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Proposed Design of Sewing Process Improvement to Minimize Polyester Technical Sportswear Product Defect at PT. X Based on The DMAIC Method Approach

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Abstract. Various companies want to improve product quality and process speed for customer satisfaction in the current era, including PT. X. Problems at PT. X is the number of defects that exceed the company's tolerance limit. The methodology used is a structured DMAIC method to identify the root causes of defects and resolve them. This study aimed to reduce defects in sportswear products caused by problems in the sewing process. The results showed that the problem in the sewing process was due to the process performance that still did not meet the standard process requirements, so the resulting output did not match the company's specifications. Therefore, it is necessary to design an alarm timer integrated with the sewing machine to minimize the frequency of defects in the sewing process. The design of the alarm timer uses the Reverse Engineering design method, which can minimize defects in the sewing process and increase the capability of the PT. X process.

Keyword: Sewing, Defect, DMAIC, Reverse Engineering

Abstrak. *Berbagai perusahaan ingin meningkatkan kualitas produk dan kecepatan prosesnya demi kepuasan pelanggan di era sekarang ini, diantaranya PT. X. Masalah di PT. X adalah jumlah defect yang melebihi batas toleransi perusahaan. Metodologi yang digunakan adalah metode DMAIC terstruktur untuk mengidentifikasi akar penyebab defects dan cara mengatasinya. Penelitian ini bertujuan untuk mengurangi defect pada produk polyester technical sportwear yang disebabkan oleh masalah pada proses penjahitan. Hasil penelitian menunjukkan bahwa permasalahan pada proses penjahitan disebabkan kinerja proses yang masih belum memenuhi standar persyaratan proses, sehingga output yang dihasilkan tidak sesuai dengan spesifikasi perusahaan. Oleh karena itu, perlu dirancang sebuah timer alarm yang terintegrasi dengan mesin jahit untuk meminimalisir frekuensi terjadinya defect pada proses menjahit. Perancangan timer alarm menggunakan metode desain Reverse Engineering. Dengan alat bantu timer alarm dapat membantu operator dalam proses menjahit dan meminimalisir defect pada proses penjahitan serta meningkatkan kapabilitas proses PT. X.*

Kata Kunci: Sewing, Defect, DMAIC, Reverse Engineering

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1. Introduction

Quality is one of the important factors in achieving business success, growth, and increasing competitiveness, because it relates to conformity to standards and specifications for customer needs [1]. Company PT. X, which is engaged in Textile Clothing, one of the products produced is Technical Sportswear, implementing a "make-to-order" strategy to meet customers. PT. X determines the Critical to Quality (CTQ) that must be met in producing Polyester Technical Sportswear products to meet customer specifications, and the product is not said to be defective [2]. CTQ (Critical to Quality) is the main characteristic that can be measured from a product and what customers expect from a product [3]. CTQ discusses process boundaries and customer goals are very important for success in a company [3]. CTQ from PT. X includes the size of the material according to the purchase order, material according to predetermined standards, sewing according to standards, design of printing and screen printing according to the purchase order, color and shading according to standards, cleanliness of materials, and accuracy of product shape [4]. Based on data on the number of productions and the number of defective products in the period range of January 2020 – September 2021 at PT.X, almost every period exceeds the tolerance that has been determined by the company PT. X is 2%, indicating that the production process for making Polyester Technical Sportswear is still not going well [5].

PT. X has tried to rework by correcting the defects that occur. Even the company can issue a 50% refund of the price if the defects that occur have a high severity and cannot be reworked so that the company incurs more costs in the production process. There are eight occurrences of defects in the production process in Table 1.

Table 1 Type of Defect Product

Defect Type	Information
The size of the material does not match.	The size of the fabric does not match the purchase order document
loose stitch	There are broken/broken seams on the product
Wrinkled seams	The sewing process is too tight, pulling the material and causing the seam to shrink.
The stitches don't match the pattern	Some stitches do not match the predetermined pattern
Screen printing doesn't match the design	Some materials are taken double during the printing process
The color doesn't match	There is a color difference between the printing material and the purchase order color code
Spotted and striped fabric	There are permanent lines and spots on the material

After it is indicated that the production process is still running well, the polyester technical sportswear production flow process is analyzed. In producing polyester technical sportswear products, there are nine stages of the process, which are described in Figure 1.

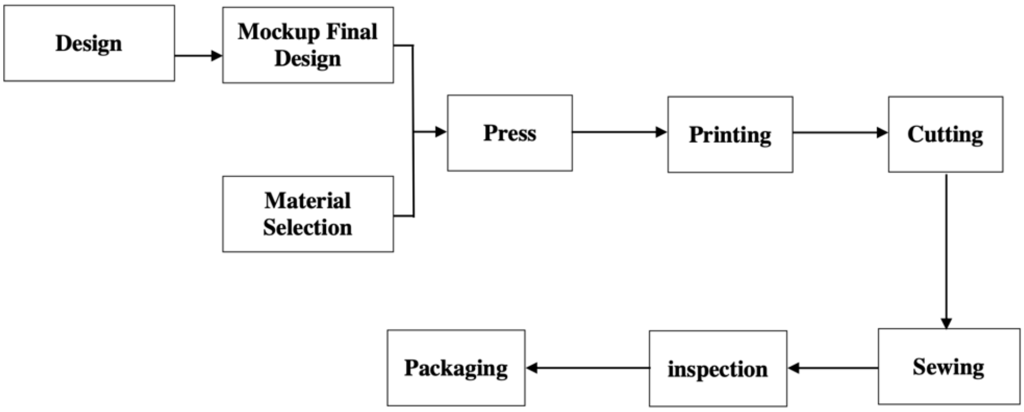


Figure 1 Polyester Technical Sportswear Production Flow

Each stage of the Polyester Technical Sportswear production process has a CTQ process set by the company whose requirements must be met [6]. However, in producing technical polyester sportswear, CTQ process requirements still need to be met, causing defects in the product [1]. Table 2 describes the frequency of occurrence of defects in each stage of the Polyester Technical Sportwear production process in the period January 2020 to September 2021.

Table 2 Frequency of Occurrence of Defect

Process	Defect Type	Number of Defects
Design	-	0
Mockup Final Design	-	0
Press	-	0
	Screen printing doesn't match	157
Printing	The color doesn't match	93
	Cloth with spots and lines	79
Cutting	The size of the cut does not match	115
	loose stitch	382
Sewing	Wrinkled seams	475
	The stitches don't match the pattern	186
Inspection	-	0

The CTQ process in the sewing process that needs to be fulfilled and can cause defects is 1) The requirement for the needle used should not be damaged and not blunt. And 2) The sewing machine tension setting should be based on the type of material. From the results of identifying the causes of problems with the CTQ process requirements that are not met, an analysis is carried out to determine the results of potential solutions to each problem.

Several previous studies [7], [8], [9] have proven that Six Sigma with the DMAIC approach is a methodology to eliminate defects in all organizational processes continuously. This research aims to design a proposal for the product manufacturing process at PT. X, to reduce technical defects in polyester sportswear products caused by problems in the sewing process. In addition, it can increase process capability and increase customer satisfaction [10], [11], [12], [13].

2. Methodology

Two methods are used in the research: the Six Sigma approach with the DMAIC stage as a method for problem-solving [1] and the Reverse Engineering method for the alarm timer design method [14]. The following are the steps of this research which are shown in Figure 2.

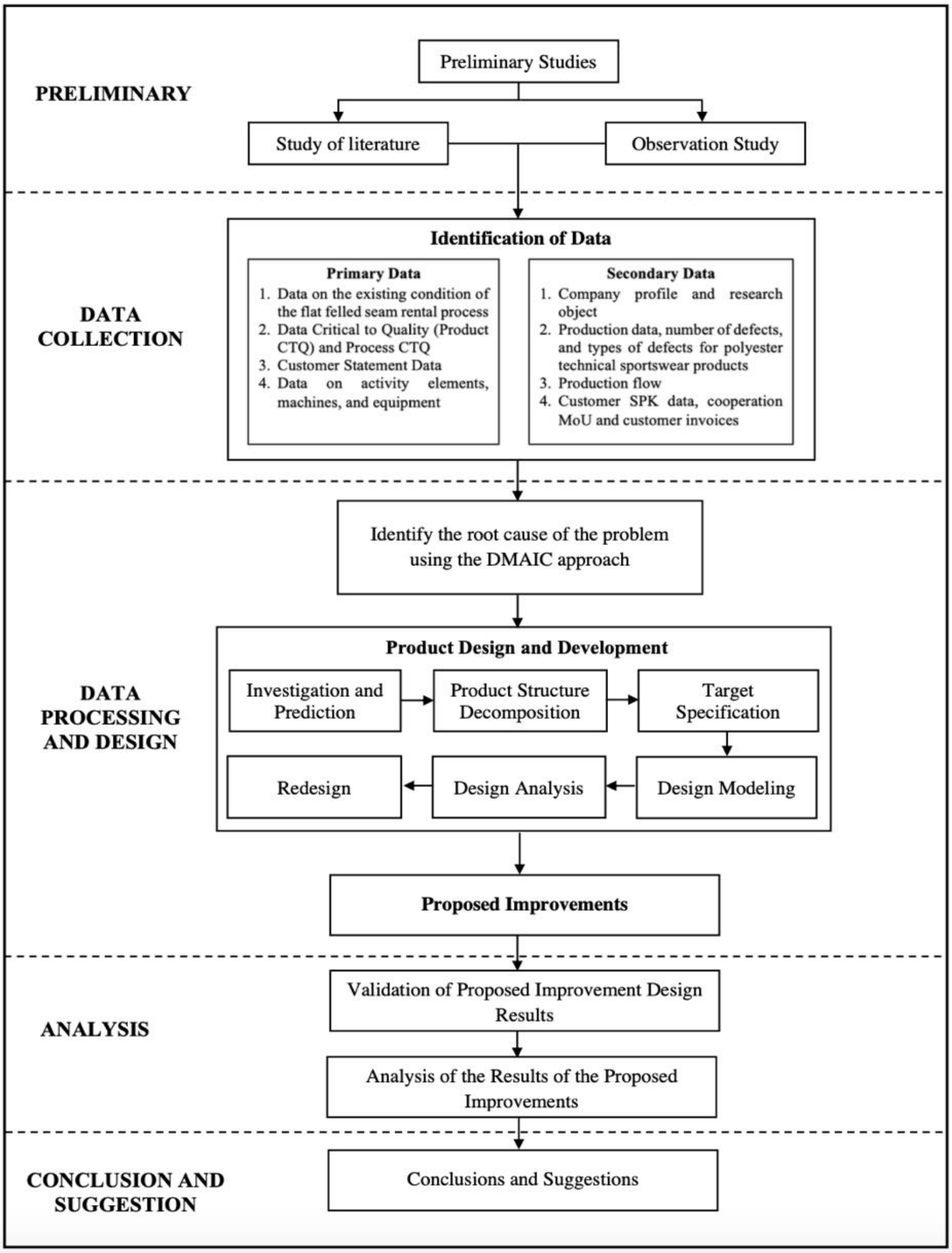


Figure 2 Design Systematics

2.1. Preliminary

The initial stage of the research is to carry out the process of understanding the problems of the existing conditions in the company based on a literature study on related theories. Process problems in the company are identified in order to describe and identify problems that occur for improvement. Then the narrowing of the problems to be solved in this research is carried out so as to stay within the boundaries of the problems that exist in the company.

2.2. Data Collection

This study uses primary data and secondary data. Primary data was generated through direct observation and interviews with several operators at PT. X. Primary data consists of product CTQ data, process CTQ, and customer statements. These data are used to analyze and identify problems in PT's production process. X. Secondary data is obtained through documents available at the company to assist the data processing along with primary data, such as company profile data and production process flow data.

2.3. Data Processing and Design Phase

The design stage displays each stage of the problems studied and the design carried out in this study [6].

A. Investigation and Prediction

This stage is the initial design stage regarding understanding and field observations to obtain problems that occur and determine goals, and systematically design tools for proposed alarm timers from existing products, namely timers with existing alarms. The results of the interview in the form of customer needs will be used as a need statement [6].

B. Product Structure Decomposition

At this stage, data collection activities for previous products are carried out to design proposed tools, specifications, and existing product features. This data will be used as a reference for the output of the tool design [6].

C. Target Specification

At this stage, benchmarking with similar products will be carried out to determine the technical specifications of the proposed improvement product. The technical specification reference looks at the need statement that has been determined in the previous stage [6].

D. Design Modeling

At this stage, the existing product design activities are carried out based on the decomposition stage of the product structure as an initial design in making a proposed improvement plan [6].

E. Design Analysis

At this stage, the product component mechanism is analyzed based on design modeling and benchmarking results as a comparison in designing the proposed alarm timer tool [6].

F. Redesign

At this stage, the final analysis and conclusions are carried out through observations of comparisons that are considered through additional product features and functions, the dimensions of the alarm timer, which are the focus of the research. Then after the observations were made, conclusions and suggestions were made on the design of product proposals [15].

2.4. Analysis

At this stage, validation analysis is carried out on the design of the alarm timer, which is integrated with the sewing machine starting from performance targets, stakeholder requirements, and reference standards. In addition, an analysis is also carried out regarding the estimated cost, advantages, and disadvantages if it is to be implemented in the company.

2.5. Conclusions and suggestions

The last stage in this research is conclusions and suggestions. The conclusion stage aims to summarize all research results based on the analysis and design results using the Reverse Engineering method. This stage answers the goals that have been set previously and whether the research carried out is a solution for the company.

3. Results and Discussion

3.1. Define

The define stage of the DMAIC methodology aims to define the problem and the problem process related to the project objectives [2]. The results of field observations indicate that the production process at PT. X in producing Polyester Technical Sportswear is indicated to be not optimal because there are still many defects [16].

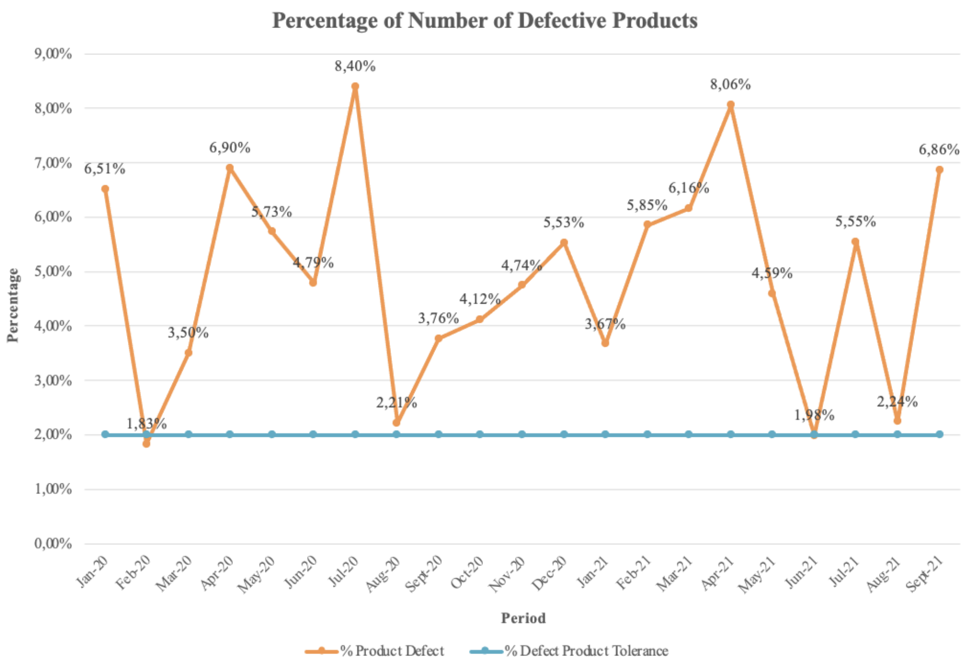


Figure 3 Percentage of Total Defect Product Polyester Technical Sportswear

From the results of historical data and observations, it is known that the defects most often found in the manufacture of polyester technical sportswear are found in the sewing process, with the types of defects, namely loose stitches, Wrinkled seams, and stitches don't match the pattern. The graph for the comparison of the number of defective products and the tolerance for defects in each period is shown in Figure 3.

3.2. Measure

The measuring stage is the stage of data collection to determine the current process performance in which the sampling method must be determined [2]. In this stage, the stability and process capability measurements are carried out [17]. Figure 4 shows the results of calculating the stability of the p-control chart process for January 2020 based on production data for the period January 2020 - September 2021 [4].

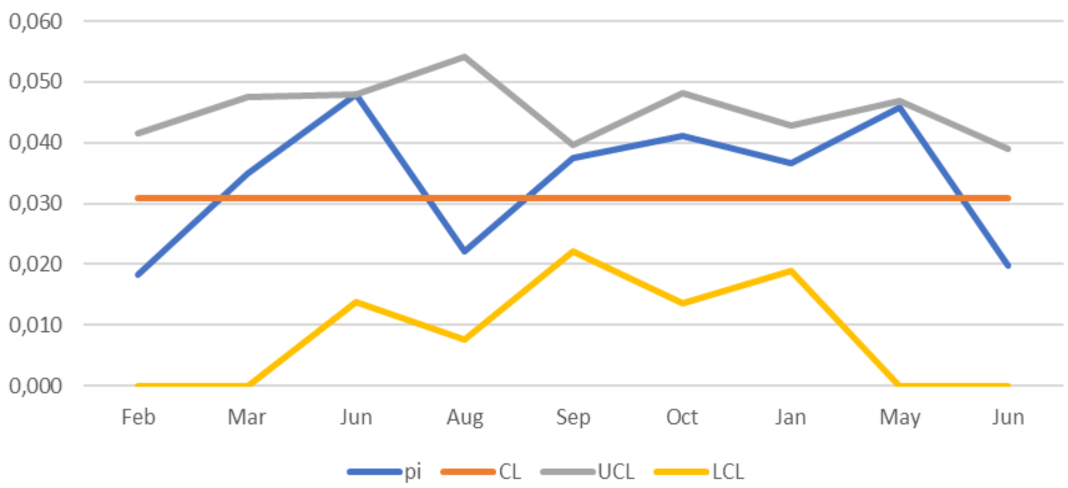


Figure 4 Control Chart p Process at PT. X

In calculating the fourth process stability measurement, all data are stable and not outside the control limits. The picture above shows the P control map on a flat felled seam product, all of which are within the control limits or can be said to be in a stable condition, where all research focuses on measuring process stability within the control limits [1], [18]. The proportion of defective products resulting from the calculation fluctuates daily, with the highest point in June 2020 and the lowest point in February 2020.

3.3. Analyze

Analysis of the root causes of problems in the CTQ process that is not fulfilled is carried out using a fishbone diagram. After identifying the production flow requirements, two process requirements still need to be met in the sewing process (flat felled seam). Namely, the needle used should not be damaged and not blunt, use the appropriate needle number, and the sewing machine tension setting should be based on the type of material. Figure 3 and Figure 4 are the results of the analysis of the root causes of the problem using a fishbone diagram.

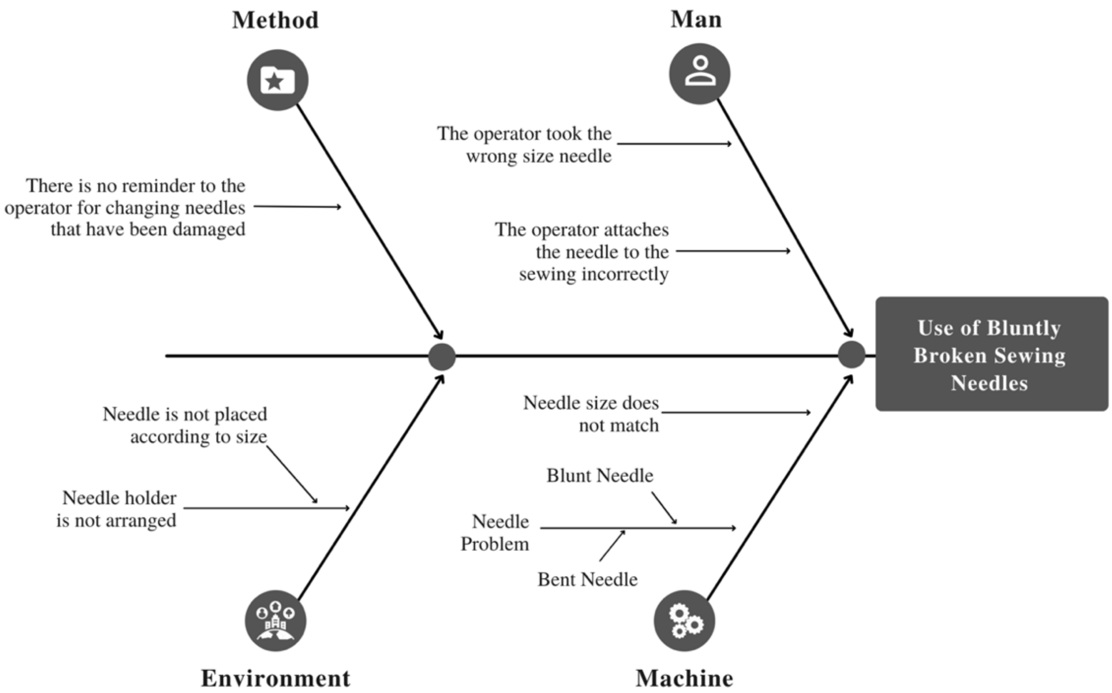


Figure 5 Fishbone Diagram Regarding the Problem of Using Broken and Blunt Sewing Needles

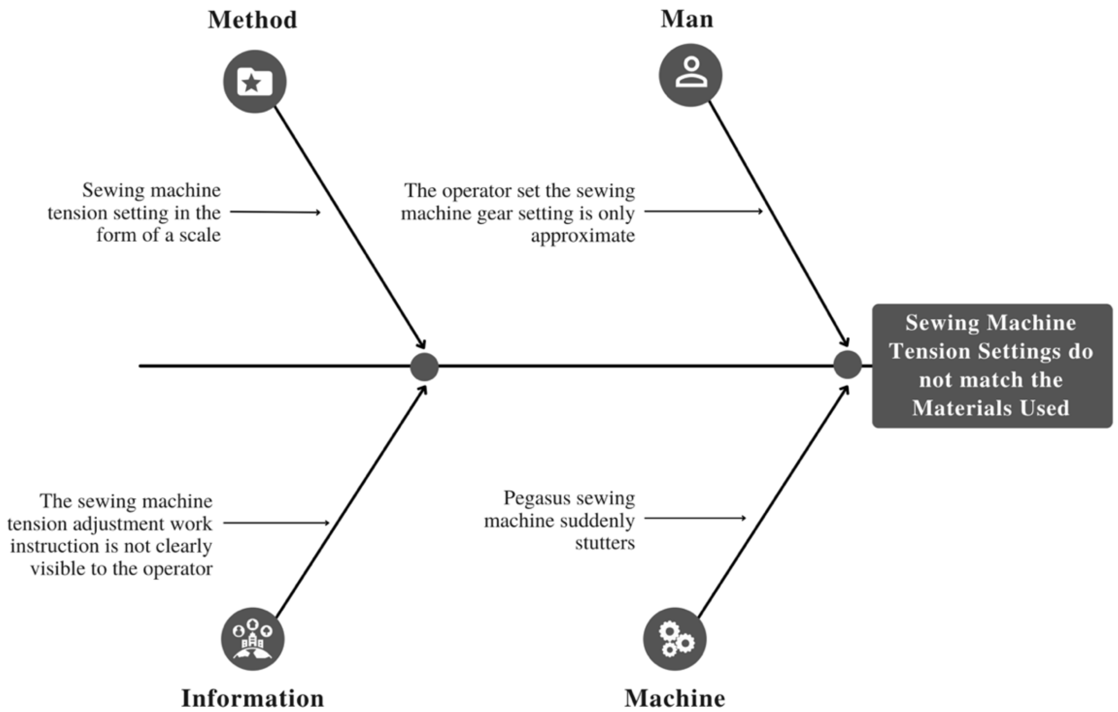


Figure 6 Fishbone Diagram Regarding the Problem of Setting the Sewing Machine Tension Incorrectly

From several root causes, from man, machine, method, and environment, in-depth interviews were conducted with several related operators. The results obtained from the interview process showed that the operator's problem in the sewing process is the problem of blunt and bent needles because there is no reminder to the operator to replace the damaged needle. Furthermore, an investigation was carried out using FMEA (Failure Mode and Effects Analysis) tools to determine the potential causes of the complex sewing process with high priority [4]. Based on the FMEA calculation, a solution for designing an alarm timer tool that is integrated into the sewing machine is needed to remind the operator to replace damaged and blunt needles. It was chosen as a potential alternative solution to these problems, which will be designed in an integrated manner from man, machine, and method to improve the sewing process at PT. X.

3.4. Improve

The fourth stage of the DMAIC methodology is to Improve. The root cause of the problem that has been found and explained in the analysis stage is carried out at this stage. The analysis aims to identify and confirm the root cause with data [2]. From the identification process, it was stated that there were process requirements that needed to be fulfilled in the sewing process (flat felled seam); namely, the needles used must not be damaged and not blunt. Due to an operator error, there is no reminder to change needles. Therefore, it is necessary to have a timer alarm device. From the results of the analysis, we need a tool that can assist operators in solving the problem of blunt and bent needles and inappropriate needle sizes, namely an alarm timer that is integrated with the sewing machine [19]. With the timer alarm integrated into the sewing machine, it can help the operator in the sewing process because, in this process, there are many defects caused by the operator forgetting to replace the sewing needle, resulting in needle bluntness. The following are the steps in designing an alarm timer that is integrated with the sewing machine using the reverse engineering method.

A. Investigation and Prediction

The first step in this research is to investigate the problems and circumstances using of previously existing products and determine need statements obtained from interviews with operators of PT. X [7].

1. The product can run and detect movement automatically when operating
2. The product has a notification feature for the user for needle change
3. The product is easy to use and operate
4. The product uses safe and durable materials
5. The product has a proportional size.

B. Product Structure Decomposition

At this stage, the disassembly of existing products is carried out so that it can find out the function of each decomposed part that can be developed or removed in the development of the proposed product. The product decomposition of the timer is described in Table 3.

Table 3 Existing Timer Decomposition

No	Component	Information
1	*Body Timer* 	This component serves as to assemble of all the components that make up the timer. The dimensions of this timer body must match the thick parts in it.
2	*Timer Button* 	This button is used for timer operation, starting from turning on, setting the timer mode, and setting the timer time.
3	LED Screen 	This component serves to display the timer time numbers visually. The dimensions of the LED timer screen adjust to the size of the timer body.
4	Battery Case 	The battery compartment is a timer component that functions to place a medium-size battery (AA-size). For the size and diameter of the battery compartment, follow the medium-size battery (AA-size)

The first step in this research is to investigate the problems and circumstances of the use of previously existing products and determine user needs (need statements) obtained from interviews with operators of PT. X [20].

C. Target Specification

At this stage, the formation of product specifications that adapt to the needs of user operators, benchmarking, and selection of products are developed. Product attributes are determined using user requirements data, as shown in Table 4.

The next step is to determine the technical specification target of the product design, which is determined based on the technical characteristics. After determining the technical characteristics, the next step is to determine the technical specification target of the product design, which is determined based on the technical characteristics. The technical specification targets will be what parameters must be achieved in designing the proposed model for improving the alarm timer that is made. Table 5 shows a table of target technical specifications [15].

Table 4 Product Attribute Determination

No	Aspect	Need Statement	Product attribute
1	Functional	The product can run and detect movement automatically when operating	The product can connect with the sewing machine The function of the product is according to the motion of the sewing machine.
		The product has a notification feature for the user for needle change	The product can be seen by the operator The product can be heard by the operator The product has a screen display to display the time duration
2	Convenience	The product is easy to use and operate	Easy to use and operate
3	Material	The product uses safe and durable materials	Product materials
4	Length, Width, Height	The product has a proportional size	Product Dimension

Table 5 Target Technical Specification

Technical Characteristics	Initial target	Unit
Controller system type	Arduino Uno	piece
Sensor system type	PCB sewing	piece
Lamp color	Red	piece
Alarm sound feature	60-85	db
Screen features	LCD	piece
Operation buttons	1	piece
Material type	Plastic	type
Product size	10 x 2.5 x 7	cm

D. Design Modeling

The next stage is designing the existing alarm timer using Autodesk Inventor software with reference to the benchmarking method for existing timer products. The 3D drawing model is shown in Figure 7.

Figure 7 Existing Alarm Timer Model Design

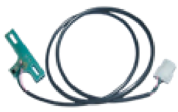
E. Redesign

In this design analysis stage, an analysis of the alarm timer mechanism that has been determined in the previous stage is carried out as well as the results of the existing benchmarking design. Three existing alarm timers will be analyzed in terms of the advantages and disadvantages of each alarm timer to be applied in the proposed tool design.

Morphological Map

Based on the functions that have been obtained, then the alternatives are described using a morphological map to make a selection of concept combinations, as shown in Table 6.

Table 6 Morphological map

Function	Alternative		
	Alternative 1	Alternative 2	Alternative 3
Controller System	 Arduino R3 Atmega 328P	 Arduino R3 Atmega 2560	 Arduino Atmega 32
System	 PCB sewing machine servo pedal GC 6-28D		

Function	**Alternative**		
	Alternative 1	**Alternative 2**	**Alternative 3**
Sensor	 Red indicator light		
Color	 SFM 27 80 db		
Light	 LCD display 4 point radix	 LCD display 6 point radix	
Feature	 push button		
alarm sound	Plastic		
Screen features	(10 x 2,5 x 7) cm		

After eliminating the alternative choices, the number of combinations of the latest morphological maps is 3x1x1x1x2x1x1x1= 6 concepts. Then there are 6 concept combination options.

Concept Screening

Then the determination of the best concept is carried out by giving a "+" sign if it is better than the reference, the "0" sign has the same meaning as the reference, and the "-" sign if it is less good than the reference [21]. The results of the concept screening are shown in Table 7.

Table 7 Concept Screening

Selection Criteria	**Alternative Concept**					
	1	**2**	**3**	**4**	**5**	**6**
The product can connect with the sewing machine	+	0	-	+	0	-
The function of the product is according to the motion of the sewing machine.	+	+	+	+	+	+
The product can be seen by the operator	0	0	0	0	0	0
The product can be heard by the operator	0	0	0	0	0	0
The product has a screen display to display the time duration	-	-	-	+	+	+
Easy to use and operate	0	0	0	0	0	0
Product materials	0	0	0	0	0	0
Product Dimension	+	+	+	+	+	+
Sum +	**3**	**2**	**2**	**4**	**3**	**3**
Sum 0	**4**	**5**	**4**	**4**	**5**	**4**
Sum -	**1**	**1**	**2**	**0**	**0**	**1**
Net Score	**2**	**1**	**0**	**4**	**3**	**2**
Rank	**3**	**5**	**6**	**1**	**2**	**4**
Continue?	**YES**	**NO**	**NO**	**YES**	**YES**	**NO**

Concept Scoring

Concept scoring is the final stage of concept selection. This is done to analyze the remaining alternative concepts in more detail so that the best concept is obtained [22]. Concept scoring by providing a rating based on relative performance with a value of 1 (much worse than the reference) to 5, which is much better than the reference [21].

Table 8 Concept Scoring

Selection Criteria	Weight	Concepts					
		1		4		5	
		Rating	Weight Score	Rating	Weight Score	Rating	Weight Score
The product can connect with the sewing machine	14,81%	5	0,741	5	0,741	3	0,444
The product's function is according to the sewing machine's motion.	14,81%	5	0,741	5	0,741	5	0,741
The product can be seen by the operator	11,11%	3	0,333	3	0,333	3	0,333
The product can be heard by the operator	11,11%	3	0,333	3	0,333	3	0,333
The product has a screen display to display the time duration	11,11%	2	0,222	5	0,556	3	0,333
Easy to use and operate	14,81%	3	0,444	3	0,444	3	0,444
Product materials	9,26%	3	0,278	3	0,278	3	0,278
Product Dimension	12,96%	4	0,519	4	0,519	4	0,519
Total Score		**3,611**		**3,944**		**3,426**	
Rank		**2**		**1**		**3**	
Continue?		**NO**		**YES**		**NO**	

The final result of the design of an alarm timer that is integrated into the sewing machine, which includes changes and additions to several features used from the existing timer, is made using the Autodesk Inventor application. Based on Table 8, the results of the selected design using the Reverse Engineering method are concept number 4 with the constituent components, namely Arduino R3 atmega 328P, PCB sewing machine servo GC 6-28D, red LED indicator light, SFM alarm 27 80 dB, LCD display 6 radix points, push-button operation, case body timer alarm. The following is the result of the design of the alarm timer integrated with the sewing machine, as shown in Figure 8.

Figure 8 Alarm Timer Integrated into Sewing Machine

Suppose the design of an alarm timer that is integrated with a sewing machine is implemented in the company PT. X, it is hoped that product defects in the sewing process will be reduced and resolved to increase the value of DPMO at PT. X. By increasing the sigma value, the DPMO value (defects per million opportunities) will minimize the possibility of defects in 1,000,000 productions [1], [2], [23].

4. Analysis of the Proposed Alarm Timer Tool

4.1. Cost Analysis

In the manufacture of an alarm timer that is integrated with the sewing machine, it is necessary to estimate a minimum cost to design an alarm timer that is integrated with the sewing machine so that the company can know if the proposed tool is implemented, Table 9 will explain the costs for each component in the design alarm timer integrated with a sewing machine.

Table 9 Design Result Cost

No	Component	Cost
1	Arduino R3 atmega 328P	Rp65.500
2	PCB sewing machine servo pedal GC 6-28D	Rp275.000
3	Red indicator LED light	Rp6.500
4	Alarm SFM 27 80dB	Rp8.500
5	LCD display 6 point radix	Rp27.500
6	Operation buttons	Rp11.500
7	Case body timer alarm	Rp20.000
8	Connecting cable ±1.5m	Rp10.000
9	Miscellaneous expense	Rp25.000
	Total	**Rp449.500**

4.2. Analysis of Advantages and Disadvantages of Tools

Table 10 analyzes the advantages and disadvantages of the design of the alarm timer, which is integrated with the sewing machine.

Table 10 Advantages and Disadvantages of Tools

Advantages of Design Results	Disadvantages of Design Results
The alarm timer can be integrated with the sewing machine to remind the operator to change sewing needles automatically to avoid damaged and blunt needles in order to minimize the frequency of sewing defects.	The Alarm Timer resource still uses a battery, and a more detailed design is needed to connect using a power source.
The timer on the alarm timer can run backward automatically when the sewing machine pedal is operated and stop automatically when the sewing machine pedal is not operated.	

5. Conclusion

This study discusses the analysis and design of a Six Sigma project with the DMAIC approach to increase the capability of the cutting process in the production process of Polyester Technical

Sportswear products. The Six Sigma DMAIC methodology is adopted to investigate the root causes of non-conformances causing defects and develop corrective measures. From the identification process, it is stated that process requirements still need to be met in the sewing process (flat felled seam). That is, the needle used must be intact and not blunt. Due to an operator error, there is no reminder to replace the needle. Therefore it is necessary to have a timer alarm device.

6. Suggestion

This research was conducted up to the DMAI and mock-up timer stages, yet to reach the implementation and control stage because it takes quite a long time to identify reduced defects. This research can be continued for future research by considering programming a timer alarm system that is integrated with sewing machines and implementation. By implementing a timer alarm tool integrated with the sewing machine, it is hoped that it will help minimize product defects and increase process capability in PT.X

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