Opsi p-ISSN 1693-2102
Vol. 17, No. 1, June 2024 e-ISSN 2686-2352

Quality control of garment product using DMAIC Six Sigma

Tiara Chayaning Tyas[1], Ida Giyanti [1]*
[1]Industrial Engineering Study Program, Faculty of Engineering, Universitas Setia Budi, Jalan Letjend Sutoyo, Mojosongo, Surakarta, Central Java, 57127

***Corresponding Author**: idagiyanti@setiabudi.ac,idw, Tel.: 0271-852518

Article history:
Received: 1 June 2022
Revised: 3 November 2023
Accepted: 2 April 2024
Published: 30 June 2024

Keywords:
Defect
DMAIC
Garment
Quality
Six Sigma

ABSTRACT

Quality control is intended to ensure that the products are in accordance with the predefined standards. PT. XYZ is a garment company that manufactures products with global target market. Hence, product quality assurance becomes an important issue for PT. XYZ. This research focuses on the Just Brand-MCJA216142 jacket product at the sewing work station on line-4 of PT. XYZ. Preliminary observations show that the number of reworked-products was experiencing an increasing trend. This study aims to determine whether the company has carried out quality control properly. Specifically, the research objectives are to identify the type and level of product defects, identify the factors causing product defects, and provide proper improvement suggestions to reduce the occurrence of product defects. This study applied DMAIC (Define–Measure–Analyze–Improve–Control) Six Sigma concept. The results showed that the quality of the Just Brand-MCJA216142 jacket product has exceeded the Indonesian industry average and is classified as the USA industry average. However, quality improvement is still needed since the products are targeted for the export market. Based on Pareto diagram at the Analyze stage, it was found that the most dominant defects occurred in the Just Brand-MCJA216142 jacket production process were broken threads and puckering. The frequency of occurrence for these two types of defect reaches 23% of the total 16 types of defects. The defects were caused by human, machine, material, method, and environmental factors. Recommendations for improvement at the Improve stage are based on root cause analysis of each causative factor that is identified using a fishbone diagram. This research results strengthen the previous related researches regarding the effectivity of DMAIC Six Sigma for analyzing quality control of products.

DOI:
https://doi.org/10.31315/opsi.v17i1.7107

1. INTRODUCTION

Companies need to pay attention to product quality in order to meet consumer demands and desires [1]. This is because product quality and service quality of the product becomes top priority for consumers' desires [2]. Quality has been realized to become a key determinant of success in all aspects of modern industry, manufacturing as well as services [3]. Therefore, companies must aware to the quality of their products so that they are able to compete with their competitors. The market segments of the product must also be clear, so that the company can determine the appropriate action that must be taken to increase consumer confidence. A qualified product is a product that is able to provide complete satisfaction to consumers, that is, it is in accordance with consumer expectations for a product [4]. In other word, quality of a product or service is the fitness of that product or service for meeting or exceeding its intended use as required by the customer [5]. To get products with good quality, it is necessary to have quality control on the product to guarantee quality standard of the product or service delivered. Quality control is an engineering and management activities in which the attributes of a product are compared with the predetermined specifications or requirements. If differences are found between the actual attributes and the standards, appropriate corrective action is taken [6]. Quality control does not merely focus on the final product. Quality control is an activity that is closely related to the production process. Quality control in the product development process is vital to the final quality of a product [7]. Quality control is a system of verification to maintain a desired level of product or process quality by means of careful planning, use of appropriate equipment, continuous inspection, as well as corrective action, if necessary [8].

PT. XYZ is a company operating in the garment industry which its products are targeted for the global market. The company's monthly production capacity reaches 150.000 pcs. This company produces high quality products and is supported by advanced technology in its production process. In general, there are several processes in garment production at PT. XYZ, namely cutting, sewing, and finishing. Some of the products produced by PT. XYZ are jackets, hoodies, trousers, T-shifts, Polo-shirts, and others. This research focuses on the Just Brand-MCJA216142 jacket product at sewing workstations, especially on line-4, since most of the components of the Just Brand-MCJA216142 jacket product are processed here. There are a total of 138 processes in sewing line-4 work station. Due to the many processes that must be carried out and the large number of components that must be made, the probability end-product defect also increases. This results in the need for repairs of defective products. The results of observations for 15 days in the July 2021 period as shown in **Figure 1** show that the number of repairs is experiencing an increasing trend.

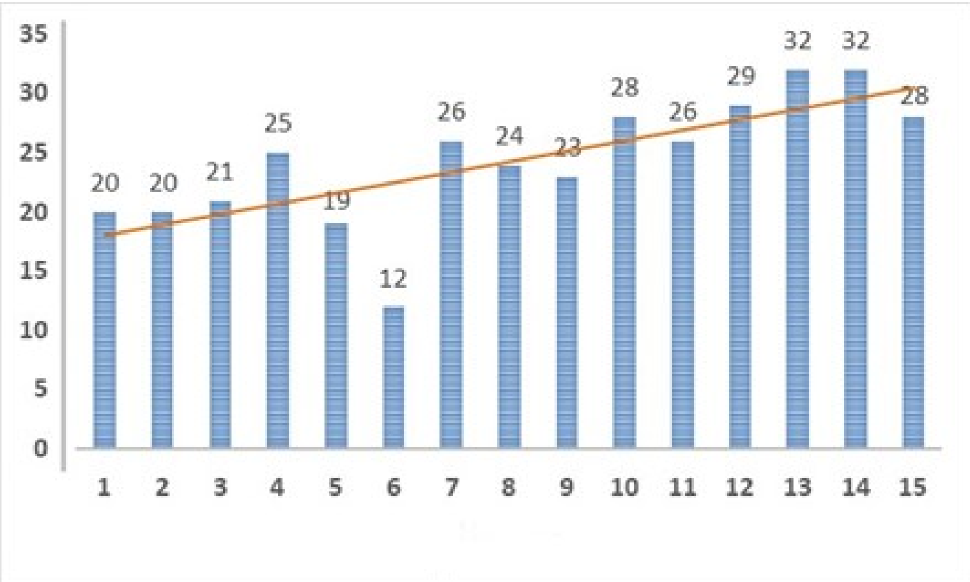

Figure 1. Number of repairs for Just Brand - MCJA216142 at Sewing line-4

Based on the problem, it is necessary to analyze the quality control of garment products, especially for Just Brand jacket products - MCJA216142 at PT. XYZ. So far, the company has collected defect data. Unfortunately, the data were only used as company's archives without conducting quality control analysis to improve product quality and reduce defect levels. In this case, quality analysis is required to find out whether the company has carried out good quality control activities. Moreover, quality control needs to be carried out in order to ensure that the product conforms to its quality standard. The quality control activities is hoped that the company can compete with other competitors in the global market. Specifically, this research aims to identify the type and level of product defects, identify the factors causing product defects, and propose appropriate improvement to reduce the occurrence of product defects.

The main objective of quality control is to ensure that product quality meets the predetermined standards [6] and to minimize inspection costs [9]. Several quality control methods have been developed by scholars, for example: Statistical Quality Control, Statistical Process Control, Seven Tools, Six Sigma, DMAIC (Define–Measure–Analyze–Improve–Control), and others. This research employs the Six Sigma method with the DMAIC concept. The Six Sigma method requires an approach with DMAIC stages. DMAIC is a structured and data-based problem solving approach [10] that helps make gradual improvements and optimizations to products, designs, and business processes so that DMAIC is consistently able to provide better results than other methods [11]. This approach was created in the 1980s as part of the Six Sigma method. The Six Sigma method was designed to encourage continuous improvement in production processes using a statistical approach [12].

Six Sigma has been successfully implemented by various companies throughout the world[13]. It has been widely applied in any type of organization, both manufacturing or service [14].The implementation of Six Sigma has yielded a significant savings of many large and small organizations [15], [16]. Six sigma is a structured method for improving processes that focuses on efforts to reduce process variations as well as to decrease product defects by using statistical approaches and problem solving tools, intensively [17]. The Six Sigma method has been applied and succeeded in reducing product defects within garment sectors [18]. Another study related to the Six Sigma method in the garment industry was carried out by Heryadi & Sutopo [19] who reviewed and looked at trends in the use of the DMAIC method. The DMAIC method used in the garment industry is able to reduce the occurrence of production defects and further improve the production process. Research on the garment industry using the Six Sigma method and the DMAIC concept was also conducted by Parasayu & Susanto [20] and Jirasukprasert et al. [21]. In their research, a DPMO (defect per million opportunities) calculation was carried out to determine the sigma level of product defects that occurred. Another research revealed that the Six Sigma method with the DMAIC stage was also successful in identifying the sources of product defects, especially in sewing work station [22], [23]. Putri et.al [22] employed additional tools namely fishbone diagrams and Failure Mode and Effect Analysis (FMEA) to determine the root causes of problematic processes and determine potential failure priorities. Based on the identified causes, then they suggested recommendations for improvements that quality analysis is started from checking the raw materials of the products. Fishbone diagrams were also used in several studies [20], [24], [25] to analyze the causal factors of defective products. The causal factors were divided into four factors, namely machinery, humans, methods, and materials. At the improve stage, suggestions for improvements are given based on analysis of the source of previous problems. Similar research uses another additional tools for Six Sigma analysis, namely the Pareto diagram [26]–[28]. The Pareto diagram is used to show the most dominant material defects so that it is easier to identify improvement priorities in order to reduce the dominant types of defects [29]. Based on a review of several previous studies related to the Six Sigma method with the DMAIC concept in the textile industry, this method is considered appropriate if applied in this research to answer the research objectives. This study also applied additional tools in quality control analysis, namely Pareto diagram and fishbone diagram, to complement the DMAIC Six Sigma method.

2. METHODS

2.1. Data Collection

To obtain an initial overview of the production process and quality control activities carried out at the company, the research began by observing the study object. Based on the results of initial observations, a problem formulation was obtained related to controlling defective products in Just Brand jacket products - MCJA216142 at PT. XYZ. Next, data collection was conducted to answer the research objectives based on the problem formulation that has been determined.

The data for product defects using primary source data obtained from direct observation for 15 days in July 2021. The data type collected in this research are daily production numbers of Just Brand jacket products - MCJA216142, types of defects, and daily number of defective products. A saturated sampling technique was applied as sampling method in this research. A saturated sampling technique was used when all members of the population are used as samples [30]. Meanwhile, the data source for identifying the causes of defects was carried out by field observation and supplemented by interviews with the production head.

2.2. Data Analysis

Data analysis in this research was carried out using the DMAIC Six Sigma method. The DMAIC stages was only carried out up to the Improve phase due to limited access to companies to conduct experiments on the improvement recommendations proposed in this research. In detail, the stages of data analysis with DMAIC Six Sigma are explained as follows [31], [32].

Define becomes the initial stage of DMAIC that explains the problems occured or explains the goals of improving the company's production process. At the define stage, data of defect type was converted into Critical to Quality (CTQ) numbers. CTQ is the number of opportunities that result in defects or what is usually called Opportunities (OP). Improvements to product defects will be more meaningful if the improvements are directly related to CTQ [33].

Measure is the second stage of DMAIC which aims to assess or measure problems that occurred. This stage is indicated by collecting data to set performance standards. At this stage, control chart analysis (P-Chart) and Defect Per Million Opportunities (DPMO) calculations are carried out. A control chart (P-Chart) is a type of control chart that is used to determine whether product defects from the output produced are still within control limits. To determine the control chart (P-Chart), equation (1) to equation (4) are used. Equation (1) is used to determine the Center Line (CL). Next, the proportion of defects during each production process is calculated using equation (2). To determine the control limits for quality control, it is necessary to determine the Upper Control Limit (UCL) and Lower Control Limit (LCL) values using equation (3) and equation (4) respectively. At this Measure stage, the DPMO value is then calculated. DPMO calculation uses equation (5). The DMPO value is then converted into a Sigma value. Convertion of DPMO values to Sigma values follows equation (6).

$$\mathrm{CL} = \overline{\mathrm{P}} = \frac{\text{Total Number of Defect Products}}{\text{Total Production Quantity}} \tag{1}$$

$$\mathrm{P_i} = \frac{\mathrm{x_i}}{\mathrm{n_i}} \tag{2}$$

$$\mathrm{UCL} = \overline{\mathrm{P}} + 3\sqrt{\frac{\overline{\mathrm{P}}(1-\overline{\mathrm{P}})}{\mathrm{n_i}}} \tag{3}$$

$$\mathrm{LCL} = \overline{\mathrm{P}} - 3\sqrt{\frac{\overline{\mathrm{P}}(1-\overline{\mathrm{P}})}{\mathrm{n_i}}} \tag{4}$$

$$DPMO = \frac{\mathrm{D}}{\mathrm{U} \times \mathrm{OP}} \times 1.000.000 \tag{5}$$

$$Sigma = NORMSINV\left(\frac{1.000.000 - DPMO}{1.000.000}\right) + 1,5 \tag{6}$$

Description of notation for above equations:

P_i: proportion of defects in each i-th sample
x_i: number of defective products in each i-th sample
n_i: number of samples at inspection i
D: Number of defective products
U: Number of units produced
OP: Opportunities (OP value taken from CTQ)

In a quality control program using Six Sigma, Sigma values are used to evaluate organizational performance measures. The sigma value indicates how often defects may occur [34]. In some literature on Six Sigma, an organization may be classified as “world class” or “industry average” or “non-competitive” based on the level of Sigma achieved at a particular point in time. The average Sigma level for most organizations is three sigma [35]. The relationship between the level of Sigma achievement and organizational performance is shown in Table 1 which is summarized from several literatures [34], [36], [37]. The goal of Six Sigma is that product defects are at the six sigma level, which means that there are only 3,4 defects out of a million opportunities [35].

Table 1. Relationship between Sigma level and organizational performance

Percentage According to Standards	DPMO	Sigma level	Description
31,00%	691.462	1-sigma	Very non-competitive
69,20%	308.538	2-sigma	Average of Indonesian industry
93,32%	66.807	3-sigma	Average of Indonesian industry
99,38%	6.210	4-sigma	Average of USA industry
99,98%	233	5-sigma	Average of USA industry
99,99%	3,4	6-sigma	World class industry

The Analyze stage aims to analyze the causes of the problem based on the highest priority. At this stage, problem analysis is carried out using Pareto diagrams and cause effect diagrams in the form of fishbone diagrams. The Pareto diagram is a bar graph that shows problems based on the number of events [29]. The Pareto diagram shows the frequency of types of defects in products in the form of a bar graph, so that the types of defects that have the highest frequency can be identified. Meanwhile, a fishbone diagram is a diagram used to identify and analyze possible main causes of product defects in the production process.

Improve is the fourth stage of DMAIC which aims to identify corrective actions after the cause of the problem is identified. Corrective action can be taken by providing alternative solutions to existing problems. The suggestions proposed is expected to improve the fundamental factors causing product quality problems from several domains, such as Machine, Material, Man, Method, and Environment. Then, the proposed improvements are given according to the results of the Analyze stage.

3. RESULTS AND DISCUSSION

3.1. Define

In the Define stage, the types of defects and the number of defects that occur in each type of defect are identified. Data on the number of types of defects becomes a reference for CTQ. Broadly speaking, the CTQ types in Just Brand jacket products - MCJA216142 are divided into two, namely defects in raw materials (fabric defects, dirt, etc.) and defects during the production process (broken threads, skipped stitches, etc.). The two types of CTQ can be further broken down into 16 main problems that cause defective products. A brief description of the 16 main problems causing defective products is depicted in Table 2. Meanwhile, Table 3 contains the results of observations of the number of defective products over a 15-day period. The sampling method uses saturated sampling because the sewing work station line-4 is a critical work station where most of the product components processed on line 4 have the potential to experience defects. If a defective product was found at the sewing line-4 work station, the company has a policy of carrying out repairs.

Table 2. Causes of defective products

No	Cause factor	Explanation
1	Broken	Broken threads that occur during the sewing process affect the durability of the product because they can cause the stitches to come apart.
2	Puckering	Puckering that occur in the product can damage the quality, especially in terms of product aesthetic beauty because it will affect the shape of the product.
3	Bubling	Bubbles in the product cause the product to be sloppy and can cause other types of defects such as broken seams.
4	Needle hole	Needle holes in products can be damaging because small holes can cause larger holes. Needle holes are usually caused by stitching errors which are then removed.
5	Skip	Skip stitches can cause sloppy stitching, thereby reducing the value of the product in terms of product aesthetic.
6	Open Seam	Open seams make the product cannot be sent to consumers because the product's durability is reduced.

Table 2. Causes of defective products (Continued)

No	Cause factor	Explanation
7	Unconsistent stitch margin	Large or small stitches can reduce the aesthetic value of the product because the stitches look sloppy.
8	Loose stitch	Loose stitches can cause other defects such as broken stitches or broken threads which can worse the quality of the product.
9	Run off stitch	Run off stitch occurs when a part of the product is not sewn so that part is still open/ not installed neatly.
10	Slanted	The stitching is slanted/ not straight according to the pattern so it is not neat.
11	Twisted	Twist stitches usually occur when sewing folds. As a result, the surface becomes wavy so it is not neat.
12	Hi-Low	Hi-Low or asymmetrical stitches usually occur when sewing paired parts, for example sleeves, pockets, etc.
13	Fabric defect	Fabric defects actually rarely occur because the fabric has already passed the sorting process when the goods enter the warehouse. However, during the production process, holes in the fabric, fabric fibers coming out, etc. can be found. Products with this type of defect cannot be repaired.
14	Oil stain	The lubricating oil in the sewing machine gets on the product during the sewing process, causing the product to become dirty.
15	Trimming	Product defects resulting from cutting errors when tidying up seams or trimming pieces that do not match the pattern.
16	Sealing	The sealing process is not adhesive or neat.

Table 3. Number of defective products

Cause factor	Day of production														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Broken	2	4	2	3	-	1	3	3	3	2	1	4	6	6	6
Puckering	2	3	3	1	4	4	2	2	1	3	2	3	3	3	3
Bubling	-	-	2	1	3	1	3	2	3	3	2	2	3	4	1
Needle hole	2	3	-	2	1	-	-	3	2	6	5	2	2	3	4
Skip	3	-	2	1	-	-	2	-	1	2	3	3	3	3	2
Open Seam	2	3	2	2	3	2	1	3	2	3	-	-	3	2	3
Unconsistent stitch margin	2	-	-	2	-	-	2	-	1	-	1	2	-	-	-
Loose stitch	-	-	3	1	2	-	1	2	1	3	1	3	1	-	2
Run off stitch	1	2	1	2	1	2	2	2	2	-	2	2	2	3	-
Slanted	-	-	-	-	-	-	-	-	-	-	2	-	-	1	-
Twisted	-	-	1	2	-	-	3	1	2	-	-	3	4	-	3
Hi-Low	3	3	3	3	-	-	2	-	-	-	1	-	3	2	2
Fabric defect	-	-	-	1	-	-	-	-	1	-	1	1	-	-	-
Oil stain	1	2	2	2	1	2	3	4	2	2	3	1	1	2	2
Trimming	2	-	-	2	-	-	-	-	-	1	-	-	-	2	-
Sealing	-	-	-	-	4	-	2	2	2	3	2	3	1	1	-
Number of defects	20	20	21	25	19	12	26	24	23	28	26	29	32	32	28
Prod. quantity	20	20	21	25	126	127	161	249	168	177	129	209	212	242	212

3.2. Measure

Based on Table 3, it is known that during the 15 day of observation period, 365 units of defective products were found from a total production quantity of 2.098 units. The data in the Table 3 was used as a reference at the Measure stage. There are two measurements at this Measure stage, namely calculations for control charts with P-Chart as well as DPMO and Sigma level calculations. The following shows an example of day-1 calculations for creating a control chart (P-Chart) based on equations number 1, 2, 3, and 4, respectively.

$$CL = \overline{P} = 0{,}17$$

$$P_i = 1$$

$$UCL = 0{,}43$$

$$LCL = \ 0{,}09$$

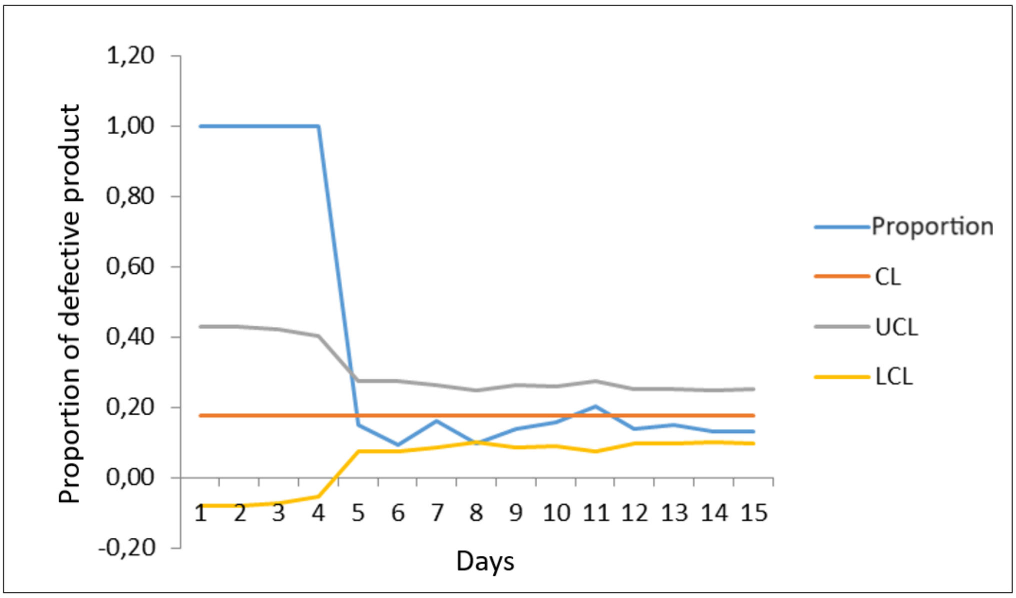

Figure 2. Control diagram (P-Chart)

A recapitulation of the data processing results for the control chart (P-Chart) from day-1 to day-15 can be seen in Table 4. The results from Table 4 are then presented in diagram form for ease of the analysis process. A control diagram in the form of a P-Chart is displayed in Figure 2. Based on Figure 2, it can be seen that the proportion of defective products produced from day 1 to day 4 exceeds the upper control limit (UCL). This shows that it is necessary to carry out quality control to reduce deviations that occur.

Table 4. Recapitulation of data processing for P-Chart

Day	Production Quantity (pcs)	Defective Products (pcs)	Proportion of Defects	CL	UCL	LCL
1	20	20	1,00	0,17	0,43	-0,09
2	20	20	1,00	0,17	0,43	-0,08
3	21	21	1,00	0,17	0,42	-0,07
4	25	25	1,00	0,17	0,40	-0,05
5	126	19	0,15	0,17	0,28	0,07
6	127	12	0,09	0,17	0,27	0,07
7	161	26	0,16	0,17	0,26	0,08
8	249	24	0,10	0,17	0,25	0,10
9	168	23	0,14	0,17	0,26	0,09
10	177	28	0,16	0,17	0,26	0,09
11	129	26	0,20	0,17	0,27	0,07
12	209	29	0,14	0,17	0,25	0,10
13	212	32	0,15	0,17	0,25	0,10
14	242	32	0,13	0,17	0,25	0,10
15	212	28	0,13	0,17	0,25	0,10

According to the results of interviews with the production head, it was known that PT. XYZ carries out production using a make to order system where the styles or design that must be processed are constantly changing. When working on orders with different styles, there were usually modifications to the facility layout to adapt to the processing flow of the ordered product. Most likely, this condition was the cause of the high level of product defects on days-1 to day-4 since at that time PT. XYZ has just reconfigured the layout to pursue a new order target.

The subsequent procedure is calculating the DPMO which is further converted into Sigma level. The following is an example of DPMO and Sigma level calculations for day-1. The DPMO calculation used reference data in Table 3. Number of defective products. Meanwhile, the CTQ or OP value was taken from the total potential causes of defects in the product, which is 16. A recapitulation of the DPMO calculation and Sigma level for 15-days of observation is shown in Table 5. Table 5 shows that the Sigma level for the Just Brand jacket product - MCJA216142 at PT. XYZ has exceeded 3. The average Sigma level is 3,65 with the resulting probability of defects being 23.141 per 1 million production. In accordance with Table 1, the achievement of this Sigma value has exceeded the Indonesian industry average. However, because the Just Brand jacket product - MCJA216142 is intended for the export market, the Sigma level is expected to be more than 4 to be classified as the US industry average so that the product is able to compete in the international market.

Table 5. Calculation of DPMO and Sigma level

Day	DPMO	Sigma Level
1	62.500,00	3,03
2	62.500,00	3,03
3	62.500,00	3,03
4	62.500,00	3,03
5	9.424,60	3,85
6	5.905,51	4,02
7	10.093,17	3,82
8	6.024,10	4,01
9	8.556,55	3,88
10	9.887,01	3,83
11	12.596,90	3,74
12	8.672,25	3,88
13	9.433,96	3,85
14	8.264,46	3,90
15	8.254,72	3,90
Average	23.140,88	3,65

3.3. Analyze

The Analyze stage is used to identify the most dominant causes of defects and to find the root cause of the problem. There are two tools used in the Analyze stage, namely the Pareto diagram and the fishbone diagram. The Pareto diagram is created based on data on the number of defects for each type of defect cause. The result of the Pareto diagram is presented in **Figure 3**. Referring to the Pareto diagram in Figure 3, it can be seen that 23% of the total types of defects in the Just Brand-MCJA216142 jacket product are due to broken threads and puckering. According to the Pareto diagram principle, companies only need to focus on 20% of the causes of product defects to be able to obtain 80% of the expected improvement results [29]. Thus, improvement can be taken by focusing on two types of defects, namely broken threads and puckering. The next stage is to identify the root of the problem of broken threads and puckering using a fishbone diagram as shown in **Figure 4** and **Figure 5**. Elaboration of the fishbone diagram was conducted by direct observation on the production floor and conducting interviews with operators at line-4 of the Sewing work station at PT. XYZ. The root cause of the product defect problem that occurs during the production process of the Just Brand-MCJA216142 jacket product is divided into five factors, namely Man, Methods, Machine, Material, and Environment.

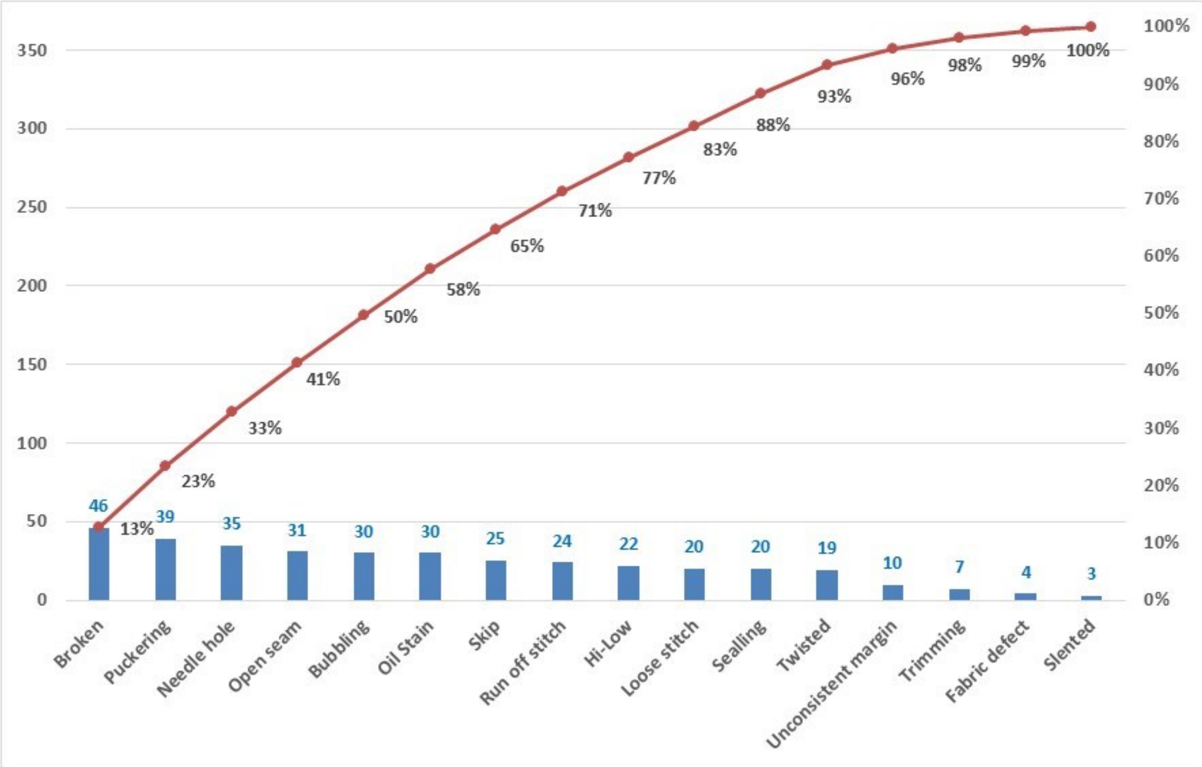

Figure 3. Pareto diagram

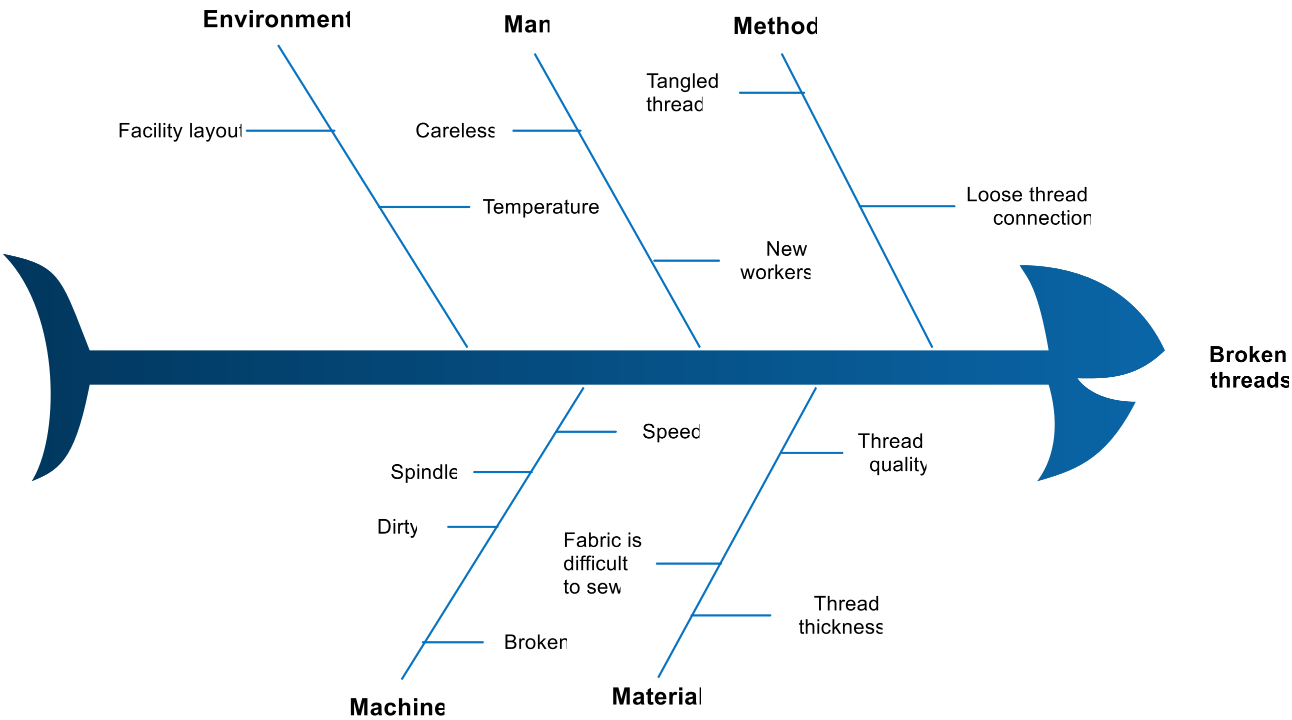

Figure 4. Fishbone diagram for the defect factor of broken threads

3.4. Improve

The Improve stage is carried out to provide recommendations for improvements to each root problem that has been identified in the Analyze stage. Table 6 and

Table 7 describe proposed improvements to the production process in line-4 of the Sewing work station to reduce defects in the Just Brand-MCJA216142 jacket product produced by PT. XYZ.

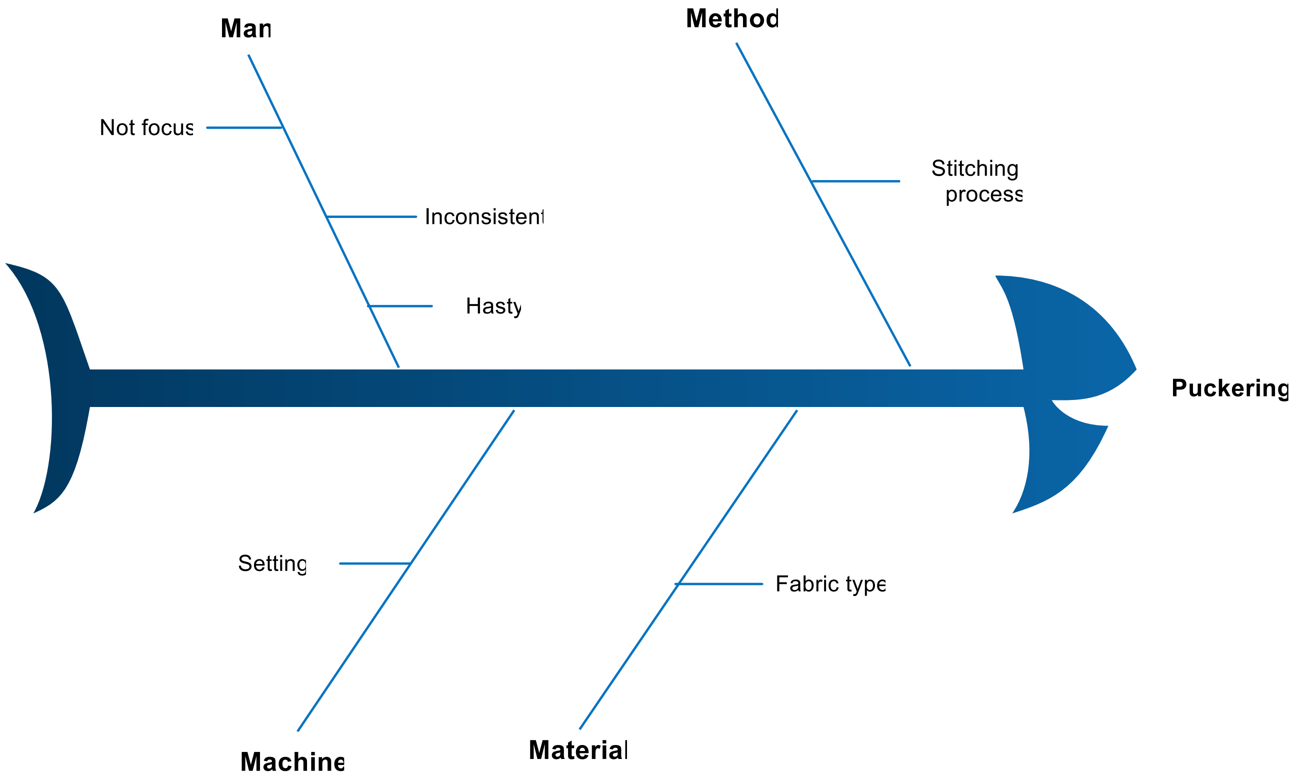

Figure 5. Fishbone diagram for the defect factor of puckering

Table 6. Improvement recommendations for the defect factor of broken threads

Factor	Problem	Description	Improvement
Man	New workers	New operators have insufficient knowledge and skills about materials, machines and methods.	Provide regular orientation and training to operators so that their skills can be improved. Provide more intensive direction to new operators during work.
	Careless	Operators tend to ignore the type of yarn being used in the production process.	Each thread requires different treatment. It requires the operator's knowledge and skills regarding the type of thread and how to handle it.
Machine	Broken	The machine experienced problems during the production process	Schedule a mechanic to always be there during the production process, so that if the machine suddenly stops working it can be handled immediately.
	Spindle	The spindle does not function optimally	Regularly check and maintain machine components.
	Speed	The machine speed is not suitable so that the yarn experiences increased tensile strength	Ensure speed settings comply with standards before the production process begins.
	Dirty	The engine is dirty cause there was a lot of invisible flying waste accumulated in small gaps of engine	Scheduling regular machine cleaning. Designing a flying waste absorber to reduce the quantity of flying waste at the production site.

Table 6. Improvement recommendations for the defect factor of broken threads (Continued)

Factor	Problem	Description	Improvement
Method	Tangled threads	The thread gets entangled during the production process	Accuracy and caution is required from the operator as well as the ability to adjust the machine speed during the production process.
	Loose thread connection	The thread connection is not strong enough	Decrease machine speed when thread splicing. Accuracy and caution is required from the operator during the thread joining process.
Material	Fabric difficult to sew	Unbalance between the thickness of the thread used and the type or thickness of the material	Providing training to improve operator skills so that they are competent at working on products with any type of material.
	Thread quality	The quality of the thread is not good or it is stringy	Ensure that the supply of raw materials meets the specified standards.
	Thread thickness	Thread thickness is uneven	Check the thread that will be used, both threads that have been spooled and those that have not been spooled.
Environment	Facility layout	The distance between machines is too close so that the operator's space to adjust machine position during production is limited	Redesign the layout by paying attention to the distance between machines, number of machines, and operators
	Temperature	The high temperature of fproduction room causing operators to heat and consequently disrupts their concentration	Provide adequate air conditioning (covering the entire room) so that operators feel comfortable and can concentrate while working.

Table 7. Improvement recommendations for the defect factor of puckering

Factor	Problem	Description	Improvement
Man	Not focus	Operators lack focus during the sewing process	The causes of this side of Man are correlated with each other. Supervision and direction are required for operators when carrying out the sewing process. To reduce rework, operators are trained to simultaneously check stitching results.
	Inconsistent	When sewing, operators are less consistent	
	Hasty	Operators work feverishly to meet production targets	
Machine	Setting	The machine settings do not match to the type of fabric	Make sure the mechanic has reset the settings, especially at the of of changing styles and types of fabric.
Method	Stitching process	The sewing process does not match with the pattern or type of fabric being processed	Provide direction to the operator regarding proper sewing techniques according to the pattern and material/ fabric being processed.
Material	Fabric type	The fabric used is thick but slippery so it shifts easily during the sewing process.	This type of fabric requires high skills during the sewing process, therefore improving operator skills is important.

Based on the quality control procedures using the DMAIC Six Sigma method that have been carried out, PT. XYZ can follow these procedures so that product defects for other types of products can be further analyzed. PT. XYZ, especially the division of Quality Control, can carry out DMAIC Six Sigma analysis of all lines on the production floor, as well as in other process parts. The DMAIC Six Sigma method is able to analyze product defects and identify their causes, and further provide suggestions for improvements according to the causal factors. This is in accordance with research conducted by Putri et.al [22] and Zaman & Zerin [23], in which the Six Sigma method was able to analyze the types of defects that occur and identify the sources of the defective problems.

The DMAIC Six Sigma stages in this research can be adopted to improve the quality of all products produced by PT. XYZ. Based on the results of the DMAIC Six Sigma analysis, the companny can develop proposed improvements to overcome problematic processes to reduce the occurrence of product defects. When quality control activities has become routinized in daily operations, in the future the companies might consider to integrate production planning, quality control, and machine maintenance schedule [38,39], such that the total cost per unit product can be minimized. Six Sigma process can also be utilized by the company since the design process of a product from the ground up to ensure high quality when the product is implemented into a manufacturing environment [40].

In this research, the Control stage, which is the stage of evaluating the results of implementing the improvement design, could not be implemented due to limited permits from the company to implement several proposed improvements to the production process. Therefore, further research can develop improvement design scenarios using simulation methods so that they do not disrupt the company's daily operations.

4. CONCLUSION

This research conducted an analysis of the causes of defects in the Just Brand-MCJA216142 jacket product at PT. XYZ by applying the DMAIC Six Sigma method with three objectives, namely identifying the type and number of defects, identifying the causes of defects, and providing recommendations for improvements to reduce the number of defective products. In the Define stage, 16 types of defects in the Just Brand-MCJA216142 jacket product were identified. The Measure stage was carried out by creating a control chart (P-Chart) and calculating the DPMO and Sigma level. Based on DPMO calculations, PT. XYZ has an average Sigma level of 3,65 with a possible defect of 23.141 per 1 million production. With this Sigma level, the product quality of Just Brand-MCJA216142 PT. XYZ has passed the industry average in Indonesia. However, the Sigma level has not yet reached the average standard for the USA industry or world class industry. Quality control is needed so that products are able to compete in international markets since the Just Brand jacket product-MCJA216142 PT. XYZ is targeted for International market

At the Analyze stage using the Pareto diagram, a proposal was given to focus improvements on two types of defects, namely broken threads (13%) and puckering (10%) with a total percentage of 23% of all types of defects that occurred. To reduce broken thread defects, the main thing that needs to be considered is that there is a match between the type of fabric, the type of thread used and the machine settings. Operators' knowledge and skills regarding the types of threads and fabrics and their treatment also need to be improved. Meanwhile, to reduce puckering defects, the important thing that needs to be considered is that the operator must be skilled in using sewing techniques that suit the pattern and type of fabric which is thick and slippery so that during the sewing process it does not shift easily, which then has the potential to cause puckers. Thus, in general, the operator's knowledge and skills regarding the type of thread and type of fabric and their treatment are crucial, especially for PT. XYZ which using a make-to-order scheme in its production system wherebt styles always continually change according to customer orders. Another thing that also needs to be considered is the working environment that is very hot. This physical working environment needs to be improved to increase operator concentration.

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