Application of the Six Sigma Method on Improving the Quality of Plastic Sacks

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Abstract

This research focuses on plastic sacks produced by a plastic recycling company. The company is a manufacturing company in the recycling industry that produces plastic seeds and plastic sacks. This research identifies defects or shortcomings in the plastic sack production process. The purpose of this study is to identify and analyze the causes of product defects during the production process. Furthermore, improvement proposals will be given to reduce product defects in the production process. The method that will be used in this research is the Six Sigma method using DMAIC tools (define, measure, analyze, improve, control). The average production produces 20,404 kg of plastic sacks in 6 months, with a defect rate of 3.12% of total production. Defects in the production process include defects in raw materials and loose stitches. Based on the calculation of Defects Per Million Opportunities (DPMO), the sigma level was found to be 3.59. An RPN value of 252 was also obtained for the detached stitch defect from the FMEA analysis. The cause of the production defect is the shifting of the bag weaving machine from its weaving groove. This research is expected to provide benefits by reducing the number of defects that occur during the production process in the company.

Keywords
Quality Control, Six Sigma, DMAIC (define, measure, analyze, improve, control), Defects Per Million Opportunities (DPMO), Failure Mode and Effect Analysis (FMEA)

1. Introduction

The rapid development of science and technology today, it makes us more open to change because of the progress and development in the industrial world. In this industry 4.0, the Company is increasingly advanced and there are also operations in the industrial sector itself that are more practical and simple. This practicality is supported by the use of sophisticated machines that will produce products with good quality. To get quality product results, it is necessary to have quality control which aims to keep the product of good quality and quality to increase consumer attractiveness to choose these products. Quality is a multifaceted concept that encompasses various attributes and characteristics of a product or service (Kostas 2020). The level of quality of the products produced including some of these characteristics must be maintained within a certain limit. Therefore, to maintain the quality of products produced within a certain limit, it is necessary to control quality based on the 4M factor (machine, material, man, method). The company in the study is one of the companies engaged in recycling plastic waste and trading plastic waste. This company carries out production by recycling sack waste taken from collectors. In the production of the sacks themselves, several work processes will be carried out such as extruder, knitting, cutting, sewing yarn, and finish good. Quality Control carried out during the sack-making process is an inspection of the knitting process which will record the amount of production, and the number of defective products produced every day to be reported to the production manager. Sack production itself is the most produced production, therefore the focus of this thesis discussion is defects in raw materials used in the production process, and also product defects produced during the sack production process. The following is data on the sack production process which has defects can be seen in table 1.

Table 1. Data on Total Production and Defects

Sample	Total Production (kg)	Raw material defects (Kg)	Defects Loose stitches (Kg)	Total Defects (kg)	Percentage
1	19951	693	34	727	3,64%
2	20733	529	36	565	2,73%
3	20691	681	35	716	3,46%
4	20268	576	35	611	3,01%
5	18933	508	33	541	2,86%
6	22043	784	36	820	3,72%
7	21354	693	34	727	3,40%
8	18633	563	33	596	3,20%
9	20475	596	35	631	3,08%
10	20324	501	35	536	2,64%
11	21743	693	34	727	3,34%
12	21272	594	35	629	2,96%
13	19436	592	35	627	3,23%
14	20049	467	36	503	2,51%
15	18293	563	33	596	3,26%
16	20292	549	35	584	2,88%
17	21493	749	35	784	3,65%
18	21486	635	34	669	3,11%
19	20328	583	33	616	3,03%
20	20898	498	34	532	2,55%
21	21589	498	34	532	2,46%
22	19974	574	35	609	3,05%
23	19435	673	35	708	3,64%
24	19990	637	33	670	3,35%
Total	489683	14429	827	15256	74,76%
Averange	20403,46	601,21	34,46	635,67	3,12%

Production defect data is quite large because it has exceeded the tolerance limit for production defects of 2%, therefore it is necessary to control quality during the production process. With the use of the six sigma method, the causes of waste that occur so that product defects can be found and handled. The application of the six sigma method in this study is only focused on defect data with the DMAIC stage for the research steps. Then proceed to calculate the failure rate of product defects at the sigma level of one million DPMO six sigma opportunities. Then get the root cause of product defects and find the right solution for the company to reduce waste.

2. Literature Review

Product quality refers to the characteristics and attributes of a product that meet or exceed consumer expectations and requirements. This can include factors such as durability, reliability, performance, aesthetics, and overall satisfaction with the product (kasmad 2022).

The goal of quality control is to maintain consistent and high-quality goods and services, prevent faults, increase reliability, and increase customer happiness (beata and edwin 2015).
Six Sigma is an approach and methodology that is data-driven and used to find and fix faults or defects in processes. It uses statistical analysis and problem-solving methods to reduce variability and enhance quality. Reaching a performance level where the likelihood of errors is incredibly low per million opportunities is the aim of Six Sigma (Rohit and Zafar 2021).

3. Research Methodology

Data collection is done by conducting interviews with the Quality Control division. The data taken is production data and defective plastic sack products from February 2023 to July 2023. After obtaining the required data, the author will process the data using the six sigma method with the stages of Define, Measure, Analyze, Improve, and Control. The first thing to do is to evaluate using SIPOC and CTQ which aims to identify what causes production defects, then measure performance at the measure stage using DPMO P control map, and process capability. Then at the analyze stage, analyze the cause and effect of the problem using FMEA and Fishbone diagram. After the root cause of the problem is found, the next step is to determine corrective action or improve which aims to improve product quality and also reduce product defects with proposed improvements. Next is the implementation of the proposed improvements that have been given. Finally, in the control stage, measurements are taken by calculating the control map, DPMO, and sigma level after implementation, which aims to compare production quality after implementation.

4. Results And Discussion

4.1 Production data and Issues

In the production of plastic sacks, there are two types of defects, namely raw material defects and loose stitch defects. Defects in plastic sack production can be seen in Figure 1 and Figure 2 below.

Figure 1. Raw Material Defects

Figure 2. Detached Stitch Defect

The next step is an analysis using the six sigma method, namely DMIAC (Define, Measure, Analyze, Improve, Control) with the aim of reducing defects in plastic sacks.

4.2 Define

At this stage, the process of identifying products and production processes is carried out. At the define stage the problem will be defined into a project charter, sipoc diagram and critical to quality.

Project charter

A project charter is a crucial part of project management, outlining the project's purpose, scope, objectives, and approach. The process of creating a project charter involves defining the project vision, system, and implementation approach (Jamil 2015). Project charters can be seen in the table below

Table 2. Project charter

PROJECTS CHARTER				
1. *Business Cases*	**3. *Constraints & Assumptions***	**4. *Projects Scope***		
The company is one of the companies operating in the field of plastic waste recycling and plastic waste trading . This company itself produces plastic pellets and plastic sacks. In the production process carried out there were still quite large *defects , reaching 3.03% defects* during the 6 month production process. Therefore, an analysis of the causes of defects was carried out using the *six sigma method* with the aim of reducing existing product defects.	3.1 *Constraints* There are restrictions for employees, namely the company requires employees to carry out the production process 24 hours continuously. Limitation All that exists for students is to be responsible and complete work *projects* according to the time given.	This research was conducted on one which was founded and started in 2019 and is located Jl. Raya Cikande Rangkasbitung No.KM, RW.11, Bojot, Kec. Jawilan, Serang Regency, Banten 42177. The focus of production used in this research is plastic sacks. The data used in this research is 6 months of production data, namely from February 2023 to July 2023		
2. *Projects Statement*	3.2 *Assumptions*	5. ***Preliminary Plans***		
2.1 *Problem Statement* There are defects in sack production, namely raw materials that do not meet *standards* and loose seams. Of those taken in February 2023 to July 2023, 490,444 kg of sacks were produced and 14,882 kg *were defective* .	The assumption used in this research is that the number of *defects* decreases so that product quality can increase.	*Timeline/ Phase*	*Start Date*	*End Date*
		Define		
		Measure		
		Analyze		
		Improve		
		Controls		
2.2 *Opportunities Statement*	***Projects Time Schedule***			
Make efforts to reduce defects with proposed methods provided by researchers so that *the defects* that occur are reduced as expected.	*Daily*	*Weekly*	*Monthly*	
2.3 *Goals Statement*	***Signature***			
This research has a target of reducing *defects* that occur in the production process, namely reaching 0-1% *of defects* that occur so that product quality can increase.	*Team Leader*	*Team Members*	*Process Over*	

SIPOC Diagram

SIPOC stands for Suppliers, Inputs, Process, Outputs, and Customers. The SIPOC model helps in identifying the suppliers and customers of a process, the inputs and outputs of the process, and the high-level steps involved in the process (Pratima and rajiv 2014). The SIPOC diagram can be seen in Figure below.

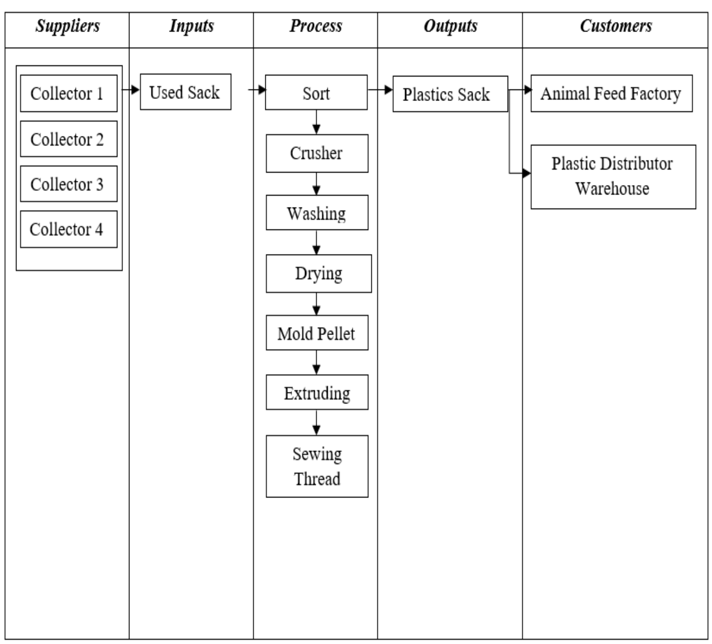

Figure 3. SIPOC diagram

Critical to Quality (CTQ)

Critical to Quality (CTQ), are attributes that are very important to consider because they are directly related to customer needs and satisfaction (Gaspersz and Vincent 2001). Critical to Quality can be seen in Figure 4.

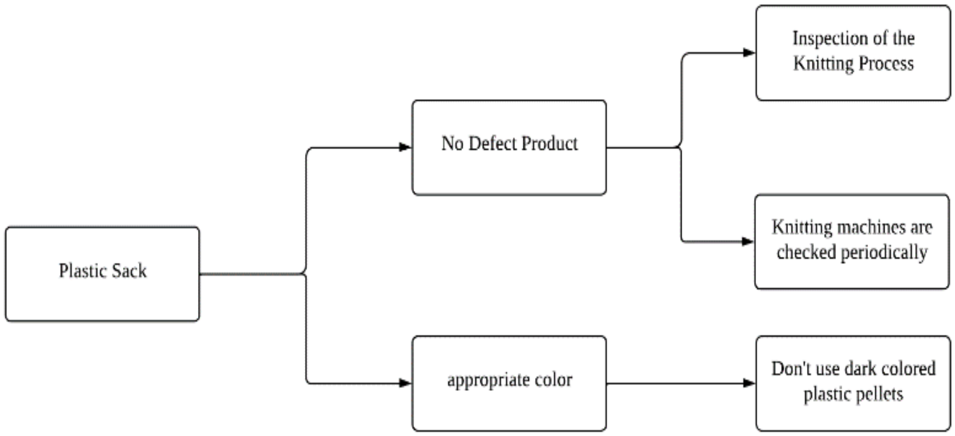

Figure 4. Critical to Quality (CTQ)

4.3 Measure

The next stage is the measure stage. The next stage is the measure stage, at this stage measuring the data obtained from the previous stage, namely the define stage. Measurements are carried out using several tools, namely the P Control Map, DPMO, and process capability.

P Control Map

A p chart is a type of control chart used in statistical process control to monitor the proportion of nonconforming items in a sample. The p chart is designed to detect shifts in the proportion of nonconforming items over time, helping to identify when a process may be out of control (muhammad et al. 2017). The data used is production data from February 2023 to July 2022 which can be seen in Table 1. The P control map can be seen in Figure 5.

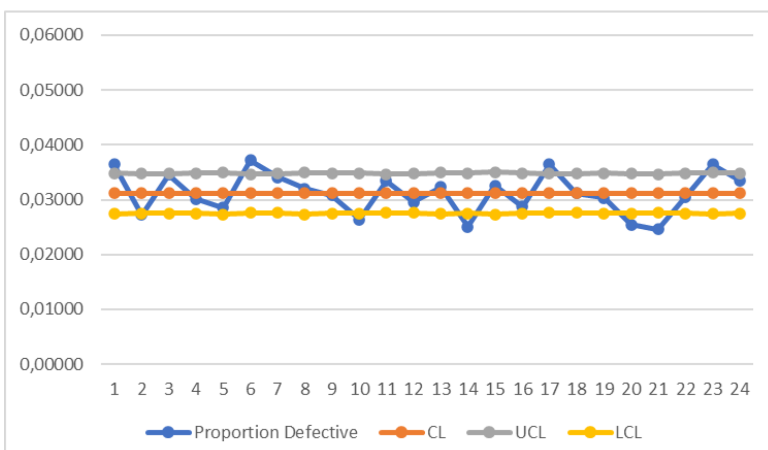

Figure 5. P Chart

Based on the p control map above, it can be concluded that some data are outside the control limits, namely 8 data points. Which at that point the number of defects has not met the standard and needs improvement.

Process Capability

The capability process refers to the ability of a manufacturing or production process to consistently meet the specified requirements or tolerances for a particular product or component (Yerriswamy 2014). Based on the calculation of Cp and Cpk above, it can be seen that the Cp value is 0.7421 where the Cp value is below one, meaning that the process has produced a product that is in accordance with specifications but still needs improvement. The Cpk value is 0.6200, where the Cpk value is below one, meaning that the process has produced products that are by specifications but still needs improvement to improve quality.

DPMO calculation

DPMO or defect per million opportunities is a useful calculation to determine the level or sigma level in the production process. DPMO is a key metric in Six Sigma methodology, where the goal is to reduce the number of defects to a level of 3.4 per million opportunities (Omkarprasad 2018). The following are the results of the calculation of DPMO and the sigma value which can be seen in table 3.

Table 3. Calculation of DPMO and Sigma Value

Description	February 2023 - July 2023
Unit	489683
Defect	15256
Opportunities	2
Defect per Unit	0,03644
Total Opportunities	39902
Defects per Opportunities	0,018220
DPMO	18219,6381
Sigma Value	3,59199

4.4 Analyze

The third stage in the Six Sigma method is the analysis stage. At this stage, the cause-and-effect analysis of defects that occur in plastic sack products is carried out. The tools that will be used in the analysis are fishbone diagram and FMEA (Failure Mode and Effect Analysis).

5 Whys Analysis

The 5 Whys approach digs deeper into a problem's layers one by one using a set of questions. The fundamental principle is that the answer you get to a question becomes the starting point for the following why (Nithin and Mimansha 2021). 5 whys analysis can be seen in Table 4.

Table 4. 5 Whys Analysis

Problem	Why 1	Why 2	Why 3	Why 4	Why 5
Raw Material Defects	Used sacks used dirty	Used dark colored sacks	Used sacks are not sorted properly	Workers do not know the appropriate used sacks to use	There is no suitable standard of used sacks to be used
Detachable Stitch Defect	There are gaps in the plastic sack	The machine used is not running well	the machine has been in use for a long time	the machine is not checked regularly	No data collection on checking and using the machine

FMEA (Failure Mode and Effect Analysis)

FMEA (Failure Modes and Effects Analysis) is a systematic methodology for evaluating and identifying potential failure modes in a system, product, or process, as well as assessing the potential effects of those failures (Claudia et al. 2014). FMEA can be seen in Table 5.

Table 5. FMEA

No	*Potential Failure Mode*	*Potential Failure Effect*	S	*Potential Failure Cause*	O	Current Process Control	D	RPN	*Rank*	*Action Recommended*
1.	Raw Material Defects	Dark colored plastic pellets	5	Workers do not sort used sacks properly	5	Collected and separated	3	75	1	Provide information on the appropriate plastic pellet color standards
						Visual Check on the Input of Used Sacks	4	100		Giving Instructions on How to Check Used Sacks as a Whole
2.	Past stitches	Knitted Sacks	6	Degraded Engine Performance	6	Accumulated to be crushed back	7	252	2	*Maintenance* Machine
				Workers Not Focused On The Knitting Process	5			210		Perform instructions to check the knitting process

Based on the RPN calculation to determine the highest priority is the detachable stitch defect with an RPN value of 252.

4.5 Improve

The improvement stage is the fourth stage in the Six Sigma method. This stage contains proposals for improvements that must be made by the company to increase productivity and reduce defects in products during the production process. The following are proposed improvements based on the analysis of the causes of failure:

1. The first suggested improvement is the creation of a standard operating procedure for sorting used sacks that will be used so that workers can know the standard of used sacks that can be used for the plastic seed production process.
2. The second suggestion given is to standardize the color of plastic seeds that are suitable for making plastic sacks. The purpose of this standardization is to avoid product defects.
3. The third suggestion is the making of a Chechsheet on a knitting machine which aims to get information about the feasibility of the products produced whether by company standards or not.

4.6 Control

The following is a comparison between DPMO values, process capability, and sigma level before and after implementation which can be seen in Table 6 below. in Table 6 below.

Tabel 6. Comparison of Process Performance Levels Before and After Implementation

Description	Before Implementation	After Implementation
Cp	0,7083	0,6101
Cpk	0,6211	0,6417
DPMO	16725,871	13503,281
Level Sigma	3,626619	3,711423

5. Conclusion

Based on the results of research and data processing carried out to reduce defects or defects in products, the conclusions that can be drawn from this research can be seen as follows.

1. Based on the research that has been done, two types of product defects occur, namely, raw material defects and detached stitch defects.

2. Based on the defects that occur there are many causes of these defects. Raw material defects occur due to errors in sorting used sacks that will be used. Detached stitch defects are caused by the absence of regular machine maintenance and the negligence of machine operators during the production process.
3. Researchers provide improvement proposals aimed at reducing product defects such as making standard operating procedures or SOPs, and standardizing the color of plastic beans, checksheets.
4. After the implementation, there was an increase in the process capability which previously Cp was 0.7182 and Cpk 0.6211 to Cp of 0.7367 and Cpk 0.6417.

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Biography

Nandita Priya is an Industrial Engineering student at Tarumanagara University in Jakarta, Indonesia. She was born on July 1, 2003 in Medan. Now, she lives in Tangerang with her family. She was graduated from 4 Tangerang State High School in 2020 and decided to continue her education to Tarumanagara University. She is currently in her seventh semester. Hopefully, she can be graduated from the University in 2024.

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Lithrone Laricha Salomon is a lecturer at Industrial Engineering Department of Universitas Tarumanagara since 2006. She graduated from Tarumanagara University with a Bachelor's Degree in Mechanical Engineering. She continued her study and got her Master's Degree from Industrial Engineering Program at Universitas Indonesia. She teaches a subject related to quality management system such as Total quality management, Quality Control, Design of Experiment and Industrial Statistics. Besides teaching she also did some research and carried out a number of community service activities in many places around Indonesia. She has written more than 50 publications on International and national proceedings and journals since 2007.