC methodology to reduce the rejection rate of cone defects manufactured by the winding section. A DMAIC analysis was utilized to investigate and reduce the defection rate of defects. Figure 1 depicts a thorough flow diagram of the study approach for this project.

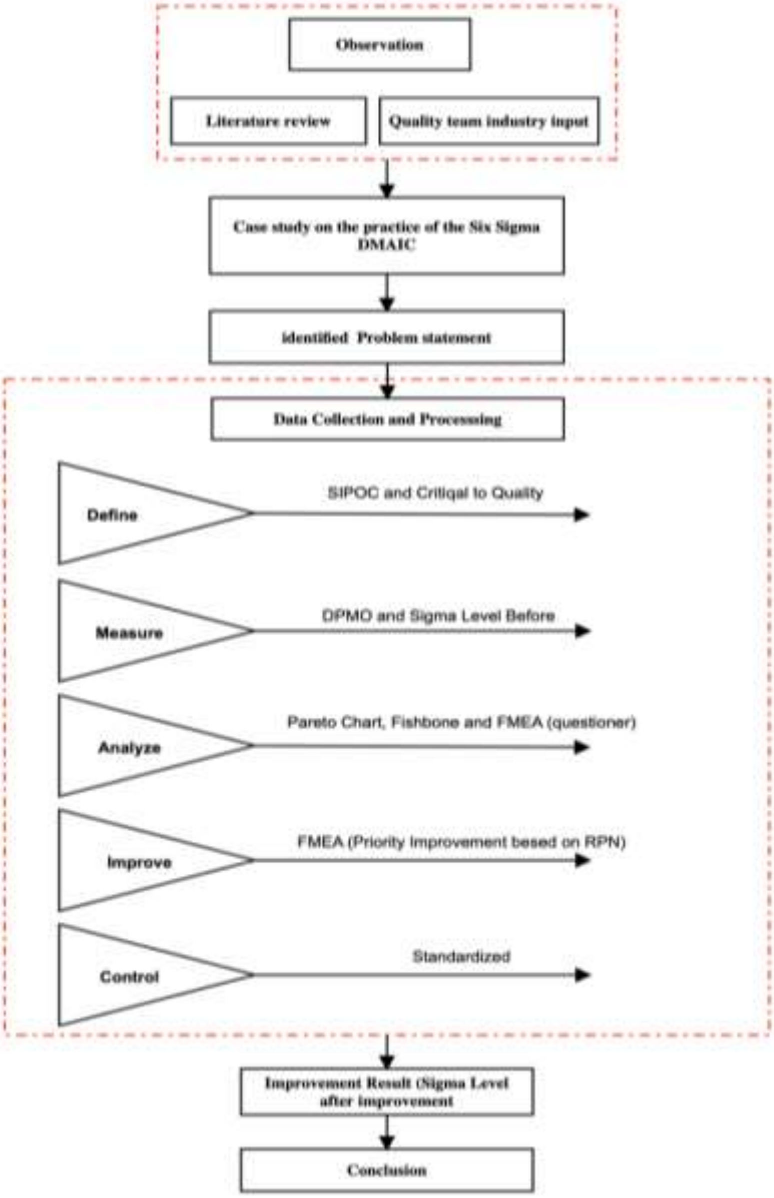

Figure 1. Research Methodology

The Six Sigma-DMAIC method employs the following approaches to solving problems:

- Define the project's problem and purpose [13], and a process map is created [17]. In this phase, make a SIPOC (supplier-Input-Process-Output-Costumer) diagram and critical to quality.
- Measure - To assess the current state of the situation [13], data is gathered, and the actual defects are counted [17].In this phase, calculating DPMO Defect Per Million Opportunity (DPMO) and Sigma Quality Level (SQL) provides a sigma value describing the level of performance of the process [6].
- Analyze- Evaluation of factors influencing the process's quality standard discovering the sources of process defects based on measurement results and potential solutions [17] using tools: Pareto, fishbone diagram, FMEA (Failure Mode and Effect Analysis) [22].
- Pareto Analysis allows to decide which challenges or projects will have the greatest payback. According to the Pareto Principle, 80% of issues are caused by 20% of the causes. [23]

- Fishbone diagram is investigation and brainstorming in the form of a cause and effects diagram. This step is used to discover the root cause of the problem [24].
- Pareto analysis charts and fishbone diagram to identify significant defects and what causes them in order to fix them and enhance the process. After a total of causes, defects were identified. The next step is to analyze the potential causes of failure and evaluate risk priorities using the FMEA (Failure Mode and Effect Analysis) method with a questionnaire filled in with related parties in the industry, including field trainers, Quality Control, and Quality Assurance.
- FMEA is an engineering process that identifies probable failure modes and their causes, assesses their impact within a particular system, and identifies decisions required to avert specific system failures [23].
- Improve - the team comes up with and chooses a set of options to improve sigma performance [17]by seeking to implement solutions to the identified root causes. It can involve mistake-proofing procedures, which offer an engineering correction that makes the error impossible [19]
- Control entails developing Standard Operating Procedures to ensure that the improvement continues over time [17] and future process performance. The progress that has been made must be maintained [18].
- Finally, the final steps of this investigation are Conclusions and Suggestions. Conclusions are made from problem-solving outcomes that are consistent with the study aims. The findings of this can provide recommendations that can be looked up on and executed in the operations of the company, as well as proposals for future research.

RESULT AND DISCUSSION

The defect rate of cones rolled by the winding section was significantly high. It was about 9-33%, causing substantial monetary loss to the business and affecting customer satisfaction. Therefore, it is decided to utilize the Six Sigma DMAIC to minimize cone defects. The DMAIC utilized in this practice is divided into five fundamental phases:

Define Phase

The project charter is the most essential step in the DMAIC Define phase since it can make or destroy the project's success. The project charter identifies the client requirements that serve as the basis for the Critical Quality Characteristics (CTQs), or the quality metrics essential to meeting the customer's needs [17]. Project charter as described below:

Case on winding section: Defects cause an excessive number of reworks that impact rising costs of concern
Identified Problem statement: Cone roll defects was 9-33%

Project aim: reduce the defect rate to under 15%

Identify CTQ Statement (Customer need): free cone roll defects from the winding section because Customer satisfaction was low because of a significant defective PPM (Parts per million) level [13].

Financial Benefits Expected: Significant cost savings owing to defect reduction

Customer Expected Benefits: Increase overall client satisfaction and impression

The analysis concentrated on the production line that provided the finished product in the "cone roll" product on the winding section. The process flow process chart is shown in Figure 2 in the SIPOC diagram of the complete conversion process from polyester and rayon fiber to yarn by cone roll. Table 1 represents various and total cone roll defects (CTQ) identified and directly impact achieving the target quality based on observations.

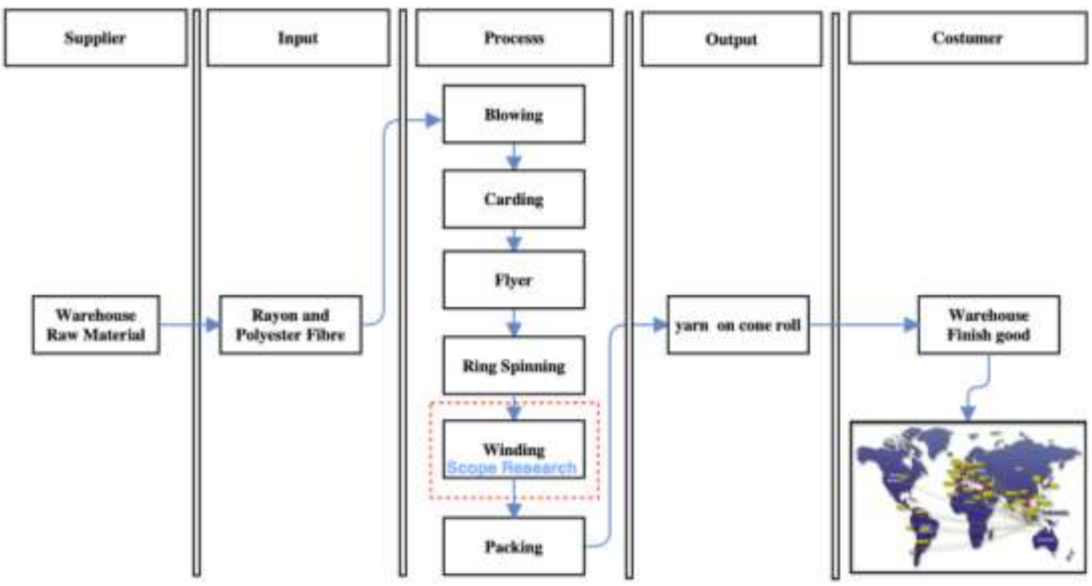

Figure 2. SIPOC Diagram

Figure 2 explains that suppliers provide the raw materials from the raw materials warehouse to produce goods from rayon fiber and polyester. Inputs are raw materials suppliers provide to be converted in production. The process stage includes Blowing: mixing the fibers, opening fiber clumps, and cleaning fiber impurities. Carding: Opening the fiber clumps further so that the fibers are separated from each other, Cleaning the dirt that is still in the fiber clumps, or that is stuck as cleanly as possible, Shaping the fibers into slivers with the direction of the fiber to the axis of the sliver. Drawing: Straightening and aligning the fibers in the sliver in the direction of the fiber axis of the sliver, Improving the evenness of the weight per unit length, sliver, mixture, or other properties employing folding, Adjusting the weight of the sliver per unit length according to the requirements in the following process (drafting). Flyer: Straightening and aligning the fibers in the sliver towards the fiber axis of the sliver, Twisting (so that it does not break easily when in the RSF machine), Forming rovings. Ring Frame: Drafting, Twisting, Winding thread in the form of cops. The final stage in the process is winding: rolling the thread from Cops into cones, removing uneven threads, and ending with packaging in boxes and sacks with pallet bottoms. The output is a cone roll ready for client distribution as a result of the manufacturing process. The customer receives the output from the process, which is then received in the finished goods warehouse, ready to be distributed to external customers.

Table 1. Data Cone Roll Defects (Critical Quality)

No	Defect Type	Number Of Defect	Percentage
1	Tailless	52	66,7%
2	Swelled	6	7,7%
3	Stepped	6	7,7%
4	End Missing	5	6,4%
5	Bulge Winding	4	5,1%
6	Saddle	2	2,6%
7	Dirty	2	2,6%
8	Whiskers	1	1,3%
	Total	78	100,0%
Week	**units check**	**Total Defect**	**defect percent per week**
1st	112	10	8,93%
2nd	112	12	10,71%
3th	112	19	16,96%
4th	112	37	33,04%
Total per month		78	17,41%%

Table 1 above explains 8 defects that often occur in Unit 2 in the Winding Saurer Schlaforst Autocoro 6 are:

1. Tailless roll: absence of a thread tail attached to the end of the paper cone, which is helpful as a connector in the following process.
2. Swelled: a spool of thread that appears on a circle's top, bottom, or top surfaces.
3. Whiskers: ends of the thread that appear or come out of the surface of the thread roll.
4. A saddle is a roll defect caused by high tension but low contact pressure with the cone, forming a saddle.
5. Dirty: parts on the surface of the cones roll.
6. bulge: showing the two surfaces of the package protruding;
7. End missing: without the end of this thread resulting from the top surface of the package curved above the take-up tube. (Sometimes, the thread bends, unraveling into the package again.)
8. Stepped: package where the thread is rolled with a shorter than standard traverse due to the deviation of the thread from its path due to several obstacles. The path of the thread leads straight to the rolled thread.

Measure Phase

The data collection of the measure phase is utilized to determine the present level of process performance. As a result, measuring the quantity of defects and eliminating them is critical to quality improvement. Defect per million opportunities (DPMO) value by calculating with eqs. [13]:

$$\text{Defect per unit (DPU)} = \frac{\text{Number of Defets}}{\text{Total number of units}} \quad (1)$$

$$\text{Defect per opportunity (DPO)} = \frac{\text{DPU}}{\text{Number of defects opportunities per unit}} \quad (2)$$

$$\text{DPMO} = 1.000.000\text{x}\frac{\text{Total defect samples}}{\text{defects opportunities samples}} \quad (3)$$

$$\text{Yield} = 1 - \text{DPO} \quad (4)$$

$$\text{Sigma level} = \text{Normsinv}\frac{\text{Total defect samples}}{\text{defects opportunities samples}} \quad (5)$$

Table 2. DPMO Value and Sigma Level

Week-	Number of units	Number of Defects	DPU	DPO	Yield	DPMO	Sigma Level
1	112	10	0,089	0,0128	0,987	12755,10	3,73359
2	112	12	0,107	0,0153	0,985	15306,12	3,66208
3	112	19	0,170	0,0242	0,976	24234,69	3,47323
4	112	37	0,330	0,0472	0,953	47193,88	3,17269
Average DPMO and Sigma level						24872,45	3,51040

Table 2 explains that the average DPMO value for the production process for cone roll defects is 24872.45, meaning there are 24872.45 possible defects every million product. While the average Sigma level is 3.51, Sigma level 3.51 is a reasonably good Sigma level. However, more attention must be paid to increasing the sigma level to reduce variations in product defects and increase production productivity, which will be profitable for the company.

Analyze Phase

During the analysis step, the acquired data was analyzed using Pareto Analysis Charts, as shown in Figure 3. Analyze the defects and their cumulative percentage of defects for the product's highest defect rate. To enhance the process, use a Fishbone Diagram to identify root causes from the highest defects found on Pareto charts, as shown in Figure 4.

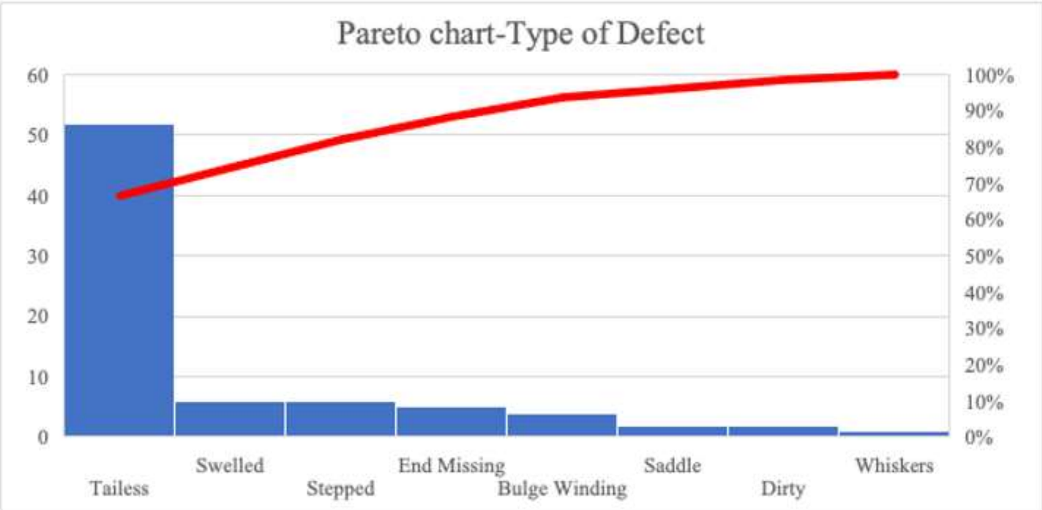

Figure 3. Pareto Diagram

Figure 3 shows eight defects that have been found, which were primarily causes for the high defect level. It may be analyzed from the Pareto chart that the percentage of defective cause by the first two defects (tailless and swelled) was considerably high, about 74,4% of the total defects. Therefore, it is decided to handle the causes of these two defects. The two significant defects' primary causes were analyzed using a fishbone diagram. A Fishbone diagram helps identify potential root problems so that appropriate action can be taken can be proposed using a systematic approach.

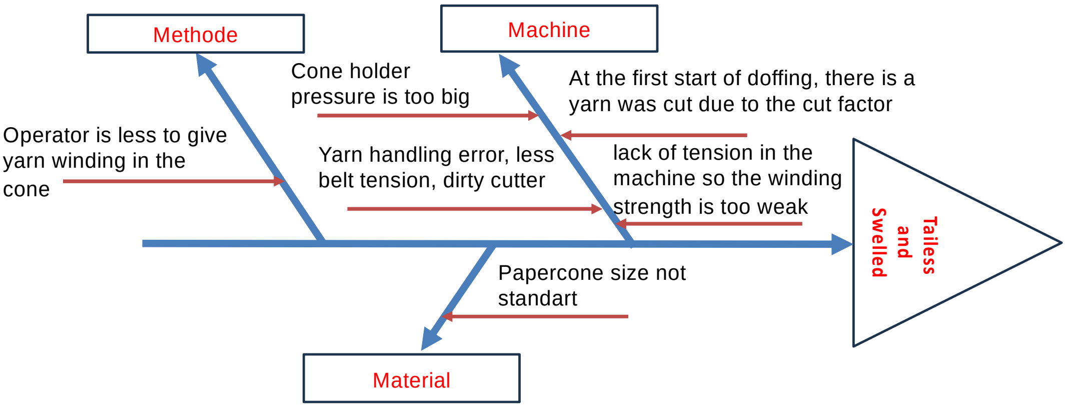

Figure 4. Fishbone Diagram

Figure 4 exhibits a fishbone diagram to recognize the varied root causes liable for the cone roll defects. A six root causes were discovered by the three causes: machine, material, and method. The following stage is to do an analysis potential causes of failure and evaluate risk priorities using the FMEA. The risk priority number (RPN) is determined by three risk parameters: severity (S), occurrence (O), and detection ratings (D). The FMEA analysis outputs are used to determine which failures are the most critical and what remedial measures are required for failure prevention. Then, multiply the three indicators to measure RPN used to determine proposed action for improving the process [25]. The weighting of values for the FMEA analysis is obtained from filling out the questionnaire form created and filled in with related parties in the industry, including field trainers, Quality Control, and Quality Assurance.

Table 3. Failure Potency and RPN Value

Failure Potency	S	O	D	RPN
At the first start of doffing, there is a yarn was cut due to the cut factor	6	5	3	90
The operator is less likely to give yarn winding in the cone	8	4	4	128
lack of tension in the machine, so the winding strength is too weak	8	6	4	192*
Yarn handling error, less belt tension, dirty and broken cutter	8	7	6	336*
Cone holder pressure is too big	7	7	6	294*
Papercone size, not standard	6	6	5	180

Table 3 shows each cause of the six factors that cause cone roll defects. It can be known that 3 root causes have the highest number of RPN values that cause defects based on respondents and their explanations: 1) Yarn handling error, less belt tension, dirty and broken cutter have the most significant RPN rating of 336, 2) Cone holder pressure is too big; the cone holder pressure is too enormous and has an RPN score of 294. The cone holder pressure occurs due to incorrect settings, such as the pressure being too big to match the size of the paper cone, causing the paper cone to be squeezed and the tail coil to fall off. Lastly, lack of tension in the machine, so the winding strength is too weak and has an RPN score of 192.

Improve Phase

The improvement phase is the fourth stage in using the DMAIC for making of the proposed improvement stage is expected to minimize defects in the product in terms of production factors in the field. During the investigation phase, process functions were studied, and presently available data data was analyzed to identify probable failure modes. Moreover, effective solutions are developed to eradicate the problem's root cause. Proposed corrective action can be observed in Table 5.

Table 4. Proposed Corrective Action Cone Defects

No	Factor	Cause of failure (defect)	Proposed Corrective Action
1	Machine	1. Some machine plates have problems such as yarn handling, less belt tension, broken belts, and dirty cutters. 2. Cone holder pressure is too big 3. lack of tension in the machine, the winding strength is too weak	1. Frequently check the state of the machine before starting production 2. Pay attention to machine settings 3. Increase the tension setting, for example, from 23 to 25 according to the Ne specification.
2	Material	Paper cone size is not standard	1. Increase Accuracy in purchasing 2. Arrange the paper cones well
3	Method	An operator is less likely to give yarn winding in the cone	In making coils, paying attention to the standard method, which is 10 turns, is necessary. If it is deemed insufficient, it can be increased to 12 or so

Improvements by proposing corrective actions are projected to raise the value of the sigma level. It serves as a quality criterion in manufacturing processes. Therefore, the cone roll defects percentage, DPMO value, and Sigma level can be obtained after improvement.

Table 5. Cone Roll Defects after Improvement

Week	units check	Total Defect	%
1st	182	26	14,29%
2nd	182	15	8,24%
3th	182	24	13,19%
4th	182	25	13,74%
Total		90	42,86%

Table 6. DPMO Value and Sigma Level after Repair

Week-	Number of units	Number of Defects	DPU	DPO	Yield	DPMO	Sigma Level
1	182	26	0,143	0,0204	0,980	20408,16	3,54539
2	182	15	0,082	0,0118	0,988	11773,94	3,76443
3	182	24	0,132	0,0188	0,981	18838,30	3,57836
4	182	25	0,137	0,0196	0,980	19623,23	3,56159
Average DPMO and Sigma level						17660,91	3,61244

Table 5 shows that the defect rate of cones rolled by winding section after improvement can reduce the defect rate under 15%, which is 14,29%. It is following the project aim in the project charter. Table 6 shows that after improvement, the DPMO value for the production process for cone roll defects is 17660.91, meaning there are 17660.91 possible defects every million product. While the Sigma level rise is 3.61, according to the Table of Cost of Poor Quality, it means above average standard Indonesian industry [26].

Control Phase

This phase saw the execution of plans for observing the performance of the system and taking corrective steps when divergences from what had been discovered.. The control stage is the fifth and final DMAIC method stage [13]. It attained by enforcing control by the Supervision of production activities is always supervised by the quality assurance (QA) section and conducts coordination meetings between the production department and the quality Control (QC) section. Some of the control measures that are treated are as follows: 1) Routinely perform machine maintenance in the production area and always maintain cleanliness; 2) Checking machine settings before starting production; 3) Do scouring and cleaning according to schedule; 4) Improve the understanding of the standard winding used by the operator to avoid mistakes when making the tail; 5) Supervisors, shift heads, team heads and related parties must routinely check the ongoing production process; 6) The shift head must routinely provide a good understanding of SOPs for workers to work well, especially workers who are new to the area.

CONCLUSION

Improvement with Six Sigma DMAIC successfully fulfills a project aim in the project charter that has been made by reducing cone roll defects percentage following target is under 15%. The quality of the cone roll in the winding section is rising. It is substantiated by the sigma value of 3.51 to 3.61-sigma. Types of cone roll defects that can identified are swelled, end missing, whiskers, bulge winding, stapped winding, wrinkles, dirty, and tailless roll. There are causes by Machine, Material, and Method; by root causes are machine plates that have problems such as yarn handling, less belt tension, broken belts, dirty cutters, Cone holder pressure is too big and lack of tension in the machine, the winding strength is too weak. Paper cone size is not standard. The operator is less likely to give the first yarn winding in the cone. Suggestions improvements that have been given based on the proposed correction action are expected to be recommendations that can be followed up on and executed for the benefit of the company, as well as proposals for future research for the Indonesian textile industry, wildly spinning industry to reduce the cone roll defects in the winding section.

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